SPECIAL TOPICS IN COMPUTING AND ICT RESEARCH

Strengthening the Role of ICT in Development

Editors

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Volume VII

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Foreword

With 34 papers being presented in this Volume VII, the Annual Conference on Computing and ICT Research (ICCIR) is growing stronger and stronger. It is apparent that the quality of research work being presented in the Special Topics in Computing and ICT is steadily receiving a much wider research audience than ever before across the world. For the last six Years, Makerere University, School of Computing and Informatics Technology, the premier Computing school in East Africa has been organizing and hosting ICCIR which has now transformed into one of the main activities for the Kampala ACM Chapter. The conference has attracted many academic scholars and industrial practitioners to submit papers and share discussions during their paper presentations. Overall more than 60 papers are reviewed by the conference program committee in each conference track. These paper cover research areas in Information systems, Information Technology, Computer Science, Computer Engineering, ICT for Development, Software Engineering and Networking. It is interesting that we span not only the practitioners-researchers gap but also the social science-technology fields that address the needs of communities.

African scholars have had an opportunity to interface with international scholars who present at this conference as Key note speakers. Besides, it is a premier event for disseminating innovative ICT research within the East and central African region. The 7th Annual Conference offers its participants;

1. Numerous well known keynote speakers including:
   • Prof. Kathy Lynch from University of the Sunshine Coast, Australia
   • Prof. Rodrigues Anthony, Bondo University College, Kenya
   • Prof. Henk Sol from Groningen University the Netherlands
   • Prof. Bernard Manderick from Free University of Brussels, Belgium
   • Prof. Ravi Nath from Creighton University, USA
   • Director for the National Information Technology Authority-Uganda
2. A PhD Colloquium, an opportunity for research students to network with different scholars
3. Explicit interaction with renowned scholars in the area of ICT
4. Interaction with the Business Community under the theme Strengthening the Role of ICT in Development

The Conference will be of interest to; Policy makers and politicians concerned with design and implementation of national and international ICT policy; R&D managers in funding agencies, in universities and research institutes, and in the business sector; Information scientists and stasticians, especially those interested in ICT and research; Researchers in the field of ICT studies; Science publishers and editors, writers and journalists and database vendors; Librarians, to mention but a few
On behalf of the organizing committee we would like to express our sincere thanks to all the presenters and panelists who shared their works and ideas with all of us and especially the Keynote Speakers. We also want to recognize the important contributions of the track chairs and reviewers for this conference and the proceedings.

Many thanks to the Local Organizing Committee, the Conference Secretariat and every one who has participated in the organization of the ICCIR’11 Conference.

Last but not the least, we would like to express our heart-felt thanks to all the organizations that have supported this conference. We are grateful to Makerere University, the Netherlands Organization for International Cooperation in Higher Education (NUFFIC), National Information Technology Authority – Uganda (NITA-U), to mention but few

ICCIR’11 General Chair
Keynote Speaker Biographies

**Anthony RODRIGUES** is currently a Professor of Computer Science in the School of Computing and Informatics at the University of Nairobi. He holds a BSc. (Hons) in Electrical Engineering, a M.Sc in Automatic Control Theory and Practice and a PhD in Mathematics of Computing/Numerical Analysis. His Research interests include: Scientific Computation, Approximation Theory, Error Analysis, Systems Modelling, Informatics Policy, and Simulation and Infrastructural Contexts from a Development Perspective. He has also been involved in the design and development of sustainable integrated management information systems at various universities and is currently studying the developmental impact of various ICT policies and strategies (or the lack thereof) in the region.

**Bernard MANDERICK** is currently professor in Computer Science at the Free University Brussels. He holds a Master in Philosophy and a Master in Mathematics of the University of Ghent. He did his PhD "Selectionism as a Basis for Categorization and Adaptive Behavior" in the AI Lab of the Free University Brussels supervised by Professor Luc Steels and for which he received the IBM-prize for Informatics. He was post-doctoral researcher at Electrotechnical Lab in Tsukuba, Japan and assistant professor in the Department of Computer Science of the Faculty of Economics at Erasmus University, Rotterdam. His research area is machine learning and he did research on evolutionary computation, evolvable hardware, bioinformatics, text and music mining, probabilistic reasoning, reinforcement learning and learning in game theory. His current focus of research is on the intersection of multi-agent systems, game theory and learning. He has been involved in long term collaborations with universities in the South including the University of Nairobi and Moi University in Kenya and UCLV in Cuba.

**Henk G. SOL** is a Professor at the Faculty of Economics and Business (Business and IT) at Groningen Nederland Netherlands and the Technical University Delft. He is a Commissioner for Groningen Airport Eelde NV te Eelde; Director / owner Sol Information Management BV, Haren, President Foundation Board PAO Informatica, Informatica seminars Foundation Board President, Foundation Board Member Allersmaborg; Member of the Board of Trustees Nicolaes Mulerius; Advisory Professor The Expertise Centre. Chaired Professor of Business Engineering and ICT at Delft and Groningen, Supervisor responsible for over 60 PhD dissertations and some 20 dissertations are presently being supervised. He has highly published in both Journals and conferences in the discipline of Business and Information Technology.

**Kathy LYNCH** (Associate Professor) is an interdisciplinary researcher with a background in education and information technology. She joined the University of the Sunshine Coast (USC) in 2007 as a researcher in the Teaching and Research Services unit. During her time in the university sector, Dr Lynch has been a founding
director of the Centre for Educational Multimedia (Monash), a founding member of the Centre for Organisational and Social Informatics (Monash) and a founding member of the Information Systems Development Research Group (Monash). She remains an associate researcher for each of these groups. Additionally, she is an honorary research associate in the Faculty of IT at the University of Technology Sydney, the School of Computing and IT at Makerere University (Uganda), and the School of IS at University of Cape Town.

Dr. Lynch is a reviewer for the Australian Research Council, the National Research Foundation (South Africa) and the Research Council for Natural Sciences and Engineering (Finland). She is a reviewer for a number of international journals and conferences, as well as local conferences. She was the Editor-in-Chief of the Interdisciplinary Journal of Information, Knowledge and Management (Vol 2 and 3), is currently an Associate Editor of the Interdisciplinary Journal of E-Learning and Learning Objects, on the editorial board of the International Journal of Mobile and Blended Learning, and a track editor for the International Journal of Computing and ICT Research (ICT for Sustainable Development). Dr. Lynch was the co-track chair for the IS Pedagogy track at ACIS 2007 and 2009. Her Australian adaption of a very successful US text book was awarded the Australian Publishers Award for the best tertiary learning and teaching (adaption) in 2010 [Baltzan, Phillips, Lynch & Blakey (2010) "Business Driven Information Systems". McGrawHill]. In 2005, Dr. Lynch spent 5 weeks in Uganda, and since her return has established Aussie Friends of VOLSET a charity organisation that supports villagers in the Lake Victoria region of Uganda to build capacity, and improve their health and education.
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Part One

Computer Science
Improving the Inversion Algorithm over Binary Finite Fields

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Abstract

Elliptic Curve Cryptography (ECC) is a good alternative for public-key cryptography algorithms in resource-constrained network systems because the same level of security can be achieved with much shorter keys than integer-based public key algorithms. However the software implementations of ECC are still slow. Research is going on to study and improve software implementation of ECC which is highly dependent on improving its underlying finite field arithmetic operations. Among finite fields operations, finding the inverse of an element is the most time consuming operation and there is less work to improve it. In this paper, software implementations of Inversion algorithm are studied and efforts are made to reduce unnecessary memory usage in implementing the inversion algorithm while keeping the implementation as fast as possible. Using these techniques the speed up of 3.36 over the original implementation of inversion algorithm in C is achieved, without any overhead of RAM memory usage.

Developed algorithms are implemented and simulated for ATmega128L, a frequent platform used for sensor network and tested with AVR Studio 4.14 which is a cycle-accurate simulator frequently used to prototype software for execution on small devices. The performance is compared with some existing work.

Keywords: Elliptic curve cryptography; binary finite fields; Inversion algorithm; Efficient Implementation; Algorithm optimization.
Introduction

Elliptic Curve Cryptography (ECC), proposed independently in 1985 by Neal Koblitz and Victor Miller, is being used for a variety of security purposes such as key exchange and digital signature. Compared to traditional integer-based public key algorithms, ECC algorithms can achieve a similar level of security with much shorter keys and parameters. For example, 160-bit Elliptic Curve Digital Signature Algorithm (ECDSA) has a security level equivalent to 1024-bit Digital Signature Algorithm (DSA) [National Institute of Standards and Technology 2000]. The advantages that can be gained from smaller parameters include speed (faster computations and therefore consumption of less energy) and smaller keys and certificates (which lead to less required space, memory and energy consumption). These advantages make ECC a much better choice of public-key cryptography, especially in resource constrained systems such as sensor nodes, mobile devices and smart cards.


In this work, the main contribution is efficient implementation of inversion algorithm by improving algorithms and techniques. The implementation results are simulated for an ATmega128L microcontroller using AVR Studio software, although the algorithms can be applied on any 8 bit devices. The results of the present study shows better performance compared with Shi and Yan [2008] and Aranha et al. [2010] work.

An overview of elliptic curve cryptography is presented in Section 2 and prior work is given in Section 3. Section 4 explains the improvements and implementation of inversion algorithm and corresponding results. Section 5 highlights the concluding remarks on the present research work.

Overview of Elliptic Curve Cryptography

An elliptic curve $E$ over a field $K$ is the set of solutions $(x, y) \in K \times K$ which satisfy the Weierstrass equation

\[ y^2 + a_1 xy + a_3 y = x^3 + a_2 x^2 + a_4 x + a_6 \]

where $a_1, a_2, a_3, a_4, a_6 \in K$ and the curve discriminant is $\neq 0$, together with a point at infinity denoted by $O$. If $K$ is a field of characteristic 2, then the curve is called a binary elliptic curve.

The set of points $\{(x, y) \in E(F_{2^m})\} \cup \{O\}$ under the addition operation forms an additive group, with $O$ as the identity element. Given an elliptic point $P \in E(F_{2^m})$ and an integer $k$, the operation $kP$, called point multiplication, is defined by the addition of
the point P to itself $k - 1$ times which obtain another point Q on the curve [Hankerson et al. 2003]:

$$kP = Q = \underbrace{P + P + \ldots + P}_{(K-1) \text{ times}}$$

As a simple example of point multiplication, let P be a point on an elliptic curve and let k be a scalar that is multiplied with the point p to obtain point Q. If $k = 23$ then $Q = 23P = 2(2(2P) + P) + P$.

Public key cryptography protocols, such as the Elliptic Curve Diffie-Hellman key agreement (ECDH) [SEC1 2000] and the Elliptic Curve Digital Signature Algorithm (ECDSA) [SEC1 2000], employ point multiplication as a fundamental operation, and their security is based on the difficulty of solving the Elliptic Curve Discrete Logarithm Problem (ECDLP). This problem consists of finding the scalar k given a point kP [Hankerson et al. 2003].

Each point multiplication involves plenty of point addition and point doubling. Each point addition and doubling involves a multiplicative inverse operation and finding multiplicative inverse is a costly operation in all finite fields.

Eliminating the inversion operations during scalar multiplication is beneficial to better performance. Projective coordinate systems are options to avoid expensive inversions with the cost of more multiplication operations [Hankerson et al. 2003]. For using the projective coordinate in elliptic curve, one has to convert the given point in affine coordinate to projective coordinate before point multiplication and then convert it back to affine coordinate after point multiplication. The entire process requires only one multiplicative inverse operation. The point multiplication operation in projective coordinate involves more field multiplication than in affine coordinate, so ECC on projective coordinate will be efficient only when the implementation of field multiplication is much faster than multiplicative inverse operation. One of the fastest projective coordinate systems is the one proposed by Lopez et al. [Lopez and Dahab 1999]. It is the most efficient coordinate system over a binary field when the ratio of inversion to multiplication is high (It will be beneficial to use LD-affine coordinate to implement ECADD if $I / M > 7$. I and M are the time required to execute a field inversion and a field multiplication respectively). In this system, a projective point $(X, Y, Z)$, $Z \neq 0$ corresponds to the affine point $(X/Z, Y/Z^2)$ and the equation of the elliptic curve is changed to $Y^2 + X \cdot Y \cdot Z = X^3 \cdot Z + a \cdot X^2 \cdot Z^2 + b \cdot Z^4$ [Hankerson et al. 2003].

Improving inversion algorithm may make no sense as people try to eliminate using inversion by using projective coordinate system with the cost of using multiplication system more. But it is important to note that there are some small devices like smart cards that use the security system which is very critical in them. They also have very little amount of RAM memory since increasing RAM memory will increase their prices. In these devices improving field multiplication and modular reduction algorithms
are impractical as all the improvement on these algorithms are based on using some extra amount of RAM memory. So the execution time of multiplication and modular reduction algorithms increases. For example without using any precomputation for multiplication and modular reduction, the cost of doing one field multiplication and one field modular reduction becomes 25,516 and 952 cycles (totally 26,468 cycles which is about 2.5 times slower than the implementation which use about 0.6 kb of extra RAM memory for precomputation purposes). In these situations using the affine coordinate systems improves the system efficiency and so improving the inversion algorithm comes into picture.

Even on devices like sensor motes with enough amount of memory in some situations (like filling the precomputation table for window based unknown point multiplication) there is no way except to calculate multiplicative inverse of the polynomial, and so improving the inversion algorithm helps to improve system efficiency.

Prior work
Although many researchers tried to apply ECC on sensor motes in various finite fields [Eberle et al. 2005, Kargl et al. 2008, Uhsade et al. 2007, Szczewiak et al. 2008, Shi and Yan 2008, Seo et al. 2008, Aranha et al. 2010, Wang and Li 2006, Blaß and Zitterbart 2005], there has been less work done to improve implementation of field inversion algorithms over binary fields. Some researchers used C and Assembly language together to improve the speed with the cost of using more code memory.

Yan and Shi [2008] implemented ECC over F(2163) in C and obtained a point multiplication in 13.9 seconds. They compared the two most popular inversion algorithms, Extended Euclidean Algorithm (EEA) for polynomials [Hankerson et al. 2003] and Modified Almost Inverse Algorithm (MAIA) [Hankerson et al. 2003], and showed that EEA is faster than MAIA and then tried to improve the EEA implementation which led to a speedup of 1.3 over the original implementation.

Aranha et al. [2010] obtained the fastest binary field arithmetic implementations in C and Assembly over F(2163) and F(2233). They reached the speed of 0.67s and 0.32s using C and Assembly respectively, over F(2163) for Koblitz curves. They used EEA algorithm to implement field inversion and to improve the implementation efficiency, they implemented six dedicated shifting functions to shift a binary field element by every amount possible for an 8-bit processor since this algorithm requires flexible left shifts by arbitrary amounts. Their implementation took 243,790 cycles to do a field inversion for F(2163).

Implementation and Improvements of Inversion Algorithm:
In this section the elements of F(2m) are represented using a polynomial basis. Let f(z) be an irreducible binary trinomial or pentanomial of degree m in which f(z) = zm + r(z). The elements of F(2m) are the binary polynomials of degree at most m − 1. A field element a(z) = am−1zm−1 + … + a2z2 + a1z + a0 is associated with the binary vector a = (am−1, . . . , a1, a0) of length m.
In a software implementation in an 8-bit processor, the element \( a \), is stored as a vector of \( n = \lceil m/8 \rceil \) bytes.

For implementing the following algorithms, GCC 4.1.2 compiler is used. The timings were measured with the software AVR Studio 4.14 [Atmel Corporation 2005] for ATmega128L with optimization level –O3. This tool is a cycle-accurate simulator frequently used to prototype software for execution on the target platform.

The inverse operation is the most time-consuming operation. There are different algorithms to calculate the inversion of different finite fields. For the binary fields the algorithms like Extended Euclidean Algorithm, Binary Inversion Algorithm and Almost Inverse Algorithm are available. Extended Euclidean Algorithm is the fastest algorithm to find a field inversion [Shi and Yan 2008] although even this algorithm is so time consuming. Algorithm 1 shows the inversion algorithm using Extended Euclidean Algorithm [Hankerson et al. 2003]. In EEA, most of the execution time is spent on the function which searches for the degree of polynomials (function \( \text{deg()} \)), and the function which performs the shift and add operations (function \( \text{shift_n_add()} \)).

To improve the inversion algorithm, efforts are made to minimize the number of times that function \( \text{deg()} \) is called. By using the fact that, the degree of polynomial \( v(z) \) in each iteration is always equal to either degree of polynomial \( u(z) \) in previous loop or does not change depending on whether the value of \( j \) is negative or not, to improve function \( \text{deg()} \), the degree of \( u \) is passed as an argument to the function \( \text{deg()} \). This eliminates unnecessary memory reading since all the bits before this argument are zero. Also, instead of using the operation “right shift by \( j \)”, \( (a[i] >> j) \) which is expensive for small devices, a combination of “bitwise and operation” (\&) and “left shift by 1” (\( t <<= 1 \)) is used which can be done in less CPU cycles. Algorithm 3 shows the modified version of function \( \text{deg()} \).

**Algorithm 1**: Inversion in \( F_{2^m} \) using the Extended Euclidean Algorithm

**INPUT**: A nonzero binary polynomial \( a \) of degree at most \( m - 1 \).

**OUTPUT**: \( a^{-1} \mod f \).

1. \( u \leftarrow a, v \leftarrow f \).
2. \( g1 \leftarrow 1, g2 \leftarrow 0 \).
3. While \( u \neq 1 \) do
   1. \( j \leftarrow \text{deg}(u) - \text{deg}(v) \)
   2. If \( j < 0 \) then: \( u \leftarrow v, g1 \leftarrow g2, j \leftarrow -j \).
   3. \( u \leftarrow u \cdot z^j v \).
   4. \( g1 \leftarrow g1 \cdot z^j g2 \).
4. Return \( g1 \)
Part 1: Improving the Inversion Algorithm over Binary Finite Fields

Algorithm 2: The usual way to implement function deg(). \( n = \lceil m/8 \rceil \) for the field \( F(2^m) \).

**INPUT:** u  
**OUTPUT:** degree of u.

1. For \( i \leftarrow n \) downto 0 do
   If \( a[i] \neq 0 \) then: break.
2. For \( j \leftarrow 7 \) downto 0 do
   If \( a[i] >> j \) then: return(\( \text{deg}_u \leftarrow 8i+j \)).

Algorithm 3: Modified version of function deg()

**INPUT:** u, \( \text{deg}_u \) (previous degree of u)  
**OUTPUT:** \( \text{deg}_u \) (current degree of u), BefBit (the value of bit before degree bit)

1. For \( i \leftarrow \text{deg}_u/8 \) downto 0 do
   If\( (u[i]) \) then break.
2. \( t = u[i] \);
3. For \( j \leftarrow 7 \) downto 0 do
   If \( !(t \& 0x80) \) then: \( t \ll= 1 \).
   Else:
     If \( j \neq 0 \) then:
       If \( (t \& 0x40) \) then: \( \text{BefBit} \leftarrow 1 \) else \( \text{BefBit} \leftarrow 0 \).
   Else:
     If \( (a[i-1] \& 0x80) \) then: \( \text{BefBit} \leftarrow 1 \) else \( \text{BefBit} \leftarrow 0 \).
   Return(\( \text{deg}_u \leftarrow 8i+j \) and \( \text{BefBit} \)).

To improve the \( \text{shift}_n\_\text{add}() \) function, the degree of polynomials is passed to the function in order to reduce unnecessary memory read, write and XOR operation for the bytes which are zero. This can be easily done for the operation \( u \leftarrow uz j.v \) as the degree of polynomial \( v \) is known. But, in the case of \( g1 \leftarrow g1 z j.g2 \), it requires that one finds out the degree of polynomial \( g2 \) before passing it to \( \text{shift}_n\_\text{add}() \) function. Since the degree of polynomial \( g2 \) increases in each loop, Algorithm 3 cannot be used and instead Algorithm 2 has to be used to find out degree of \( g2 \). Although this will increase the time required for finding the degree of polynomials it does improve the time spent executing the inversion algorithm.

During experimentation, it is observed that degree of \( g2 \) is always less (but very close) or equal to \( m - \text{deg}_u \). Using this fact, the overhead of executing \( \text{deg} \) (\( g2 \)) is reduced and improves the inversion algorithm further.

Another improvement is to speed up the Inversion algorithm as discussed below. It is observed that whenever \( \text{deg}_u \) (degree of polynomial \( u(z) \)) is not equal to \( \text{deg}_v \) (degree of polynomial \( v(z) \)) then the behavior of next shift and add operation is related to the bit before degree bit. To explain this, let us suppose \( j \leftarrow \text{deg}_u - \text{deg}_v \) and \( j > 0 \), then the next \( \text{shift}_n\_\text{add} \) operation \( u \leftarrow uz j.v \) will clear the degree bit of \( u \). To simplify the description, the bit which is immediately before degree bit is called “BefBit”. If both
BefBits of polynomials u and v are 1, or if both of them are 0, that means by doing the shift_n_add operation, 2 bits of u get cleared at a time. This is graphically explained in Figure 1(a) and (b).

If BefBits of polynomials u and v are not equal, that is BefBit_u BefBit_v = 1 (Figure 1(c)), then using shift_n_add operation, only one bit gets clear. But in the next loop degu - degv = j-1 which is again a non negative number (this is because j>0). So in the next loop the operation (u ← uz j-1.v) will get executed (Figure 1(d)).

This means that the operations (c) and (d) could be directly done using u ← uz j .v operation (Figure 1(e)). Since the bits of g1 and g2 changes exactly like bits of u and v, the same operations can be done on g1 and g2.

The same description can be used to explain the case j ← degu - degv and j<0. Using this technique one can make sure that whenever j< 0 in every shift_n_add operation at least 2 bits get clear at a time.

Also the shift_n_add operation has been improved further by minimizing the number of expensive shifts which is shown in Algorithm 4. Algorithm 5 shows the modified version of Inversion algorithm.

\[ u(z) \leftarrow u(z) \oplus z^j \cdot v(z) \]

\[ u(z) : 0 \ 0 \ 0 \ 0 \ 0 \ 1 \ 1 \ 1 \ 1 \ 0 \ \ldots \]
\[ v(z) : 0 \ 0 \ 0 \ 0 \ 0 \ 1 \ 1 \ 0 \ 1 \ 1 \ \ldots \]

\[ j = \text{degu} - \text{degv} = 1 \]

\[ u(z) : 0 \ 0 \ 0 \ 0 \ 0 \ 1 \ 1 \ 0 \ 1 \ 1 \ \ldots \]

\[ v(z) : 0 \ 0 \ 0 \ 0 \ 0 \ 1 \ 1 \ 1 \ 1 \ \ldots \]
Part 1: Improving the Inversion Algorithm over Binary Finite Fields

Figure 1: Polynomials $u(z)$ and $v(z)$ and the shift_n_add operation for various inputs.

**Algorithm 4**: Modified version of function shift_n_add()

**INPUT**: $u$, $v$, mask, $j$, degv.

**OUTPUT**: $u$.

1. If $j = 0$ then:
   1. For $i \leftarrow (\text{degv} + j)/8$ downto 0 do
      $u[i] \leftarrow u[i] \cdot v[i]$

2. Else if mask = 0 then:
   2.1 For $i \leftarrow (\text{degv} + j)/8$ downto 1 do
      $u[i] \leftarrow u[i] \cdot v[i] \ll j$
   2.2 $u[0] \leftarrow u[0] \cdot v[0] \ll j$

\[ U(z) \leftarrow U(z) \oplus z^j \cdot V(z) \]

\[ U(z) : 0 0 0 0 1 1 1 1 0 \ldots \]
\[ \oplus z^j \cdot V(z) : 0 0 0 0 1 1 1 1 0 \ldots \]

\[ j = \text{deg}u - \text{deg}v = 1 \]

\[ U(z) \leftarrow U(z) \oplus z^j \cdot V(z) \]
\[ U(z) : 0 0 0 0 0 1 1 0 1 \ldots \]

\[ j = \text{deg}u - \text{deg}v = 1 \]

\[ U(z) \leftarrow U(z) \oplus z^j \cdot V(z) \oplus z^{j-1} \cdot V(z) \]
\[ U(z) : 0 0 0 0 0 0 0 1 0 1 \ldots \]
3. Else:
   2.1 For i ← (degv + j)/8 downto 1 do
   2.1.1 t1 ← v[i]<<(j-1), t2 ← v[i-1]>>8-j;
   2.1.2 u[i] ← u[i] t1<<1t1t2>>1.
   2.2 t1 ← v[0]<<(j-1)
   2.3 u[0] ← u[0] t1t1<<1
4. Return(u).

Algorithm 5: Modified version of Inversion in F2m using the Extended Euclidean Algorithm

INPUT: A nonzero binary polynomial a of degree at most m −1.
OUTPUT: a−1 mod f.
1. u←a , v←f.
2. g1←1 , g2←0.
3. temp ← 0 , degv ← m.
4. degu ← deg(u , m-1, &BefBit) //using algorithm3
5. While u ≠ 1 do
   5.1 j ← degu − degv , mask ← tempBefBit.
   5.2 If j < 0 then: u ↔ v , g1 ↔ g2 , degu ↔ degv , j ← − j , temp ← BefBit.
   5.3 if(j=0 or !mask) then:
      u ← u z j .v.
      g1← g1 z j .g2.
   else:
      u ← uz j .v z j -1 .v.
      g1← g1z j .g2z j -1 .g2.
5.4 degu ← deg(u , degu -1, &BefBit) //using Algorithm 3
6. Return(g1)

Analysis of inversion algorithm:
The modified inversion algorithm suggested in this work shows that calls for function deg() has been reduced to 50%. Further the improvements in function deg() reduces the time spent on this function. Since the frequency of the time that BefBit of u and v are not equal is about 50% and as every two function call is integrated in one, this means the number of call to function shift_n_add operation is reduced by about 25%. This also leads to reduction in the number of call to function deg() by about 13% more. This totally reduces 63% of call to function deg().

One may think about improving further by taking more than one bit before degree bit in to account to combine more shift_n_add operation in one. This possibility cannot be considered, because it requires many combination of bits, and that will increase the overhead of shift_n_add() function.

Using all above techniques, implemented inversion function provides 3.36 times faster operation than the original implementation. This to our knowledge is the fastest
implementation in C language for 8 bits devices, with an overhead of less than 1 KB of code memory and no overhead of RAM memory.

The implementation results are summarized in Table 1 and 2. Table 1 gives the summaries of improvements to inversion algorithm. As the execution time for inversion algorithm depends on the degree, number and dispersion of ones in the input polynomial, numbers are calculated for the average of 40 random polynomial input. Table 2 compares the results of this work with previous works.

Table 1: Summaries of improvements to Inversion algorithm.

<table>
<thead>
<tr>
<th></th>
<th>No of call to function deg()</th>
<th>No of calls to function shift_n_add()</th>
<th>Execution time on ATmega128L (cycle)</th>
<th>Speed up over original Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>The original EEA (Algorithm 1)</td>
<td>294</td>
<td>294</td>
<td>549608</td>
<td>-</td>
</tr>
<tr>
<td>Algorithm 1 + changing the function deg() (a)</td>
<td>294</td>
<td>294</td>
<td>509511</td>
<td>1.08</td>
</tr>
<tr>
<td>(a) + changing the function shift_n_add() (b)</td>
<td>441</td>
<td>294</td>
<td>241530</td>
<td>2.27</td>
</tr>
<tr>
<td>(b) + reducing no of call to function deg() (c)</td>
<td>148</td>
<td>294</td>
<td>196269</td>
<td>2.8</td>
</tr>
<tr>
<td>Using Algorithms 3,4,5</td>
<td>112</td>
<td>222</td>
<td>163629</td>
<td>3.36</td>
</tr>
</tbody>
</table>

Note:
(a): Improvements to function deg() by passing previous degree of polynomial to function deg()
(b): Improvements to function shift_n_add() by passing the degree of polynomial to this function. As it can be seen, it increases the no of calls to function deg().
(c): Reducing no of call to function deg() by removing call to find out degv and by using the observation that deg(g2) < = m – degu.

Table 2: Comparison between different implementations in C language. The timings are presented on a 7.2838 MHz device.

<table>
<thead>
<tr>
<th></th>
<th>Number of instructions(cycle)</th>
<th>Improvement over original implementation</th>
</tr>
</thead>
</table>

Part 1: Improving the Inversion Algorithm over Binary Finite Fields
Yan and Shi [2008] | 422775 * | 1.3
Aranha et al.[2010] | 243790 | 2.25
This work | 163629 | 3.36

* It is an approximate value which is calculated according to the number of cycles for original implementation and the improvement which they gave to that. (Speed up of 1.3 over the original implementation)

Conclusion and Future work

In this work, few upgradations are proposed to reduce unnecessary memory usage in implementation of inversion algorithm to make the implementation as fast as possible. The proposed techniques lead to a speed of up of 3.36 times faster than the original implementation of inversion algorithm in C, without any overhead of RAM memory usage.

Developed algorithms were implemented and tested on AVR Studio 4.14 which is a cycle-accurate simulator frequently used to prototype software for execution on small devices and simulated for ATmega128L, a frequent platform used for sensor network, although the techniques can be used for any 8_bit devices.

As further work, efforts will be made to use the same techniques for implementing the inversion algorithm in assembly language to reach a faster implementation.

References


NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY, 2000, Digital Signature Standard(DSS), FIPS Publication 186-2.
Part 1: Improving the Inversion Algorithm over Binary Finite Fields

An Approach for Agent-Based Modeling Using AiC+

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Abstract

In this paper, we present AiC+, an extension of the AiC framework designed for the explanation of human actions especially in the environmental field. We use first order logics to describe the semantics used to explain the action selection of the agent (actor) using an agent hierarchy system and a fuzzy typing relation. An example is illustrated using the AiC+ to validate the framework and discuss possible future extensions to the framework.

Key words: Action-in-context, Agent hierarchy, First order logics, Fuzzy typing relation, Involvement function.

Introduction

Recent years have witnessed a wide spread-interest in the multi-agent system approach to modeling. Multi-agent modeling offers a variety of ways in which many existing complex behaviors can be modeled. The potential benefits of multi-agent modeling will only be fully realized, however, on a basis of a systematic approach towards analyzing, designing and implementing the agent models. While there are many useful models
of agents and multi-agent systems, they are typically defined in an informal way and applied in an ad-hoc fashion.

This paper introduces an extension of the Action-in-Context (AiC) framework designed for the explanation of human actions, commonly in the environmental field [De Groot 1992]. Based on the concept of progressive contextualization [Vayda 1983], the idea of AiC is to start out from the action to be explained, then identify the (individual or collective) actors directly causing this action, then identify the range of options available to these “primary” actors and the motivations attached to these options, and then identify other (“secondary”) actors and factors influencing these options and motivations, thereby putting the action in its relevant causal context without a priori bias towards any scientific discipline [Vayda 1999]. With that, AiC is a fully actor-based framework, which is a logical choice for explanatory work because actors, not systems, are the social entities that cause change directly.

The AiC framework has four interconnected components [Overmars et al. 2007]. The first is an often repeated “core element,” comprising of the action, the actor, his options and his motivations. In [Elster 1989], the latter two are called “opportunities” and “desires” but the structure is of the same simplicity: in order to act, people must have both the capacity and the will to do so. The other components of AiC are elaborations of the core element. The second component, the “actors field” is an aspect of AiC that describes the chains of social influence (causality, power) that run from the primary actors outward to other actors. Moving from primary to secondary actors and further is the actor-based way of moving from proximate factors to underlying drivers. The next component is mixed freely with the preceding one and consists of a “deeper analysis” of the options and motivations of selected actors. The final component is called the “actor model,” which defines how the actor evaluates the options and motivations to come to his decision.

This model has so far been used in the Mameluke framework [Huigen 2004] which offers the modeler a generic format to implement the interacting behavior of the modeled entities. This generic format is a hybrid of the traditional belief-desire-intention (BDI) architecture [Rao and Georgeff 1995], the agent group role (AGR) architecture [Ferber and Gutknecht 1998; Rouchier et al. 1998; Kendall 1999], and behavioral decision and action models [De Groot 1992]. In the Mameluke framework, the behavioral model of a cognitive agent, i.e., the agents rules, is structured in potential option paths (POPs) and potential option nodes (PONs). Formally, a PON is a transaction interface between an initializing agent and a recipient agent. A POP defines a sequence of PONs. As a group, the POPs represent a theoretical construct of agent behavior and decisions that the framework user wishes to explore.

The current version of the AiC model is still informal and therefore the objective of this paper is to propose a formal extension and additional features to the AiC which we have denoted as AiC+. The use of formalisms is appropriate since they allow
unambiguous descriptions of complex systems and also provide mechanisms which enable the construction of reliable and robust models.

The AiC+ framework uses an agent hierarchy based on an agent typing system which provides a more flexible description mechanism. In the hierarchy, each instance has associated a most specific type that inherits all properties of its ancestor type with the option to redefine actions introduced in the ancestor type. There also exists a fuzzy typing system where the fuzzy relation describes the type of relation between an instance and the agent types defined in the agent hierarchy. In this sense, the AiC+ is a more expressive and applicable model that can be deployed to interdisciplinary domains.

Most current models are partial in expressiveness and usability. We emphasize that AiC+ is an appropriate model which entails both properties depending on the application domain that we describe. Many models either have the expressiveness but lack the usability in the practical sense, or are useful in practice but are not expressive, in that no properties are given to determine the behavior of the system as a whole.

The remainder of the paper is organized as follows. The structure of the Agent is described in section 2. In section 3 we present the semantics of agents in the model. The description language of the model is introduced in section 4. In section 5, we offer an example that is used to validate the model. Finally in Section 6, we conclude with a discussion of the analysis of the model, and state the future work for our research.

Agent Structure
In this paper, we focus on the characteristics of the AiC+ agents in isolation. An AiC+ model introduces a set of agent types that are grouped in a type hierarchy. Agents are assumed to have a sensory system to evaluate the environment that is shared by all agents [DeLoach and Valenzuela 2007]. An instantiation of an AiC+ model is a set of agent instances (or agents for short), where each agent has its own state at each moment. We assume that communication between agents can only be effectuated by communication actions. We assume an environment (arena) for all agent activity.

A communication action passes a message to another agent typically referred to as direct communication. This communication action has five parameters described as the expression send (Receiver, Performative, Language, Ontology, Content) where Receiver is the name of the receiving agent, Performative is a speech act name (e.g., inform, request, etc.), Language is the name of the language used to express the content of the message, Ontology is the name of the ontology used to give a meaning to the symbols in the content expression, and Content is an expression representing the content of the message. The other kind of communication is the indirect one where the effect of the action on an environment is described as an external action [Dastani 2008]. An external action is supposed to change the state of an external environment. The effects of external actions are assumed to be determined by the environment and might not be known to the agents beforehand. An agent thus decides to perform an external action and the external environment determines the effect of the action. The agent can
know the effects of an external action by performing a sense action (also defined as an external action), by means of events generated by the environment. It is up to the designer to determine how the effects of actions should be perceived by the agent as described in [Dastani 2008].

**The Agent Hierarchy**

AiC+ is based on a typed agent system, where we distinguish between an agent (actor or instance) and an agent type. The agent type describes the properties that are shared by agent instances of that type. Type hierarchies are introduced to provide for a more flexible description mechanism. In a type hierarchy, each instance has associated a most specified type, that inherits all properties of its ancestor type, with the option to redefine actions that have been introduced in an ancestor type. So basically, an agent instance is assigned a most specific type, and is also related to its ancestor type.

**Figure: 1 Agent type hierarchy**

![Agent type hierarchy diagram]

In AiC+ we have a more fuzzy typing system: there is a fuzzy relation describing the type relation between an instance and the agent types defined in some agent type hierarchy. So consequently, based on this fuzzy relation, an agent instance may make a fuzzy choice between actions that are available to all agent types in that hierarchy.

Let $A$ be the set of agent types, then the agent hierarchy is described as the partial order $(A, \text{IsSpecOf})$. An agent type $A$ is called a “pater familias” if it is not the specialization of another agent type: $\neg \exists_B [A \\text{IsSpecOf} \ B]$. In the AiC+ model, each agent type must have associated its (unique) pater familias $\Pi(A)$.

In the AiC+ model, each agent $A$ type must have associated its (unique) pater familias $\Pi(A)$. We will call agent types $A$ and $B$ type related $(A \sim B)$ when they have the same pater familias:

$$A \sim B \equiv \Pi(A) = \Pi(B)$$
We write HasType \((a, A)\) to denote that agent \(a\) is an instance of agent type \(A\). We will also refer to \(A\) as the base agent type of \(a\). The fuzzy relation between an agent instance \(a\) and its related types then is expressed by the involvement function \(\text{Inv}\) where \(\text{Inv} (a, A)\) is the degree in which agent instance \(a\) is related to agent type \(A\). We make the following assumptions:

1. each agent is involved in its base agent type:
   \[
   \text{HasType} (a, A) \implies \text{Inv} (a, A) > 0
   \]

2. each agent type is most involved in itself:
   \[
   \text{HasType} (a, A) \land B \neq A \implies \text{Inv} (a, B) < \text{Inv} (a, A)
   \]

3. an agent is related to at most one agent type hierarchy:
   \[
   \text{Inv} (a, A) > 0 \land \neg A \sim B \implies \text{Inv} (a, B) = 0
   \]

4. each agent is involved as least as much in its generalizations:
   \[
   \text{Inv} (a, A) \land A \text{ IsSpecOf } B \implies \text{Inv} (a, B)
   \]

**Agent Type Definition**

An agent type is defined as a structure \((C, N, s0, G, Act)\). We subsequently describe these components.

- \(C\) is set of the general conditions (boolean variables or attributes) that apply to an agent of that type. \(N\) is the set of variables (attributes) for that type of agent. From the two variables above, we build the set \(E\) of expressions, in the conventional way:
  - from the numeric variables, we build relational numeric expressions
  - from the boolean variables and relational numeric expressions, we build boolean propositions.

Some of the variables or values come from the inspection of the outside world (the macro environment), where the actor does not make a difference, while others are internal parameter settings of the agent (micro-environment) where the actor may have an impact on the physical or social environment. In each agent state, each variable has some value. Besides, each state may involve value assignments to variables from the agent type in which the agent is involved. States of agents of this type are determined by a value assignment to these variables. The agent type has initial state \(s0\).

The agent type also has an overall activity expression, \(G\). This expression \(G\) specifies under what conditions the agent will be active at all. This may not be necessary as an explicit condition, as it may be integrated with the start condition for each action the agent may perform. Adding the overall activity condition \(G\) is more expressive which results in understanding the intention of the agent.

The component \(Act\) is a set of actions defined for that type of agent. The set \(Act\) is the set of actions specific for that agent type. We will use the expression TypeFrom \((t) = A\) to denote that the action \(t\) is specific for agent type \(A\). An action describes the behavior of an agent during a transition from one state to another. The AiC+ agent has its goal as its benefit of action which is an overall benefit related to the motivation in the AiC+ model.
Each action is a tuple \( sc, bt \) where \( sc \) is the start condition and \( bt \) is the benefit of that action expressed as a relational numeric expression. The start condition is a boolean proposition, which is an essential parameter used to evaluate whether the action can be triggered or not. The benefit parameter is the profit, so to say the goal the agent wants to achieve though it may not explicitly be stated in the model.

**Semantics**

In this section, we present the semantics of the agent in a particular state. At any one moment, the agent is in a particular state which is defined as a value assignment to its variables. The agent then will select an action to perform. Preferably the agent will select an action from its associated agent type or ancestor type. But in the \( \text{AiC}+ \) model the agent also may choose an action from any other agent type in its agent type hierarchy, depending on the level in which that agent is involved (at that moment) in that agent type. Therefore we introduce the extended action set \( \text{Act}+(A) \) for each agent type \( A \) as follows:

\[
\text{Act}+(A) = \bigcup_{X \in A} X.\text{Act}
\]  

The applicability of each action in the agent extended domain is obtained from the involvement function \( \text{Inv} \).

The agent considers all actions in its extended set of actions. The selection of the next action for an agent of type \( A \) being in state \( s \) is done as follows. Find the actions \( t \in \text{Act}+(A) \) that are enabled,

1. The activity expression for the agent type associated with \( t \) is satisfied: \( s \models \text{TypeFrom}(t).G \)
2. The start condition of \( t \) is satisfied: \( s \models t.sc \)

This leads to a shortlist of \( \Upsilon(a, s) \)

\[
\Upsilon(a, s) = \{ t \in \text{Act}+(A) \mid s \models \text{TypeFrom}(t).G \wedge t.sc \}
\]  

The shortlist is ordered according to the level of involvement and the benefit:

\[
t \preceq t' \iff t.bt(s) \cdot \text{Inv}(a, \text{TypeFrom}(t)) \leq t'.bt(s) \cdot \text{Inv}(a, \text{TypeFrom}(t'))
\]  

The operator \( \preceq \) is referred to as the order of preference. So when an action has a high benefit, it will be considered even if the agent hardly is involved in the associated agent type. It may result in a change of involvement, when the agent decides to take another profession by changing its base agent type. In this paper we will not discuss changing of base agent type. Furthermore we assume that each agent has a special action called
sense that only re-evaluates the environment leading to a modification of its state when a change of environment is observed.

**Behavior of the AiC+ Agent**

Each agent instance has its unique possible execution, also known as the trace of action [Chainbi et al 1998]. The potential behavior of the agent is described by the set of all possible executions which are finite sequences of the form \( s_0 \xrightarrow{\alpha_1} s_1 \xrightarrow{\alpha_2} s_2 \). This is inductively defined as:

1. If \( \text{HasType}(a, A) \), then \( A.s_0 \) is a possible execution of that agent with final state \( \text{st}(X) = A.s_0 \). X being a possible execution of an agent instance.

2. If \( X \) is a possible execution of agent \( a \) with \( \text{HasType}(a, A) \), and
   - \( \text{st}(X) \models A.G\cdot t \cdot \in \Upsilon(a, \text{st}(X)) \)
   - \( \text{st}(x) \xrightarrow{t} s \)

then also is a possible execution of agent instance \( a \) with final state \( \text{st}(x) \xrightarrow{t} s \) = s

We will assume that the possible executions \( X \) and \( x \xrightarrow{s\text{ense}} s(X) \) are equivalent, and call a reduced version \( s(X) \) denotes the final state of the agent instance after a sense action on the environment. The set \( \mathcal{ST}(a) \) of all possible executions of agent instance \( a \) consists of all most reduced possible executions of that agent.

**The Description Language**

**The Description Framework**

Figure 2 describes the structure and features of the AiC+ framework for describing an agent type. In box 1, we find the action which is eventually performed by the Actor. The Actor, labeled (box 2), takes a central position as the active element. The next level describes implementable options or simply put, what the actor can actually do, and the motivations (box 3.2) as the criteria through which the actor determines what implementable option he likes best. Similarly, the following level describes potential options defined as everything the actor knows how to do (box 4.1). In addition to these potential options, there is capital defined in (box 4.2) as the sum of all the resources the actor can access. Capital determines which of the potential options are implementable. Put together therefore, potential options and capital form the implementable options (box 3.1). Some of the motivational criteria of the actor are readily quantifiable, e.g in terms of money, hours, calories etc; these define the objectified motivations (box 4.3).
Other criteria act as multipliers (with values from 0 to higher than 1) on the objectified motivations; they are the degree to which the actor actually appreciates the objectified motivations; they are termed as interpretations (box 4.4). All arrows in the figure denote causal relations. The last level describes the interaction of the actor with the environment and other agents. It is at this layer that social and cultural features are described for instance the actions implemented are determined by ones status, or societal norms. Micro-environment (box 5) is any structure, physical or social, where the actor can has an impact for instance on his farm or his internet community. Macro-environment (box 6) is where the actor cannot make a difference, for example the oil market. For more information see [De Groot 1992]

### 4.2 The Specification Language

Using the specification language, one can formally specify what should be expressed as a structure of the agent and what should be written in each component of the AiC+ framework. We use the BNF notation to present the specification language. The specification language describes for each agent type in the following format:

```
Agent  ⟨ Name⟩
Specializes  ⟨ Name SupertypeList⟩*
```
Attributes  ⟨ AttributeList ⟩
Requires  ⟨ Condition ⟩
Actions  ⟨ ActionSpecList ⟩

We use Name to denote the name of the agent type. Name SupertypeList is the name of the ancestor or the general agent type. The AttributeList is the list of numerical variables and their dimensions as well as conditional variables. Condition is an expression used to specify under what conditions the agent type will be enabled, and ActionSpecList is the list of actions the agent can actually do.

The Semantics of the Specification
Describing the specification language using the AiC+ framework enables us to derive how the agent determines its optimal choice out of actions in a shortlist, given a pool of options Act+(A). From the fuzzy typing system, the agent makes a choice between the actions that are available to all agent types in the hierarchy. Each agent type must have associated its unique pater familias. Consequently, the fuzzy relation between an agent instance and its related types is then expressed using the involvement function Inv. This is done because the agent considers all actions in its extended set of actions, eqn (1).

Using the motivations represented in (boxes 4.3, 4.4, and 3.2), aids the actor, given the capital in (box 4.2), to determine the implementable actions in (box 3.1). This is done only if the agent is enabled and that the actions are from the same agent type hierarchy. The implementable actions also referred to as the shortlist, eqn (2), are the actions the agent executes in that particular state. The actor then selects the best action from the shortlist using the level of involvement as well as the benefit, eqn (3), as seen in box 1. It can be the case that due to interaction with the environment by the agents using the sense action described in subsection 3.1, influences the choice the agent would take thereby having the need to re-evaluate the execution sequence of the agent.

The Example
We have described the behavior of how an AiC+ agent evaluates its options and motivations in a given state and how the agent makes a fuzzy choice between actions that are available in an agent hierarchy. In this section we provide an example from the environment domain. The objective of the example is to illustrate how domain experts can use the model to explain the way actors in this environment would rationally make choices. This representation is done at a higher level of abstraction however most of the details are not included.

Central to the example are the agent types “farmer” and “fisherman” who specialize the general agent type or ancestor “person”. All persons can farm or fish. In our example, we only show the farmer description and leave out the fisherman but will formally describe his details later. The person “farmer” has more interest due to how tasty the food is and the prestige derived out of growing a particular crop (box 4.4) combined
with farming results which include profit, subsistence security incase of low prices on the market, and labor intensity—the amount of human energy required to grow a crop (box 4.3). He also has a higher capital for farming i.e more land (acreage), equipment, credit, social capital etc the reverse being true for the fisherman as well. This is true in reality since farmers will go fishing if needed say during drought and fishermen would go farming if the fish stocks decline or there’s a boom in selling crops.

Figure: 3  The farmer description

In figure 3, we observe that before the farmer can execute an action from (box 4.1), he needs enough capital which is represented in (box 4.2) for it to be listed in (box 3.1). A list of all actions that can be done is found in (box 4.1) which include crops 1, 2, 3 and fish. The farmer then evaluates the attributes in (box 4.3) in relation to the appreciation attributed to food taste and prestige in (box 4.4) for all the options listed in (box 4.1). The result is represented in (box 3.2). Using the result from (box 3.2) combined with the options in (box 3.1), the farmer applies the involvement function and the maximum benefit heuristic, eqn (3), to determine the best option which in this case is crop1, as seen in box 1. Note here that we choose crop 1 but in reality, a combination (intercropping) of the best two crops (e.g crop1, 3) could be chosen for instance to avert drought risk.
Figure 3 is richer and provides more than just the basics and gives more elaborate explanation of the behavior of the agent. It contains the essentials and provides a working environment for the agent, therefore easier to reason about the agents by the domain experts.

Note also that from the figure, there are other factors which may influence the choice of actions due to the interaction with the environment as shown in component (box 5), where the farmer has control over factors like soils, village relations etc. while some factors are external to the actor like the markets, climate or international lending institutions like the World Bank, component (box 6), however the formal details of this is not discussed in this paper, as it is currently being worked on. A complete formal description is given below:

<table>
<thead>
<tr>
<th>Agent Person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specializes Person</td>
</tr>
<tr>
<td>Attributes</td>
</tr>
<tr>
<td>capital, knowledge: Conditional</td>
</tr>
<tr>
<td>Requires True</td>
</tr>
<tr>
<td>Actions</td>
</tr>
<tr>
<td>sense sc = True</td>
</tr>
<tr>
<td>bt = void</td>
</tr>
</tbody>
</table>

For the fisherman, we consider three parameters for the fishing activity; the time of fishing, the capacity of the boat, and the size of the fish net. Similarly for farming, it has three parameters that we use: the month of the year the crop is harvested, the area required for cultivation - the acreage and the output described in terms of the yield to determine the start conditions for both activities.

<table>
<thead>
<tr>
<th>Agent Farmer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specializes Person</td>
</tr>
<tr>
<td>Attributes</td>
</tr>
<tr>
<td>acreage (acre), labor intensity (calories/acre), cost1, cost2, cost3 (dollar/acre), yield1, yield2, yield3 (dollar/acre) bt1, bt2, bt3 (dollars), subsistence security, nutr1, nutr2, nutr3 (Joule/acre): Numeric</td>
</tr>
<tr>
<td>land, equipment, capital: Conditional</td>
</tr>
<tr>
<td>Requires capital \land</td>
</tr>
</tbody>
</table>
Part 1: An Approach for Agent-Based Modeling Using AiC+

Actions

crop1
\[ sc = \text{Env.Month} \leq \text{March} \land \text{acreage} \geq 3 \land \text{acreage} \times \text{yield1} > 0.60 \]
\[ bt1 = \text{acreage} \times (\text{yield1} - \text{cost1}). \]
crop2
\[ sc = \text{Env.Month} \leq \text{February} \land \text{acreage} \geq 5 \land \text{acreage} \times \text{cost2} < 0.70 \]
\[ bt2 = \text{acreage} \times (\text{yield2} - \text{cost2}). \]
crop3
\[ sc = \text{Env.Month} \geq \text{May} \land \text{acreage} \leq 1 \]
\[ bt3 = \text{acreage} \times \text{nutr3}. \]

Agent Fisherman
Specializes Person
Attributes

- net size (inches), time(hours), catch(dollar/tonne),
- capacity1, capacity2, capacity3 (tonnes),
- bt1, bt2, bt3 (dollars)
- cost1, cost2, cost3 (dollars):

  Numeric

- equipment, capital, boat:

  Conditional

Requires capital \land boat

Actions

fish1
\[ sc = \text{netsize} \leq 0.75 \land \text{capacity1} \leq 5 \land \text{time} > 17:00 \]
\[ bt1 = (\text{catch} \times \text{capacity1}) - \text{cost1}. \]

fish2
\[ sc = \text{netsize} \leq 0.5 \land \text{capacity2} \leq 10 \land 07:00 < \text{time} < 12:00 \]
\[ bt2 = (\text{catch} \times \text{capacity2}) - \text{cost2}. \]

fish3
\[ sc = 0.5 < \text{netsize} \leq 1.5 \land \text{capacity3} \leq 15 \]
\[ bt3 = (\text{catch} \times \text{capacity3}) - \text{cost3}. \]

Conclusion and Future Work

In this paper, we have described the AiC+ model an extension of the AiC framework by providing formal semantics which guide in explaining the complex behavior during optimal action selection by an agent in an environmental arena. From the example, we observe that using the agent type hierarchy, the agents “farmer” and “fisherman” specialize “person”. We do not however consider the attributes of the fisherman here in the description framework. Using the involvement function Inv and the maximum benefit criteria leads us to the eventual action that is executed by the actor (farmer).

The main advantage of our model is that it is presented in a formal and non-ambiguous terms. According to Luck and d’Inverno [1995], formalization provides clarity in characterizing the nature of concepts. There is a demand of formal modeling
with the need for implementation by providing clear and unambiguous definitions of state and operations on state which provide the basis for program development. We have explained how the AiC+ model has a complex population schema in terms of an agent typing scheme. There’s an agent hierarchy where there are types and instances, the type inherits all the attributes of the instances sometimes referred to as subtypes. The relationship between the instances and the type is in the weighting scheme of the subtypes. This typing is dynamic in the sense that the instances can take on any action given the motivation and preference. The AiC+ also has a more fuzzy typing system where there is a fuzzy relation describing the type relation between an instance and the agent types defined in some agent type hierarchy. In this way we can, with ease, map a most specialized agent type with its “pater familias”. We are yet to work on the formalization of different interaction schemes in the model which currently is under development. We are considering modes of interaction between the agents themselves and also between the agents and the environment.

References


An Image-based Diagnosis of Virus and Bacterial Skin Infections

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Abstract
Skin diseases in sub-Saharan Africa tend to be prevalent due to the climate as well as the living situation of the vast majority of people. The situation is compounded by the low numbers of trained medical personnel that diagnose and treat these diseases effectively. A lot of the rural medical personnel use whatever past experience they have to diagnose the general cause of the skin disease and as such give blanket treatment. In this study we propose an image-based diagnosis method where images of skin disorders are used to classify whether the skin disease falls in the broad category of virus infections or bacterial infections. We show that with a few training images we can get very good performance results with accuracy precision of as much as 100%.

Categories and Subject Descriptors: I.2.1 [Computing Methodologies]: Artificial Intelligence - Medicine and Science.

General Terms: Image Processing, Feature Detection, Scale Invariant Feature Transformation, Automated Disease Diagnosis.

Introduction
Skin diseases have been found to be prevalent in hot, humid climates and in overcrowded places and are very common in developing countries where the majority of people have a low income and live in resource-poor settings. Skin diseases account for as much as 11% of new attendances at out-patient departments in major hospitals in developing countries [Bernard Naafs, 2009]. In Uganda, skin conditions are usually treated using local herbs or other traditional less formal methods and the cases that get
reported to more formal clinics or hospitals are the ones that have persisted despite previous efforts. The most common skin conditions that are reported in hospitals in Uganda are ones caused by allergies, auto immune reactions, bacteria and viruses. Others are cancers, haemangioma, fungus and pellagra. These skin diseases are ideally diagnosed by carrying out a laboratory investigation that can include blood examination, culture of skin scrapings and histology. Unfortunately, this method is usually used as a last resort because of some hindrances like the cost involved and risk of leaving a scar or even exposure to infections. Therefore, the commonest diagnosis method of skin diseases in Uganda is by physical evaluation of the patient and for the difficult cases, joint or multiple reviews are provided. Unfortunately, with this method, many times patients are misdiagnosed and given wrong treatment for the diseases.

This work focuses on diagnosing skin diseases that are caused by viruses and bacteria because they are the most common skin diseases that the doctors in hospitals in Uganda encounter. We suggest that a photo of the affected area is taken and then image processing and machine learning techniques applied in order to train the computer to diagnose the skin infection. This is an alternative diagnosis method for these skin infections and is safe and poses no risks, side effects or inconveniences on the side of the patient. It is also advantageous to doctors because it is fast and can be implemented in various ways like through mobile phones, computers and digital cameras. More over, it can be safely used by lowly-skilled or non-specialized medical personnel.

The rest of this paper is arranged as follows. Section 2 presents some previous related work. Section 3 describes the data collection methods that we used. Section 4 and 5 discusses the feature extraction methods that we used. Section 6 presents the results that we obtained from the proposed image-based skin detection method. Concluding remarks are then provided in Section 7 as well as some ideas of future work to be pursued.

**Previous Related Work**

The major aim of Image analysis is the use of image processing techniques in an attempt to provide a machine interpretation of an image, usually in a format that allows some decision criterion to be easily made. This recognition decision can be based on either one or a combination of the image processing, analysis and machine vision techniques.

Let us suppose we have an image which is given by a function $f(x; y)$ and contains some objects described by a set of features $f = f_1; f_2; \ldots; f_n$. The idea is to define a sample which is somewhat close to this object in terms of a matching set. This task can be reduced to the construction of some function determining a degree of proximity of the object to a reference of the object [Turner et al. 1998]. Image classification is usually achieved through recognition which is the process of comparing individual features against some pre-established template, subject to a set of conditions and tolerances. This process commonly takes place in four definable stages [Jain 1989]: (i) image acquisition and filtering; (ii) object location; (iii) measurement
of object parameters and (iv) object class estimation. Within image acquisition and filtering, a physical object is digitally imaged and the data transferred to memory, e.g. using any current image acquisition hardware available commercially. The image is preprocessed through filtering to reduce noise and to remove unnecessary features such as light flecks as well as highlighting of desirable features. Object Location involves the digital image being transformed and regions of interest identified using any image processing techniques including segmentation and feature detection operations. Within segmentation, the image is divided into individual objects to perform a separate analysis of each region. This step includes such operations as thresholding, morphological analysis and texture detection [Laws 1980].

Measurement of object parameters or Feature Extraction involves feature vectors being computed from the object images and corresponding transformed images. The features are numeric parameters that characterize the object and depend on the method of extraction and the uniqueness of the image in question. This can include an n-dimensional vector consisting of descriptors of texture or shape, color, motion or spatial location.

Object Class estimation then returns the decision on whether the image belongs to a given class of objects. Usually, machine learning techniques are used to train a group of feature sets in order to learn the behaviour and patterns of the classification. It involves assigning a probability to a predefined set of classes. Probability theory and fuzzy logic can be applied to estimate the class probability vectors from the object feature vectors.

Figure 1: Sample skin images that were used

Skin disease diagnosis has been carried out in relatively few recorded situations and those few cases use other skin types or dispositions other than the Ugandans situation.
In a recent skin diagnosis method [Abbadi et al. 2010], psoriasis is detected using skin and texture features and color is represented by three color moments while texture is represented by entropy, energy, contrast and homogeneity. Classification is then aided by the neural network analysis. Another skin diagnosis method proposed by Jones and Regd [Jones M. J. and Regd J. M 1999] uses color features that are represented by the color histogram and classified using the Naive Bayesian classifier. Kula and Dana [2002] use texture and specifically, 3-D texture representation using texton histograms to identify skin appearance. Although the results are impressive, they do not apply to skin diseases. Other computer based skin disease diagnosis methods have also been studied especially for the detection of malignant tumours and other cancer related skin conditions. More details can be found in Iyatomi [2010].

Data Collection
For this study, sample skin images were collected from skin clinics in three Uganda districts of Kampala, Gulu and Mbarara. First, the patients were clinically analysed by a professional (dermatologist/medical doctor), then laboratory tests were conducted to ascertain and confirm the skin disorder. The doctor then captured some images from the patients whose results showed that they had a viral or bacterial infection. Some preprocessing of the images was done to rescale them and in some cases some were split where it was deemed different parts of the images were fairly distinct and would aid the classification. One hundred and twenty seven images in total were obtained for this study. Figure 1 shows examples of the sample images we obtained for bacterial and viral skin diseases.

Feature Selection
Quantitative characterization of skin appearance is a difficult task. The skin surface is a detailed landscape, with complex geometry and local optical properties. In addition, skin features depend on many variables such as body location like the forehead or cheek, subject parameters like age or gender and imaging parameters like lighting or camera and also the direction from which it is viewed and illuminated. Bacterial and viral skin infections generally affect the skin by decolorising it and distorting the skin in places of infection. In more advanced cases, they also cause blisters and different skin textures.

Generally, images can be described using five major descriptors which are color, texture, shape, motion or spatial location. The specific tools that can be used to describe these concepts include but are not limited to the following. For color, it is the dominant color descriptor, the scalable color, color structure, color layout and group of frame descriptor. Texture can be described in terms of homogeneity, the texture browsing descriptor and edge histogram. Shape is described using a region based descriptor, contour based or a 3-D descriptor. For motion, it is the motion activity, camera motion, motion trajectory and warping and parametric motion descriptions. Lastly, the spatial location can be described by the region locator or spatial temporal locator.
In order to identify the major image descriptors that will effectively differentiate the viral and bacterial lesions, we carried out a feature selection process that involved testing the five major image descriptors in order to identify the ones that would ably categorise the two classes. We carried out experiments that would automatically segment the data set. The normal skin is not what we are interested in but rather the affected regions (object). Therefore, we make the region that is not affected to be our background and the affected regions to be our object or foreground.

In these experiments, we first transformed the color images into grayscale, then filtered the image based on shape and color. When transformed back into color, visual analysis showed that the viral and bacterial lesions were clearly distinguished by shape and color (See Figure 2). The virus shape follows a regular pattern while that of a bacteria follows an irregular pattern scattered all over. This visual analysis led to the selection of features that describe the images using color and shape, and they are the ones that we extracted from the images.

**Feature Extraction**

In this work, we extracted two features from the images, one based on color and another on shape interest point descriptors. The color-based method involved converting the image to HSV color space to obtain a normalised histogram of the hues of pixels. The hue distribution of each image was calculated using 10 histogram bins and was then normalized. The shape features that were extracted were the Scale Invariant Feature Transformation (SIFT) features [Lowe 2004] corresponding to a 4 x 4 grid of histograms around each key point location. SIFT feature extraction schemes generally output a range of descriptors per image. For our purposes, we averaged out the descriptors per image to obtain a representative feature vector per image in a sense representing an overall description of the shape characteristics of the image.
Fig. 2: Skin Data Set: (a) Original Virus (b) Gray-Scale representation (c) Preprocessing using entropy (d) Segmented Virus by texture filter (a) Original Bacteria (b) Gray-Scale representation (c) Preprocessing using entropy (d) Segmented Bacteria by texture filter

Results

For experimental purposes, we tried out four classification methods which are the naive Bayes (NB), a two layer multi-layer perceptron neural network1 (NN), a 2-norm support vector classifier2 (SVC), and a k-nearest neighbour classifier3 (KNN).

The results obtained for the standard algorithms were obtained as 10-fold cross validated scores. The best classifier was KNN and Neural networks that gave a diagnosis accuracy of 100%. This was followed by Support Vector Classifier with 92%. Other results are shown in Table I. It is worth noting that generally, low performance was registered for the HSV extracted feature set. This is probably because there is not much variation in the color of the infected part of the skin in both classes of diseases. SIFT feature detection results in much better performance as evidenced by Neural Networks, and KNN classifiers. This could be attributed to shape being a better discriminator for this situation than color.

<table>
<thead>
<tr>
<th>Classifier</th>
<th>HSV</th>
<th>SIFT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naive Bayes</td>
<td>0.7222 +- 0.0962</td>
<td>0.7778 +- 0.0962</td>
</tr>
<tr>
<td>Neural Network</td>
<td>0.6667 +- 0.0962</td>
<td>1+- 0</td>
</tr>
</tbody>
</table>

1 Parameters: number of hidden neurons = 10, number of training epochs = 100, regularization = 10^14.
2 Parameters: C = 0, degree = 1, = 0, regularization = 10^-14.
3 We used k = 9.
### Table I: 10-cv AUC scores for HSV and SIFT features

<table>
<thead>
<tr>
<th>Classifier</th>
<th>HSV</th>
<th>SIFT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support Vector Classifier</td>
<td>0.6667 +- 0.0962</td>
<td>0.9167 +- 0.1076</td>
</tr>
<tr>
<td>KNN</td>
<td>0.7778 +- 0.0962</td>
<td>1+- 0</td>
</tr>
</tbody>
</table>

Please note that although viral and bacterial skin diseases can be more specific, for the purposes of simplicity and as a first step towards application of computer vision techniques towards solving a local problem prevalent in Uganda, the classification here generalized a condition as viral or bacterial. The specific condition is not identified. It is noteworthy however that in most rural clinics this presents enough information for the medical practitioner to issue treatment to a patient depending on whether it is a viral or bacterial infection and not for a very specific category of infection within this broad classification i.e. viral or bacterial classification.

### Conclusion

This project is proposing a pilot study of image-based skin disease detection in Uganda. It will be helpful to the medical practitioners because it presents a fast and risk free method of diagnosis. Our experiments indicate that it is possible to obtain good performance in terms of distinguishing broad categories of disease and this presents a good start in the direction of using computer vision techniques for automatic skin disease detection. Such a system can be used to complement or supplement medical knowledge in a resource constrained environment. When successful, similar techniques can be extended to diagnosis of other diseases in Uganda. In future we intend to obtain and work with more skin image samples as well as increasing the number of classes to capture other similar diseases like fungus-based diseases. This work can also be extended to developing applications for mobile applications.

### Acknowledgments

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### References


BERNARD NAAFS, V. P. 2009 Rural dermatology in the tropics. Clinics in Dermatology , 252 - 270.


IYATOMI H. 2010. Computer-based Diagnosis of Pigmented Skin Lesions
Part Two

Data Communication and Networks
Readiness of Uganda for Analog to Digital Migration by December, 2012

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Abstract
International Telecommunications Union (of which Uganda is a signatory) in its Geneva 2006 conference set the analog-to-digital broadcasting transition deadline for June 2015. Uganda (under the Ministry of Information and Communications Technology) set its switchover date to 31st December 2012. This paper provides a situational analysis of whether Uganda is on track or not to meet the deadline. We discuss and analyse the actions taken by broadcasters and various government agencies including the regulator in support of this transition. Based on this analysis we recommend some further measures to both government and consumers to further enhance the chances of Uganda successfully meeting the deadline.

Key words: Analog-to-digital broadcasting transition; digital broadcasting; set top box; analog transmission; digital transmission;

Introduction
Digital Broadcasting Migration is a process by which broadcasting services offered on analog networks are transferred to digital networks over a specific period [MoICT, 2009]. The main purpose of the migration process is to ensure that all analog services will be
replicated on the digital networks with the aim of switching off the analog services at a specific point in time. While the migration process is applicable to both television and radio broadcasting services, this paper addresses the main issues concerning transitioning of television broadcasting since radio is less critical due to FM availability.

Although satellite broadcasting systems exist, the terrestrial broadcasting networks continue to be the primary delivery systems for television and radio broadcasting services, and in the terrestrial broadcasting services, the analog broadcasting systems require significant radio frequency spectrum which is a finite resource [Jared Baraza, 2009; MoICT, 2009].

Digital broadcasting systems, besides other attributes, are meant to improve the issue of radio spectrum which is a scarce resource, through the use of modulation and compression to transmit video, audio and data signals to the receiver sets or consumer access devices by digital radio transmitters broadcasting programmes such as music, news, sports and so on.

**Background of the Study**

Broadcasting services in Uganda started back in 1952 when the government first started radio broadcasting services and later in 1963 introduced television broadcasting services [Jonas M. Bantulaki, 2009]. The analog broadcasting services were provided by only government until the early 1990s when the broadcasting sector was liberalized. Ever since the liberalization policy was put in place, there has been tremendous growth in private radio and television broadcasting services in Uganda [MoICT, 2009]. Analog television broadcasting services in Uganda are offered in VHF and UHF frequency bands (174-230 MHz and 470-862 MHz respectively) in accordance to the 1989 Geneva (GE-89) agreement that provides for international protection to broadcasters against any interference from other users of the radio spectrum in contracting member countries of these treaties.

Digital broadcasting spectrum is currently fragmented into relatively narrow bands, scattered over many frequencies, and intertwined with digital broadcasting channels. This is a consequence of spectrum planning options adopted by various countries based on traditional use of broadcasting spectrum [MoICT, 2009; Huawei, 2010]. The GE-89 agreement provided flexibility to open up the spectrum for other uses. However, this flexibility is limited under the existing technical conditions and, in practice, the current system is not conducive to the allocation of this spectrum to more efficient alternative uses.

Hence, the switch-over from analog to digital broadcasting by mid 2015 worldwide as the GE06 agreement (The GE06 entails the digital broadcasting plan which allows for implementation of High Definition TV services using DVB-T), shall free up significant amounts of spectrum since techniques used in digital broadcasting require less spectra for the transmission of a television signal of higher quality. Hence digital migration offers a unique opportunity to meet the fast growing demand for wireless communication services by utilizing freed spectrum to ensure that other important social and economic uses, such as broadband applications have access to spectrum [Jared Baraza, 2009].
It is also important to note that, the International Telecommunication Union (ITU) has extended the digital broadcast migration deadline for 34 countries because of challenges involving the technology, standards, licensing and investment in the necessary infrastructure and the need for people to replace their televisions. The global digital switch over date is 2015, but the ITU extended the deadline by five years to 2020 for 30 countries in Africa and four in the Middle East. Among the 30 countries in Africa that have asked for extension, North African countries like Egypt, Tunisia, and Morocco stand out, given their advanced technological investments compared to other countries in sub-Saharan Africa, which form the countries whose deadline has been extended [MoICT, 2009; David Mugabe, 2009].

Rationale for Uganda’s Digital Migration

The Regional Radio communication Conference (RRC-06) of which Uganda is a signatory, set June 17, 2015 as the deadline for all countries to migrate from analog to digital terrestrial broadcasting [MoICT, 2009; David Mugabe, 2009]. The reasons for this migration are that:

i. Analog signals are expensive to maintain,
ii. They are also frequency inefficient and,
iii. They are gradually becoming obsolete.

Frequency spectrum is a scarce resource and its efficient use is critical. Digital broadcasting means that more valuable spectrum can be released and used for other services like fire, ambulance, police, military and other emergency services. All over the world, migration to digital broadcasting is taking place. Uganda however plans to shut off the analog signal by December 2012 in order to ensure a smooth transition [Jared Baraza, 2009; MoICT, 2009; Huawei, 2010].

Benefits of Digital Broadcasting

The digital migration strategy is tailored to support the following values [Jared Baraza, 2009]:

i. **Availability of Choice:** Consumers are best served when they have choice, high quality programmes, access to different service providers and different transmission platforms and a wide selection of digital equipment having various levels of functionality. For instance, under multi-casting where multiple programming channels are transmitted over a single digital frequency. In digital broadcasting one frequency is be able to carry about 12 channels, because the service providers are encouraged to produce more content, so as to utilize more channels on a single frequency, otherwise they would be losing, any existing channel. For example NTV, one of Uganda’s largest broadcasters, will be able to provide many more channels on their own, like NTV - Sports, NTV - News, NTV - Movies all as dedicated channels.
ii. **Interoperability with different Systems**—Equipment used should be able to receive content from any service provider in order to ensure that consumers have the ability to switch between service providers operating on the same platform.

iii. **Ensuring existence of a Competitiveness in the Market**—Competition benefits the consumer through the provision of more affordable services, better quality, more services and innovative products.

iv. **Efficient Use of Spectrum**—Spectrum is a finite scarce resource and should therefore, be used to its maximum potential so as to benefit from the “digital dividend”.

**Related Works**

**Overview of Analog and Digital Transmission**

**Analog Transmission**

In the Regional Radio Communications Conferences (RRC) of 2004 (RRC-04) and 2006 (RRC-06), ITU developed a digital terrestrial broadcasting plan. The Geneva 2006 (GE06) Agreement that resulted from RRC-06 set the switch-over date for analog to digital broadcasting to June 2015 when all countries party to the agreement must have migrated from analog to digital transmission. Therefore, Uganda developed a digital broadcasting plan in which the Ministry of Information and Communication Technology (MoICT), constituted a broadcasting group in accordance with the international decision to move from analog to digital terrestrial broadcasting by 2012 as the switch over date.

In analog broadcasting, the transmission method of conveying voice, data, image, signal or video information uses a continuous signal which varies in amplitude, phase, or some other property in proportion to that of a variable. It could be the transfer of an analog source signal using an analog in modulation method such as FM or AM, or where modulation is not done at all. In Uganda, most of the air interface transmission is analog, broadcasting radio and television stations have cameras, that pick up scenes, this can be DVCAMS, video tape recorders, magnetic players, humatic players, video and audio mixers. The recorders used in the field, content players and other studio equipment are digital while beyond the studio towards the air interface, transmission is analog, hence the need for a sync process to stabilize pictures [Huawei, 2010]. The studio then sends signals to a satellite uplink system through a signal input point; it is beamed on the carrier, it is encoded, compressed, multiplexed and amplified using TWT (Travelling Wave Tube) amplifiers. It is then converted to VHF (Very High Frequency) of about 7 GHz and it is beamed to the satellite - Intelsat 906 on transponder 11, a link that belongs to UBC but shall be shared with other broadcasters after digitization. By satellite, the signal can then be down-linked to several distribution stations across the country which is normally transmitted at a frequency of 4 GHz over line of sight due to the high frequency [MoICT 2009, Huawei, 2010]. The signals received by the upcountry/
offsite station, by satellite receiver box are fed to a transmitter which amplifies the signal (both audio and video). They are amplified separately, combined and the transmitter beams it to a certain channel which acts as a carrier, through the antenna system. The signal is then broadcasted in the area of coverage. This broadcast can be on VHF or on UHF; however, VHF has its own antennas, which are heavier, relaxed and can bend signals into shadow areas not necessarily in line of sight. UHF is line of sight based and has light antennas, which operate in respect to visibility of the transmitter [Huawei, 2010]. Once transmitted, a set top box is required to convert it.

**Digital Transmission**

Digital broadcasting explains the physical transfer of data in digital bit stream over a point-to-point, point-to-multipoint transmission medium or multi point to multipoint in discrete levels. This can be over media such as copper wire, optical fiber, wireless communication media, and storage media. In digital video transmission, the cameras, recorders and studio equipment are digital. In addition, digital files are smaller compared to analog due to more sophisticated compression techniques. A digital signal is a discontinuous signal that changes from one state to another in discrete steps [Jared Baraza, 2009; Huawei, 2010]. The main push factor for network operators migrating to digital is the efficiency of bandwidth and its associated increase in service provision and service quality. In the digital system, one frequency is able to carry about 12 channels; where by the 12 channels can broadcast 12 different images/messages at a given time unlike in the analog system where one frequency would be broadcasting a single message.

**Operation of a Set Top Box**

When a signal is received, one needs a digital receiver set to receive the digital signal that will be shown on the screen or a set top box that will receive the digital signal and convert to analog displayable on local television sets. Below is the architecture of a set top box.

![Fig. 1.1 Integrated Digital Set Box, adopted from [David Banks, etal, 1997]](image)

Digital architecture physically separates channel decoding, which is access network dependent from source coding, which is access network independent. The separation
is enhanced using a Serial Bus Firewire which supports both delay sensitive and non-real time traffic by deploying isochronous and asynchronous services, which is sent to the TV appliance. However, the cable to be used depends on the interfaces provided on the TV set. Old CRT TVs have audio/video (AV) input ports and do not cater for firewire cables, or even may have only RF input used for connecting local antennas creating the need for an extra device known as a Radio Frequency (RF) modulator.

A set top box is a device which will be required by viewers to convert the digital signals onto their analog televisions. Between a set top box and the TV set is an IEEE 1394 High Performance Serial Bus – Firewire - which caters for both non-delay tolerant and non-real time traffic through its isochronous and asynchronous services [David Banks, et al, 1997].

**Fig. 1.2: A high power digital transmitter**

In the above system in Fig. 1.2, the terminator sends a signal to the exciter which transmits the signal to the antenna of the TV and it can be viewed.

**Measures undertaken by other countries**

In any technological transition, an array of approaches may exist. Below are some of the options for analog - digital migration:

**General Approaches For Transition To Digital Broadcasting**

i) **Market Driven Technological Transition**: where a progressive replacement of analog technology with digital technology takes place. For instance, the South Africa government adopted a market driven approach, which allows a progressive replacement of analog technology to ensure a smooth transition [MoICT, 2009]. In this, competition among broadcasters is the drive without noticeable government intervention.

ii) **Policy Driven Technological Transition**: primarily focuses on free to air broadcasting services. Here the government sets policies that force broadcasters to make the switch.

Further, due to the advantage of early switch off, Uganda has adopted policy driven technology transition with a determined switch off date set to December, 2012 [Jonas M. Bantulaki, 2009]. In this paper, three approaches used by three chosen countries are presented as below:

**United Kingdom [UK]**

In Europe DVB, which is a suite of internationally accepted open standards for digital television (EBU – TECH 3334, 2009), had its project set up in 1993 and a phased approach to switch was adopted starting with a few major cities. Currently, UK is experiencing a full scale digital switchover and all analog transmitters have been switched.
off. An Independent group, Digital UK was setup to handle the migration. About 80% of European Cable Systems have been upgraded to support digital transmissions and digital services, but to date, a few cable operators have commercialized digital access and few households are actually receiving digital signals through cable connection [World DAB Forum, 2001].

South Africa
Currently, South Africa is the leading African country to achieve fast digital migration growth. In South Africa, digital migration is a government development agenda with a main theme of universal access to information and e-government programs. In addition, the migration strategy was strongly accelerated by the FIFA World Cup that was hosted in June, 2010. This held the biggest technology shift of TV broadcast after color TV. An Independent Communications Authority of South Africa (ICASA) issued new regulations for digital migration for all incoming broadcasters to adhere to the new digital migration policy. South Africa went ahead to quickly decide on crucial migration issues such as standards, where Digital Video Broadcasting Terrestrial Second Generation (DVB-T2) was chosen.

Kenya
Kenya considered the ITU framework for their local transition, reviewing the broadcasting regulatory framework internally, allocating digital broadcasting frequency bands and policy and regulatory considerations in transition among others to transition from analog to digital under the Kenyan Government and Communication Regulator Commission. By April 2007, over 110 TV channels and 264 FM stations had been licensed by Kenya Broadcasting Corporation, by December, 2009, Kenya became the second country to migrate to digital television after South Africa. Kenya set the date for analog switch off as December, 2012 [Jared Baraza, 2009]. Kenya’s digital migration strategy has been accelerated by government participation such as subsidizing set top boxes, ensuring that a larger portion of the populace can afford them. Further, the Kenyan government has taken a step to stop the importation of analog television sets with immediate effect in support for the digital migration growth in all areas in the country [Jared Baraza, 2009]. In terms of standard, Kenya also chose the Digital Video Broadcasting Terrestrial Second Generation (DVB-T2).

Uganda’s Digital Migration Situational Analysis
This section gives an overview of the situation in Uganda including the broadcasting Industry, the pilot project that was carried out and analyzes Uganda’s readiness for migration.

Players in Uganda’s Digital Migration Process
The number of Television and Radio Stations available in Uganda has grown tremendously. As of December, 2008, Uganda had licensed 220 radio stations with 188 operational and 32 off air stations and 50 TV stations 35 on air and 15 off air. Uganda’s
electronic media has since attracted several investors following the liberalization of the sector in the early 1990s (David Mugabe, 2009). The world is going digital and so Uganda has to. By June - 2015 the analog signals shall be switched off (Jared Baraza, 2009, MoICT, 2009, David Mugabe, 2009; Huawei, 2010) thus failure to migrate shall make Uganda be isolated. Uganda has set up strategies to go digital, a full ICT ministry has been established, a pilot group has been appointed towards this, a frame work has been set up for it and a renown digital transition company Next Generation Broadcasting (NGB) has been contracted. NGB piloted similar projects in Ghana, Tanzania and Mozambique, equally developing countries like Uganda (David Mugabe, 2009].

Uganda is set to enjoy improved reception quality, a variety of channels, clear audio signals, and sharper visuals with the adoption of digital broadcasting. The switch to Digital Terrestrial Television (DTTV) is being engineered by Next Generation Broadcasting (NGB) and Uganda Broadcasting Corporation (UBC). UBC is a national broadcaster and could easily be entrusted by government in carrying out the project; it already has some infrastructure and also can acquire more infrastructure relatively easily. While NGB is a private firm that has been accepted in Uganda for trial purposes, based on the time it has spent in Uganda, it has demonstrated strong success in digital broadcasting. NGB Executive Director, Kwame Rugunda is positioning the digital switch as mandatory and insists that migration in Uganda should be completed by December 2012, which is East Africa’s switch over deadline.

**Uganda’s Digital Migration Plan**

Uganda’s plan of migration to digital broadcasting can be divided in four distinct phases [Jared Baraza, 2009]:

i. **Preparatory Phase (Begun in July 2009):** This is the period that immediately follows the approval of the policy on analog to digital migration. This however also allowed licenced broadcasters to carryout digital broadcasting on a pilot basis under terms and conditions specified by UCC and Broadcasting council and policy was approved by government in June 2009.

ii. **Digital Switch On (scheduled for July 2011):** Official launch of digital broadcasting services in Uganda. Its expected that digital broadcasting infrastructure including set top boxes and all intergrated receivers will be available in the country [Jonas M. Bantulaki, 2009].

iii. **Simulcast Period (July 2011 – December 2012):** This is a one and half year transition period before total digital broadcasting system is established. The period will ensure viewers without set top boxes (Digital TV adapters) are not deprived of services. During this period analog and digital television will have to be broadcasted in tandem.

iv. **Analog Switch Off (December 2012):** Termination of analog transmission. This will assume completion of switch over process from analog to digital broadcasting.
Pilot Project
However, Private TV Broadcasters are not contented with NGB and UBC, taking a monopoly in the digital migration process since the government of Uganda awarded them the sole responsibility of distributing digital signals to all consumers. For several months, NGB in collaboration with UBC has been carrying out a DTT pilot project in which they distributed set boxes and transmitted digital signals to homes of about 200 pilot users in Kampala, whereby seven channels have been running on the pilot service, five of which are local and two international.

On the other hand, there are TV and Radio stations producing digital content that is being transmitted over analog signals. Most radio stations produce analog content and transmit over analog signals to analog radio receivers. Some television broadcasters produce digital content, which they are transmitting over analog signals, for instance UBC television, NBS TV, Record TV among others. However, NTV Uganda produces digital content using the most current broadcasting software but is still being transmitted over analog signals. UBC TV/Radios has digital equipment and the production studios produce digital content but are transmitted over analog signals because it has not yet migrated to digital broadcasting. Hence, in reality, both digital and analog content can be transmitted using either transmission mechanisms. Digital data can be transmitted over analog signals; analog signals can be transmitted digitally.

The pilot study was carried out but was not very successful because it was a study on a small sample populace since not so many people could be availed with reception equipment for digital signals; this rendered the pilot study negligible as concluded by the technical team.

Uganda's readiness for Digital Migration [David Mugabe, 2009]
This section seeks to underline the chronological steps Uganda has taken towards achieving digital migration, they include;

- An advisory body has been set by Uganda known as the National Digital Terrestrial Migration Taskforce that is offering advisory services to NGB and Star TV which are undertaking the project. This advisory body is to help Uganda resolve seemingly far deeper issues that could still affect the digital transition such as harmonizing policy and choice of formal digital broadcasting standards. Countries that have successfully migrated chose standards that they followed.
- Neighboring and regional countries are migrating or have migrated as a technological trend as sometimes signals are rebroadcasted in neighboring countries, for instance during regional tournaments such as East and Central African Championship (CECAFA) that was hosted by Tanzania in January-2011, Uganda rebroadcasted the signal from Tanzanian national television -Tanzania Broadcasting Corporation (TBC) hence the need for a single standard.
Part 2: Readiness of Uganda for Analog to Digital Migration by December, 2012

• There are several display standards used worldwide in digital broadcasting systems including ATSC, DMB-T/H (Digital Multimedia Broadcasting-Terrestrial/Handheld), ISDB-T (Terrestrial Integrated Services Digital Broadcasting) and DVB-T/DVB-T2 (Digital Video Broadcasting Terrestrial).

• Uganda towards the end of February, 2011 (i.e. 27th) progressed by choosing the DVB-T2 as the preferred standard; DVB-T2 uses MPEG-4 compression standard as opposed to the current MPEG-2. DVB-T2 is an upgrade of DVB-T. With its compression, at a single point the more picture elements (pixels) shall be broadcasted resulting in better picture quality for the viewers.

• Uganda stopped importing analog TV sets, and also halted the licensing of analog broadcasters [Andy Sennit, 2011]. In January 2011, Uganda effectively halted the importation of analog television sets citing that with the imminent digital transition, the sets will be obsolete hence a loss to the populace buying them [Andy Sennit, 2011].

Challenges facing Digital Migration in Uganda

Digital conversion has the potential to provide new openness and diversity to the airwaves by creating multiple new channels through the downsizing of the amount of frequencies that is needed for a single station’s broadcast.

However, in LDCs, this process is not only costly but also highly politicized and could pose a significant threat to freedom of information and democracy in developing countries. For example, in situations where the applicant for frequency is an opposition member to the government in power he/she could fail in bidding for digital frequency. Also, a financial disadvantage by a given broadcaster, could send a broadcasting house out of business in a situation where the fee for digital signal is increased [John Burges, 2003].

Additionally, the outright challenges include cost of new equipment, which can accommodate high encoding algorithms for digital data over the air interface.

There is a need to replace the analog receivers with digital receivers for reception of digital signals or integrating a Set Top Box. Most of the channels in the digital plan are incompatible with the existing analog channels hence, proposed digital channels are used after existing analog channels have been converted. The GE06 Agreement requires that agreement of neighboring countries be obtained before a number of Uganda’s digital channels can be utilized because they will affect these countries’ existing analog stations [Jonas M. Bantulaki, 2009].

There should be an amicable measure to resolve the dissatisfaction caused by the merging of UCC and Broadcasting Council [Daily Monitor, 2010], which can lead to a diversion of attention to legal matters instead of concentrating on the technicalities of digital migration.
General observations on Digital broadcasting;
We also envisage what digital broadcasting can result into:

Digital broadcasting could easily enhance the implementation of the Ugandan ICT plan and the broadcasting policy; through the establishment of multi-channel infrastructure which should be able to reduce the overall cost of additional services.

The cost of infrastructure will be reduced due to enhanced sharing. In monetary terms the cost shall be shared and still the owner of the base infrastructure shall be paid by private broadcasters using the infrastructure.

Digital television migration conversion affects most aspects of the broadcasting value chain from content production through broadcasting and reception. These all require technical upgrading to support digital broadcasts and it may even span as far as replacing support personnel.

Digital technology shall be important in eliminating the impairment caused by multi-path propagation that eventually fades the signal as it propagates. Analog signals can be impaired by low signal levels and noise as the receiver moves further from the transmitter. Very effective error correction in the receiver is able to mask the impact and continue to produce perfect pictures and sound up to the point where the error correction can no longer work and the picture will fail completely. This therefore needs adequate digital transmission power levels.

The Proposed Architecture of the Digital System for Uganda’s Broadcasting:
This section explains the architecture of the shared transmission infrastructure based in Kololo, Kampala which shall be used by all television broadcasters to transmit their signal. The figure below shows the proposed system architecture for Uganda’s digital migration plan which was developed by the Huawei Group of Companies on behalf of Uganda Broadcasting Corporation (UBC).
Beakdown of the Proposed Technical Composition of the Uganda Shared Digital Television Network:

Head-End: It supports TV signal receiving, encoding, multiplexing, scrambling, EPG editing and inserting and other value-added services system. The multiplexer will integrate several SPTS (Single Program Transport Stream) into MPTS, in which SPTS is the output signal from encoder. The Head-end component receives the local programs and the external programs from microwave and satellites, and multiplexes them to several multiplex data flows. The data flows are delivered to each transmission station. Also, there are CA (Conditional Access), EPG (Electronic Program Guide) and SMS operation together with Multiplexers in Head-end. The contents for the exchanging among head-ends are without CA protection. And the contents from a head-end to transmission stations for broadcasting are protected by CA [Huawei, 2010].

Electronic Program Guide (EPG): Is also fed into the multiplexers as special program data with which the subscribers can see the program guide information on TV. The scrambler is embedded in the multiplexer and each output stream is with scrambling.

Network Management System (NMS) and Program Distribution Network (PDN): NMS is used for management of multiplexers in the head-end. Specifically it is used for multiplexer configuration, parameter view, edit and modification. PDN carries out the transmission task for the digitalized TV signals from head-end to head-end, and the head-end to transmission station. Usually it is done by microwave or fiber network [Huawei, 2010].
Remote Monitoring Control and Monitoring Subsystem: Remote monitoring and control is used to monitor the equipment operation status and to send the control instruction from control center to the controlled devices while monitoring subsystem monitors operation conditions of the head-end and transmission stations [Huawei, 2010].

Transmission Stations: The transmission station includes transmitters and antenna. The transmitters are the digital ones, which are used to modulate the input program data flows and broadcast them out. It broadcasts the modulated signals of a TV program to the open space by RF (Radio Frequency), and the wireless signals may cover the related service area [Huawei, 2010].

Conditional Access (CA), Service Management System (SMS) and Subscriber Authorization Management: CA is used in digital TV system for protection of content by requiring certain criteria to be met before granting access to this content. SMS is used for billing, subscriber service, accounting and resources management, and it is also a heart system for the digital TV operator. Subscriber Authorization and Management authorizes and manages user information, and provides many different client services, such as billing, charging, and querying [Huawei, 2010].

STB/ Terminal Subsystem: It helps the subscribers receive the DVB-T signals by DVB-T antenna. The signal is sent to STB. With the smart-card, the subscribers would see the digital programs using their TV set. The signals sent digitally can be displayed on analog TV sets using the STB as the digital-analog converter [Huawei, 2010].

Approaches so far taken by the Government to ensure an effective Transition of Digital Terrestrial Broadcasting By December, 2012

Below are the measures taken by government towards the transition;

i. Put in place Policy, Legislative and Regulatory frameworks to enable smooth migration process.

ii. Undertake fiscal measures to enable consumers procure set top boxes and digital TV receivers at affordable prices, through tax waivers and subsidies.

iii. Provide appropriate incentives and support for signal distributors and broadcasters to put in place necessary digital infrastructures and systems.

iv. Support the development of local content.

v. Become engaged in consumer awareness media, workshops, public relations and marketing campaigns to encourage consumers to adapt to using digital equipment.

vi. Upon switch off of the analog broadcasting transmitters, the frequency assignment to broadcasters should revoked by UCC.

vii. As by February -2011, there is already massive user campaign towards digital television broadcasting. Television adverts are running towards Analog to Digital Conversion on NTV- Uganda and the Monitor newspaper giving December -
2012 is given as the date when Analog TVs shall not be able to pick up signal; this gives confidence and an assurance to the populace that by that date, the transition shall have taken place.

**Technical Requirements set by Uganda Communications Commission**

It has been noted that UCC has no threshold for requirements both in terms of hardware and software needed to broadcast digitally. Encoding techniques for the network is of great importance because the physical equipment is able to transmit some encoding standards but not all, therefore using an encoding standard that is not supported by the network capabilities by any of the broadcasting houses sharing the transmission equipment.

Therefore UCC should come up with a minimum encoding standard to allow output/ stream display of content from all broadcasting houses since transmission infrastructure shall be shared and also the software installed on the transmitters is uniform.

**Action taken by Private Broadcasters in Response to the Transition Plan:**

As a directive by the government and also as a necessity, broadcasters have installed digital studio equipment. Broadcasters are required to migrate from analog to digital technology in the studio facilities; in this, the content recorded from the field is digitized through the digital system for instance NTV- Uganda, Record Television and UBC have implemented this strategy.

Additionally, broadcasting houses in the country are already translating most of their archives into digital content. This is to have the content ready to be played back over the digital system that is to be set up. Studio owners and producers are purchasing digital recording equipment, which is to allow on-air studios to play digital content without need for translation. More observably, there is use of teleprompters in news anchoring mainly for TV stations. NTV- Uganda, WBS and UBC TVs use teleprompters where content or news stories are played as the anchor reads, such content is digitized but only the transmission over the air interface is analog [Mugabe, 2009].

**Recommendations and Conclusions**

First we discuss recommendations to the various issues raised and we conclude the paper.

**Recommendations**

The recommendations are both to government and to consumers who are the ultimate users;

**To Government**

i) Government should ensure availability of set top boxes through fiscal and other low cost measures. This should make it easier to access set top boxes. Currently Master Electronics, a store in Kampala provides them. Startimes DTV and Mo TV Africa Ltd also have pay television boxes.
ii) Uganda National Bureau of Standard and UCC should be able to define the minimum standard of set top boxes to be used in Uganda.

iii) UCC should be able to assign frequencies to signal distributors and also hasten the speed of frequency allocation before the simulcast period.

iv) The regulator (UCC) should ensure that signal distributors provide services to broadcasters promptly on request.

v) UCC should provide appropriate regulation and incentives towards the implementation of digital broadcasting.

vi) Find an amicable mechanism to resolve the stand-off between Law Society and the merging of UCC with Broadcasting Council so as to have one point of focus in migration other than court wrangles [Daily Monitor, 2010].

vii) Uganda should take the best practices from developed countries that have successfully migrated and are broadcasting in digital.

To Consumers

i) Consumers are very sensitive to drastic changes; therefore to avoid non compliance, consumers should be given adequate and timely information on migration implementation timeframe to enable them prepare for change.

ii) The Digital Migration Board should respond to public concerns even beyond the switchover date as all concerns may not be anticipated in time.

iii) Government is sensitizing a section of people; however Consumer Education should involve Broadcasters, Retailers and other players in the broadcasting industry as well as local users who may not read Newspapers, which is the current mode of information dissemination about the transition, in order to yield the expected benefits.

iv) The importation of Set top boxes for digital broadcasting should be zero rated to reduce their cost to the final consumer (buyer).

v) The implementation strategies should target the vulnerable such as groups like people with disabilities, marginalized areas and the poor to ensure that they are included in the migration process hence social responsibility.

Conclusion and Future Work

In this paper we have discussed the current status of digital migration in Uganda, analysing the actions taken by broadcasters and government agencies as well as the prevailing challenges. Based on this analysis we have made some recommendations to government as the leading stake holder, so as to keep Uganda on track to meet the migration deadline. The following areas need further investigation.

1. IPTV: Internet Protocol Television is a system through which internet television services are delivered using the architecture and networking methods of internet protocol suite over packet switched network infrastructure. This shall be necessary incase cable TV is installed in homes and also when video-streaming is adopted to enhance wide viewability of the local TV stations online.
2. Mobile TV: Television watched on a small handheld device such as a mobile phone. Here, the small devices would need low resolution pictures that can display on mobiles that have constrained resources.

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References
The Feasibility of National Roaming in Highly Competitive Mobile Markets: A Case Study of Uganda

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Abstract
Various telecommunications regulators have mandated infrastructure sharing in general and national roaming more specifically in their respective countries. Currently in Uganda, there is a “co-location and sharing of infrastructure” policy, however, it is silent on issues of national roaming and it has not been actively enforced by the regulator. In this paper, we evaluate the technical and economic feasibility of national roaming in Uganda considering the current mobile market structure. We find that Uganda’s mobile market consisting of 12 licensed operators is highly competitive as evidenced by the price wars that started in late 2010. Of these operators, only 4 boast of national network coverage. Based on observations, a review of related work, and interviews with three senior engineers of two of these operators, we conclude that national roaming is technically feasible. However, anti-competitive monopolistic behaviors among well established operators need to be addressed before national roaming can be economically feasible. This can be achieved by defining an inclusive national roaming policy, which is one of the recommendations we make. The other recommendation is enforcement of standardization of telecommunications equipment and the regions (given their populations and telecoms infrastructure characteristics) in Uganda where national roaming is most beneficial.

Key words: national roaming; infrastructure sharing; mobile market; technical feasibility; economical feasibility;

Introduction

Background

The Ugandan telecom sector has gone through a major transformation. Thanks to the successful liberalization process of 1998, Uganda now counts on a good number of telecom service operators, three of which have been in the market for quite a good number of years: MTN Uganda, Uganda Telecom, and Airtel (formerly known as Zain Uganda). Warid Telecom entered the market in February 2008, Orange Uganda launched in March 2009, joined by Smile Telecom and I-Tel among many more others. New entrants are expected to continue to join the market. Increased competition is driving down prices, which may be a big threat to new entrants as they may not be able to compete freely and fairly, due to their low generated geographical coverage area, and lack of enough time to finally assemble a complete network to be able to compete.

A form of telecoms infrastructure-sharing among the telecom companies can be considered as a better option to further foster the competition and encourage new players in the market. Both the incumbent and the new operators can perceive economic benefits whereby the former raise extra revenue by renting out some of their infrastructures and the latter benefit through reduction in their cost of Capital Expenditure (CAPEX) as fewer infrastructures need to be setup. Infrastructure sharing limits duplication and gears investments toward underserved areas, product innovation, and improved customer service. However, a clear policy and commercially friendly price-regulation mechanism is a pre-requisite for successful infrastructure sharing. Many national telecoms regulatory agencies around the world are driven to favour infrastructure sharing as a way of stimulating competition. They are beginning to formulate policies that would regulate and encourage sharing of infrastructure among telecom companies as a key lever to foster competition and optimize telecom investments [Chanab et al.2007]; Just like those nations in the world, Uganda Communication Commission (UCC) has favoured infrastructure sharing in the past, by setting up “Co-location and Sharing of Infrastructure policy” stated in Policy guideline 16 [UCC 2010]; but the policy has been silent in its implementation in the past, because the Commission wanted to encourage growth and development of communication infrastructure countrywide according to the UCC’s service development specialist. The authors of this paper believe this is the right time now to put the policy to work to the benefit of all telecom stakeholders.
Benefits Achieved in Sharing Infrastructure

Infrastructure sharing presents a number of advantages that cut across the telecoms service providers, policy makers and regulators, and end users of telecoms services. Some of the advantages include but are not limited to the following;

**Extra source of revenue:** Incumbent operators can generate additional revenue from new entrants who may wish to use their infrastructure. Revenues generated from the infrastructure sharing can exceed 10 percent of the total annual revenue raised by providers.

**Less investment costs:** Infrastructure sharing divides the investment burden among the operators rather than being shouldered by a single operator. Optimized investment contributes to better sustainability of Telecoms operators, justifies higher investments in the long run due to the reduced or shared risks among the operators and can cut the infrastructure costs by almost a half as predicted by telecoms equipment vendors.

**Better use of scarce resource:** In its simplest form, sharing infrastructure can help optimize the use of national resources. For example over-digging of roads by multiple telecoms providers to lay fiber cables and copper wires can be minimized if all providers use the same duct if not fiber cable to transmit their traffic. Also, the effect of having several towers on one hill belonging to multiple providers may be reduced as sharing infrastructure encourages tower sharing as well, hence better national air space. In its complex form, sharing infrastructure can allow better use of spectrum through either direct leasing of spectrum by providers or through other spectrum sharing techniques like spectrum pooling.

**Easy Market entry by new players:** When infrastructure sharing is enforced, telecoms markets can become more attractive and new players can easily join, increasing competition in the industry with optimized and effective investment.

**Improved innovation and better customer service:** By sharing the network deployment burden and reduction of financial and operational cost constraints, operators can focus their attention towards improved innovation and better customer service hence better telecoms product offerings and fair competition.

**Achieving Universal Service goals:** Sharing infrastructure encourages telecoms operators to undertake network expansion to underserved or rural areas, using finances generated from savings, due to less investment cost incurred in urban areas. That way the preset universal service targets by policy makers and regulators can be easily met.

**Less negative environmental impact:** Telecoms infrastructure setup and deployment has had a negative effect on the environment. Infrastructure sharing can be a viable solution to some of the environmental problems, and may be supported by various conservation groups, as less network buildup results into fewer environmental hazards.
All the benefits stated above can be achieved through a proper liberalization process in the telecoms industry. The liberalization of the telecoms industry can enable economic growth across various sectors, but the extent of its success depends entirely on the transformation of regulatory policies that must be conducive to the development of competition and on the other hand attract investment and new players in the market.

This study answers the question of whether it is feasible or not to have national roaming mandated considering the current stiff competitive telecom market structure in Uganda. It also gives recommendations as to what the government should do to make a conducive environment for National Roaming. The rest of the paper is organized as follows: Section two explains related work in terms of telecoms infrastructure categories and existing sharing models, specifically elaborating on National Roaming as a form of infrastructure sharing. In addition international experience on infrastructure sharing is highlighted. Section three discusses the current telecommunication market structure, and then evaluates the technical and economical aspects regarding the feasibility of National Roaming in Uganda. Section four provides the recommendations to stakeholders obtained from the study and finally concludes the paper.

Related Work
In this section, we briefly cover some of the common existing telecoms infrastructure and sharing models including National Roaming and its implementation in various countries around the world and how those countries have benefited from it.

Telecoms Infrastructure Categories and Sharing Models
Telecoms infrastructure considered in this research is limited to mobile infrastructure, since generally the scope of telecoms infrastructure is very broad ranging from fixed-line to wireless and mobile infrastructure. Regardless of the design, a cell site of mobile operators is normally categorized into active and passive infrastructures [Chanab et al.2007]. Active infrastructure concerns the electronic elements such as Base Station Transceivers (BTS), microwave radio equipment, switches, antennas, transceivers for signal processing and transmission, and all other electronic systems and components of the mobile network. Passive infrastructure basically concerns the non-electronic infrastructure including, but not limited to, towers, shelters, air conditioning equipment, diesel generators, battery banks, and electrical supply, accounting for almost 60 percent of network rollout costs.

Infrastructure sharing models can take multiple options amongst telecoms service providers, and the model adopted may depend on the telecom regulation and legislation or policy in place in a particular country or economy. In [Chanab et al.2007], the main forms of infrastructure sharing included site sharing, network sharing and spectrum sharing. These forms were later joined by the following variations, Mobile Virtual Network Operators (MVNO), National Roaming, and Tower Companies.

Spectrum Sharing: Operators can trade part of their spectrum to other operators through either direct leasing or other spectrum sharing techniques like spectrum pooling.
This form of infrastructure sharing can solve spectrum scarcity problems, hence more operators can be accommodated by the existing limited spectrum.

**Network Sharing:** This is a typical example of active infrastructure sharing. Save Home Location Registers (HLR), Billing Systems, and Boarder gateways to other external networks, elements shared here can include Radio Network Controller (RNC), Mobile Switching Centers (MSCs), Visiting Location Register (VLR) and Serving GPRS Support Node (SGSN). This type of infrastructure sharing requires that the participating networks have greater capacities to handle traffic from either way, hence proper network planning is a pre-requisite.

**Site Sharing:** The basic and simplest form of infrastructure sharing. Infrastructure shared includes towers and masts, commercial power supply or generators, site space and transmission equipment like the microwave dishes and underground fiber cables among others. This type of infrastructure sharing is common in cities and other highly populated areas, where site mounting may be expensive, e.g trench digging or underground subway tunnels.

**Tower Companies:** This form of infrastructure sharing requires an independent company to acquire and manage wireless infrastructure for multiple operators. Tower companies can ensure fair treatment to new players as well as provide financial benefits to incumbents by buying and managing their infrastructure, hence lowering the incumbent’s Operating Expenditure (OPEX) in the long run.

**Mobile Virtual Network Operators (MVNOs):** These have neither networks nor rights to spectrum. They basically rely on infrastructure sharing to access subscribers and offer services.

**National Roaming:** mandatory national roaming allows new entrants to share infrastructure with incumbents while their networks are still under initial stages of deployment in particular geographic areas. National roaming accelerates competition by allowing new players to launch their services within a short period of time. The main objective of this paper is to evaluate the feasibility of National Roaming in Uganda considering the current mobile market structure and provide recommendations accordingly.

**National Roaming as a Form of Infrastructure Sharing**
The primary requirement for any kind of roaming is the existence of a roaming agreement between the two participating parties followed by technical implementations. Generally, the following takes place in roaming. When a subscriber enters into or switches on his mobile in a foreign network, the mobile handset accesses the visited network. A request for service is detected by the network and the handset is recognized as not being registered with the local Home Location Register (HLR). The originating home network is then identified, using the International Mobile Subscriber Identifier (IMSI) number in its SIM card, and contact is made with the home network to request
service information on the roaming handset (specifically, authorization to roam and credit status). All roaming call details are returned to the home operator, as shown in Fig.1.

Fig.1. Roaming implementation between two networks [Palmigiano et al. 2007].

“Geographically, experience has shown that the area where national roaming may be used is subject to resource constraints [Winbeg 2007], requiring operators to invest in network capacity hence expanding their Capital Expenditure (CAPEX) of which may not be in their interest.” National Roaming in areas with high population density is practically possible but not advisable. Due to a lack of network capacity that may be required to handle a huge traffic generated by the highly populated areas or urban areas, national roaming should rather be implemented in rural areas and other areas where one provider has network coverage and the other does not.

Use of Different Suppliers in Value Chain: Operators often complain of incompatibility of equipment and systems employed by other operators as major deterrents to infrastructure sharing. This hinders interoperability, which is the ability of systems or equipments from both sides to operate without problems of mismatched configurations. This is due to the fact that many operators often employ different vendors in their value chains as a source of competitive advantage [Onuzuruike 2008]. This may be partly blamed on the national regulators for lack of proper inspection and labeling of all telecoms equipment that enters the country.

Use of Inferior Equipment: Some operators deploy systems of inferior quality and so others that deem to have superior systems might not be willing to share with these in order to maintain their competitive advantage [Onuzuruike 2008].

International Infrastructure Sharing Experiences
This research paper presents the study conducted to find out the feasibility of National Roaming in highly competitive mobile markets in Uganda. Most of the paper is dedicated to motivate the problem, to review its benefits and illustrate some technical
issues related to roaming operations. Some case studies from various countries are also presented below.

**Tanzania**
Tanzania’s mobile market has four operators, namely; Mic (T) Ltd, Vodacom (T) Ltd, Zantel Ltd and Celtel (T) Ltd [Tanzania Communication Regulatory Authority, 2006] and is one of the developing countries in Africa that has implemented National Roaming. Vodacom Tanzania resides and operates in Tanzania mainland while Zantel operates on the Zanzibar Island. Vodacom Tanzania acts as a Mobile Virtual Network Terminal (MVNO) for Zantel and this validates the existence of National Roaming in Tanzania [Vodacom Tanzania, 2010]. However, some Tanzanian mobile phone operators have expressed their dissatisfaction as a result of the ongoing price wars and this may end up discouraging new investments in the industry [Kioko 2011]. According to Zantel, there are signs that the ongoing competition may have ramifications on telecommunications firms, and consumers will have to endure poor services instead of benefits.

**China**
In a bid to optimize telecoms constructions, a resolution was reached between the Ministry of Industry and Information Technology (MIIT) and the State-Owned Assets Supervision and Administration Commission (SASAC) in China to promote joint construction and use of telecoms infrastructure [Kanel 2008]. These two bodies together issued a notice requiring the large telecoms operators of China (China Telecoms, China Mobile, and China Unicom) to implement with immediate effect the sharing and joint construction for all towers and pole lines as well as sharing and joint constructions of Base Transceiver Stations (BTS).

**Switzerland**
“In Switzerland, it’s a license requirement [Chanab et al. 2007] [Kanel 2008] [Pakistan Telecommunication Authority 2007]; for all operators to share the operations building and the antenna masts or towers as long as the towers or masts still have capacity to support the extra load.”

**Netherlands**
Netherlands Competition Authority (NTA), Independent Post and Telecommunications Authority (OPTA) and the Ministry of Transport, Public Networks and Water Management (V&W) issued a joint memorandum in 2001 calling for collaboration in deployment of 3G networks by operators. 3G service providers can have a joint construction and use of network components save joint use of frequencies and core network, provided that competition between them is maintained in providing 3G services [Chanab et al; Kanel 2008] [Nisar and Nasir 2007].

**Brazil**
The Brazilian National and Telecommunication Agency (ANATEL) issued guidelines on sharing of ducts, conduits, poles, towers and utility easements by the telecoms
operators. The guidelines apply only to infrastructure with capacity [Chanab et al. 2007] [Kanel 2008] [Nisar and Nasir 2007].

Norway

Norwegian parliament approved government proposal on 3G infrastructure sharing framework. The Norwegian Post and Telecommunications Authority (NPT), the Ministry of Transport and Communications outlined the following network components to be shared— all masts, antennas, feeder and fiber cables, power supply, combiners and buildings among others. Although node-Bs and RNCs are shared physically, logical control must be reserved to the particular operators. Mobile Switching Center (MSC) and the frequencies were not allowed for sharing [Chanab et al. 2007] [Kanel 2008].

Sweden

Regulatory bodies in Sweden encourage infrastructure sharing provided that each service provider can deploy up to 30% of the nation’s populations with their own infrastructure, and then can share with others the remaining 70%. Both passive and active components are open for sharing [Chanab et al. 2007] [Kanel 2008].

India

The Telecoms Regulatory Authority of India (TRAI) made amendments in the license condition to allow both active and passive infrastructure sharing. Despite the fact that the authority encourages sharing of network elements ranging from feeder cables, node-B, transmission systems to buildings and power supply etc, the authority does not permit sharing of spectrum [Chanab et al. 2007] [Kanel 2008].

USA

Regulation of telecommunication services in the states is being guided by the Communications Act of 1934, as amended [Clinton 1996]. The guidelines contained collocation and infrastructure sharing requirements whereby all carriers are required to provide access to poles, ducts, conduits and rights-of-way to competing carriers. And the incumbent local exchange carrier must provide to any requesting carrier non-discriminatory access to network elements on an unbundled basis at any technically feasible point on terms that are nondiscriminatory, otherwise the regulators may be forced to intervene contrary to their proposed approach of not intervening on matters concerning infrastructure sharing [Chanab et al. 2007] [Kanel 2008] [Nisar and Nasir 2007].

Hong Kong

“The Telecommunication Authority reserves the right to direct any licensees to share telecoms facilities [Chee-hwa. 2000] [NTA 2008] [Chanab et al. 2007] if it’s seen to be in the public interest save in cases where the facility is a bottle neck, can be duplicated or substituted, critical facility for the supply of service by licensees etc.” The authority encourages operators to negotiate for fair commercial and technical terms in facility sharing.
**New Zealand**
Mobile site sharing is mandatory upon request. Operators have the freedom to set their own pricing arrangements for collocation [Chanab et al. 2007] [Kanel 2008].

**France**
Autorité de Régulation des Télécommunications (ART) encouraged Infrastructure sharing in 3G between different providers provided that the sharing agreements do not hinder competition in the market and as long as they do not share frequencies. In the infrastructure sharing model, ART presented five levels: sharing of sites and passive elements, antenna sharing, base station (Node-B) sharing, Radio Network Controller (RNC) sharing and sharing of backbone elements [Kanel 2008].

**Lebanon**
Bearing in mind the need to safeguard competition and investment incentives, the Telecommunication Regulatory Authority (TRA) of Lebanon promoted infrastructure sharing of the civil engineering and non active elements of a network (e.g., towers, masts, ducts and conduits). Implementation is to be carried out in areas where it is not economically sustainable for multiple operators to build infrastructure and where environmental and social concerns are particularly important (e.g., to reduce the proliferation of mobile network masts, and limit disruptive civil works) [Shehadi 2010].

**Feasibility of National Roaming Considering the Current Telecoms Market Structure.**
While liberalized markets with effective regulatory structures have traditionally observed several forms of infrastructure sharing, including co-location and National Roaming, more advanced forms are expected to emerge, which may involve various passive and active network components. These will provide significant revenue-generation opportunities for incumbent operators, and facilitate the developments of virtual operators and next-generation service providers. However, favorable regulation and economic incentives especially the market structure are key aspects in the development of effective infrastructure sharing.

**The Telecommunication Market Structure in Uganda**
The current status of ICT in Uganda has been influenced by various policies, statutes, laws, acts and regulations, passed and enacted in the past ten years. These have brought about liberalization in various social-economic sectors leading to an impressive economic performance [Clinton 1996] [Kibuuka et al. 2004]. The most noticeable ones include the enactment of the telecommunications policy of 1997, with the main objective of using the private sector to increase the penetration and level of telecommunication services throughout the country, the Rural Communications Development Policy of 2001 [Clinton 1996] [Kibuuka et al. 2004], with an objective of providing access to basic communication services within reasonable distance to all people in Uganda and lastly
the Electronic Media Statute of 1996 [Clinton 1996] [Kibuuka etal. 2004]. The National ICT Policy was developed (2003) and has provided for the electronic transaction bill, the computer crime bill and the e-signature bill, all passed into law currently. All of these transformations are responsible for the current ICT status in Uganda.

As the number of mobile service providers increase in the market, the competition gets stiffer by the day. Currently, Uganda counts on up to 47 licensed telecoms operators [UCC 2010] of which 12 are mobile operators and 9 are operational. The active operators include Warid Telecoms, Orange Telecoms, Air Tel Uganda, MTN, Uganda Telecoms, I-Telecoms, Talk Telecoms, Smile Telecoms and Bukasa Telecoms. Many others including Tigo Telecoms are expected to launch their services in the country. MTN Uganda, is believed not only to have the largest subscriber base estimated at 5.6 million but also the widest network coverage. Air-Tel Uganda is the second largest operator with an estimated two million subscribers and second widest network coverage after MTN Uganda, followed by Uganda Telecoms Ltd and others. Despite the fact that many mobile telecoms operators have joined the Ugandan market in the past decade, Uganda still has a low telecoms penetration. According to [Kagenda 2010], it was estimated at 39.0 percent in 2009 and expected to grow to 70.7 percent by 2014.

Mobile providers have responded differently to current stiff competition caused by the price war. While some telecom takes the advantage of its wider network coverage and uses it as a competition tool to efficiently deliver extra services like the money transfer to its customers besides low pricing, others have strategically focused on sharp discounts on calling rates and improvement of the network quality to maintain their customers. Given this nature of the mobile market structure described above, we evaluate whether it is feasible or not to deploy National Roaming.

**Technical Feasibility of National Roaming**

The study was carried out through consultation of documents about infrastructure sharing, interviewing engineers from the two leading mobile telecoms companies and observations by one of the authors, who is a telecoms engineer. For confidential purposes, the names of the telecoms companies will be withheld as was requested by the engineers. In this study, we refer to those telecoms companies as networks “A” and “B”. Below, first we discuss the implementation of National Roaming then the perspective from the engineers interviewed.

**National Roaming Implementation**

Roaming ensures that the wireless device is kept connected to the network, without losing the connection once moved to the foreign network, but for that to happen two things have to be in place: first, the basic roaming infrastructure comprising roaming agreements defining the Interconnection structure between Public Land Mobile Network (Inter-PLMN) and billing, and secondly, roaming services of which subscribers from either networks can access.
Roaming Agreement
A roaming agreement basically refers to bilateral or multilateral understanding between wireless telephone companies stating clearly the terms and conditions under which to carry out roaming service to each other’s subscribers. Roaming agreements covers both operational and economical aspects including tariffs, interconnection, and pricing, data format to be exchanged and exchange mechanisms.

Inter-PLMN (Networks)

Fig 2. Inter-Network/PLMN Connections

In reference to figure 2, roaming interconnection can exist in the above shown three forms:

- SS7 signaling links between the participating networks are required for the subscriber’s information exchange between the Home Location Register (HLR) and the Visitor’s Location Register (VLR) of the visited network.
- Interconnection links to transport the circuit-switched voice services across the two roaming networks.
- Packet-switched interconnection to transport packet data between the roaming networks.

Billing
The Visited Network (PLMN) generates the Call Detail Records (CDRs) for all the services accessed by the roamer and then, depending on the billing terms stated in the roaming agreement by the two networks, an invoice can be raised by the visited network or bill reconciliation can be performed to settle the bills.

Roaming Services
These include all the services that the user enjoys on the visited network. Such services include the voice, data, video, VoIP among others as stated in the roaming agreement between the roaming networks.
Communication between the VLR of the Visited Network “B” and the HLR of the Home Network “A”.

When a mobile subscriber or roamer from Network “B” approaches the visited Network “A” or switches on a mobile station (MS) for the first time in a visited network, the VLR initiates the update location procedure with the roamer’s HLR.

Figure 3: MGT based routing [siddiqui 2006].

At this point the only information available in the VLR of visited Network “A” is the International Mobile Subscriber Identity (IMSI) of the roamer; this will be used by the visited Network “A” to build routing information (Signaling Connection Control Part Message (SCCP) addressing known as the Mobile Global Title (MGT) or E.214 used to communicate back to the roamers home Network “B”.

Then the roamer’s HLR i.e. Network “B” responds to the VLR of the visited Network “A” by including its own E.164 address in the Calling Party Address (CgPA) of the SCCP message. The E.164 part, as defined in the ITU-T E.164 recommendation, is used to identify the country and PLMN (in this particular case, we referred to the PLMNs as networks “A” and “B”) or PLMN and HLR, where the roamer is registered.

On receiving an initial response from the HLR of Network “B”, the VLR of Network “A” then builds the routing information for subsequent or future communication with the HLR of network “B” from the calling party’s address in the received response.

Therefore the VLR of the visited network “A” can address the HLR of the home network “B” using an E.214 MGT that has been originally built from the roamer’s IMSI and an E.164 HLR address. An E.214 MGT translation can be done either at the application level or at the SCCP level in the VLR using a routing table.

The design of both the HLR and VLR depends totally on vendor’s choice, some vendors have one component performing switching and VLR (all together named MSC) functions while others have them separated. In most network designs, the HLR is always kept as a single component.

**Engineer’s Perspective**

This study considered two network operators in Uganda, which for confidentiality purposes are referred to as A and B. Three network engineers were interviewed, one from A and two from B. The authors had planned to interview at least 5 engineers but due to their availability only three were interviewed. Based on the study and the results from the interviews, National Roaming is technically possible, but the operator’s perspective
if it were finally mandated is in question. Mobile Network Operators (MNOs) are most likely to argue that roaming charges may need to be a little higher as compared to the existing interconnection fee of 131 shillings mainly resulting from the increased costs of technical infrastructure and its operation. To assess this most probable claim we were forced to seek answers to the following questions:

- Is the handling and billing of a nationally roamed call more expensive than just a mere interconnected call and, if so, by how much?
- What extra technical infrastructure elements are required for National Roaming?
- What are the actual levels of extra costs for roaming and the likely future costs of developments?

Unfortunately, neither the operators nor the regulators had the data to answer these questions publicly available since they are considered commercially confidential by the two telecoms operators consulted (A and B). However the following comments drawn from some of the engineers from those companies gives a better understanding and probably indirectly answers those questions.

One of the network “A” Roaming engineers we interviewed stated: “First of all, National Roaming will meet strong resistance from the operators. An operator will not want subscribers from a competitor network to use his network after putting in much investment. Secondly, an operator who has been boasting of large coverage will lose because subscribers from other networks will be able to use his network in locations where their providers have no coverage i.e. there will be nothing like saying Network “B” covers the whole Uganda since say a network “A” subscriber will be able to use network “B” where network “A” has no coverage. And lastly if the operators are forced to allow it then the subscribers will find it more expensive to make calls while roaming on other networks and they will therefore avoid roaming”.

A network “B” Intelligent Network (IN) engineer stated: “That is not practical in our market, and the call will definitely be more expensive. By how much, depends on the roaming agreement between the two parties, though billing such a call will be through reconciliations of CDRs between the two networks. But from a customer perspective, if you are to be charged 3/= per sec on your network, and because they can’t provide you this coverage, you end up being charged more, is not really a practical thing. Most times what I expect is done, in the roaming agreement, they reconcile the bills from both operators and one pays the offset”.

And finally network “A” Intelligent Network (IN) engineer said: “No extra infrastructure is needed other than mapping the GT of the roaming party on to the hosts switch and HLR for identification of roaming MSISDNs. The extra costs may be due to taking into consideration the traffic from another network being harbored, services like data whose bandwidth is quite limited for most operators, fuel costs on the running BTS etc.” So, in summary from all our interviews, we realize that, the
biggest issue about National Roaming is not its technical implementations but rather the economical aspect associated with it.

**Economical Feasibility of National Roaming**

Based on our one to one talk with some of the employees of both networks “A” and “B”, their line of argument is economical. National Roaming is most likely to meet strong resistance from the operators. An operator will not want subscribers from a competitor network to use his network after putting in so much investment.

Furthermore National Roaming involves site sharing, but this entails a high degree of common costs between operators. The substantial common costs limit the scope for price competition on retail markets and this leads to co-ordinate effects. Also, the extent of site sharing is very limited to masts, antennae, power supplies, etc., but the most sensitive parts of the sites (Intelligent elements which determine the nature and range of services) constitute the majority of the costs which are only shared in exceptional circumstances. Hence, the level of common costs which in turn influence decisions on prices and output is likely to be low [Petit 2004].

Monopolistic behaviours among well established providers: | New entrants into telecoms markets often complain of anti-competitive or unfair monopolistic behaviours adopted by dominant incumbent players who would have established wide network coverage before the entry of the new players. Hence, these monopolistic players can create barriers to entry by showing unwillingness to share infrastructure. A typical example is network ”B” that enjoys a competitive advantage of having the largest GSM coverage in the country. In this case, roaming with other operators may deprive it of that advantage. So they will have to have a second thought before they finally sign the roaming agreement.

Roaming between operators may result in higher tariffs due to agreements between operators. This is specifically an issue when it comes to bundled subscriptions e.g. where a number of free SMSs or a specified amount of downloaded data is included in the subscription. In such a situation, the tariffs are reverted down to basic pricing models such as price per SMS or per Kbyte of data generated. But many operators have become multinational operators providing the same tariffs “Whenever you are” as a means of competition [Winberg 2007].

Roaming rates regulation hinders investment in network deployment and reduces incentives for smaller carriers to expand the geographic coverage of their network. If the competitive advantage of building out nationwide or large regional networks is reduced, larger carriers’ incentives to expand, upgrade or maintain their existing networks diminishes [Pines 2010].

**Recommendations**

The main objective of the study was basically to investigate the feasibility of National Roaming taking into account the current telecomunication market structure (with stiff competition among the existing mobile operators) in Uganda. We have seen from our
own evaluation and the technical perspective of the engineers interviewed from the
two companies that National Roaming is technically feasible, but from the economic
perspective, a lot still has to be done. Our recommendation below to the regulatory
body can be adopted as a basis to mandate National Roaming as a way of encouraging
fair competition and at the same time attracting new players in the telecommunication
market.

• In Uganda, the guidelines for infrastructure sharing exist and UCC supports it [UCC 2010]. In addition, UCC has encouraged development of
points of interconnect outside Kampala, metering will be effected using the
information provided within the signalling information and transit safeguard
caps of 25 Ugx per second are recommended [UCC 2009]. However, the
commission has not mandated it because they wanted to first encourage a
form of infrastructure development, which is believed to have been achieved.
Uganda has many players in the market today, and all with infrastructure
setups. Therefore, time has come, if new entrants are to be attracted to
this stifly competitive telecommunication market, that mandatory roaming should
take effect. UCC should have a well pronounced roaming policy in place
that suits the current market structure and the user demands, because it will
rather be hard to regulate roaming activities without a clear or comprehensive
policy that will cater for all the major stakeholders (users, operators, vendors,
etc.). For example, UCC should implement a policy to guide operators on
whether the roaming charges by all telecoms operators should be standard/
uniform or remain on bilateral agreement. This will prevent operators from
imparting high roaming and termination charges among themselves, and
eventually shifting the burden of high charges to the end users.

• Prior to mandatory National Roaming, there is a need for UCC and all other
stakeholders like the National Bureau of Standards (NBOS) to promote
telecoms product inspection and labeling which is currently either done
unsatisfactorily or not done at all. The commission does not label any of
the telecoms product/equipment imported into the country. This breeds
inconsistencies and interconnectivity problems between operators, which
may hinder roaming implementations once mandated.

• Due to high capacity requirements that may arise in densely populated
or urban areas, we do recommend that National Roaming should only be
mandated in areas with low coverage or areas where one of the roaming
providers has either dotted or absolutely no coverage. In Uganda such areas
do exist: the northeastern (Kotido and Moroto region) and the southwestern
(Kanungu region), the Buvuma and Kalangala islands. In other words, one
operator can supplement coverage of the other.

Conclusion

In this paper, we have shown that National Roaming is technically feasible in Uganda. However, given the highly competitive mobile market with some well established operators exhibiting unfair monopolistic behaviors, a National Roaming policy curbing such behavior needs to be defined before National Roaming can be economically feasible. We also recommend that UCC along with NBOS should enforce the standardization of telecoms equipment to ensure that interconnectivity is achieved when National Roaming is mandated. Finally, considering the population and network infrastructure characteristics of different regions in Uganda we highlight which areas would benefit the most from National Roaming.

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References


WINBEG, O. 2007. Utilization of Civilian Telecom Technologies, FMV.


TANZANIAN COMMUNICATION REGULATORY AUTHORITY, 2006, Change in Mobile Network Destinations Codes and Subscriber Numbers.

Ambulatory Sensor Networks: Data Source Authentication Concerns

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Abstract
This paper investigates target authentication and the associated data integrity concerns in Ambulatory Wireless Sensor Networks (AWSN). The relationship between AWSN security goals and deployment assumptions are evaluated, in order to ascertain their influence on the guarantee of data source authentication. From our investigation, AWSN are vulnerable to sensor swapping attacks since there is no logical bond between the sensor measurements received by the remote monitor to the physical object being monitored. To mitigate sensor swapping attacks, a Target Authentication Scheme (TAS) based on data redundancy that binds sensor measurements to a unique patient (user) is proposed.

Key words: Integrity, Remote Care, Authentication, Reliability, AWSN

Introduction
The growing demand of healthcare services due to the aging and expanding population, changing combat requirements and increases in natural disasters has motivated the development of Ambulatory Sensor Networks (AWSN). Notable projects include CodeBlue [Shnayder et al., 2005], MobiHeath [MobiHealth, 2009], MyHeart Project [Philips, 2010] and Warghter Physiological Status Monitor (WPSM) [Reed et al., 2002] among others [Mirembe, 2006]. In a typical AWSN deployment, a user wears wireless sensors which monitor his physiological status like blood pressure (Figure 1) and relay the
data to the care provider at a remote location via wireless communication technologies. Since case management depends on reliable data, there is need to verify the source of data in order to safeguard against sensor swapping attacks, akin to biometrics. Figure 1 shows a typical AWSN deployment where Tier 1 is composed of wireless sensors attached to the user and the Personal Server (PS). Tier 2 represents the data gateway and Tier 3 the healthcare service provider Backend.

Past works on secure AWSN has focused on routing [Perrig et al., 2002] and authentication of sensors [Karlof et al., 2004] but not data integrity. Thus, concerns about data integrity and reliability still persist. While biometrics would be an option, the lack of biometric support on the tiny sensors make it impossible to implement in AWSN without increasing the system complexity.

**Fig 1: Typical Deployment Architecture**

Contribution

This paper makes the following contributions.
1. Presents AWSN data integrity and reliability concerns.
2. Proposes a Target Authentication Scheme (TAS) to mitigate sensor swapping attacks.

The rest of the paper is organized as follows. Section 2 presents data integrity concerns. Section 3 presents TAS and section 4 presents related works. Section 5 concludes with future work.

**Data Integrity and Reliability Concerns**

Intuitively, remote data collection presents a challenge of target authentication and guarantee of data integrity. Thus, AWSN which often operate in hostile environments are vulnerable to Sensor Swapping attacks in which an attacker can switch a sensor between a legitimate user pi and a false user px in order to compromise the integrity of the medical record of user pi. The above threats are feasible because users operate in
hostile environments, but also because of nature of AWSN in which tiny sensors can easily be lost or even swapped by attackers especially in congested places and nursing homes where the motivation of life benefits are the leading cause of assisted suicide.

Let \( k = \{v_j\}_j \) be a set of users being monitored and \( m = \{v_j\}_i \) be a multi-set of sensors. Then, let \( S^j = \{S^i_j\}_{i=1}^k \) be a set of sensors monitoring \( v_j \). To maintain data integrity measurements from must be logically associated to user \( v_j \). Otherwise a scenario of

\[
S^j = \{s^j_{r}, s^x_{k}\}_{r,k=1}^{(n,m)}
\]

For \( j \neq x \) \& \( s^x_{k} \notin S^j \) is likely.

This implies that measurements from a set of sensors of may contain readings from other objects via sensor, hence violating the medical record integrity of user pi. The above scenario highlights the difficulty associated with remote validation of sensor readings.

**Target Authentication Scheme (TAS)**

Based on data redundancy and similarity of measurements, we propose a Target Authentication Scheme (TAS). Since sensors are small and lightweight [Reed et al., 2002], multiple sensors can be deployed to monitor a given set of conditions on, thus introducing data redundancy. The introduction of redundancy also improves data reliability as the impact of failure or loss of one sensor is minimized without increasing system complexity. We reason that by computing the similarity between sensor measurements, we can detect swapping attacks.

**Assumptions:**
1. Errors due to sampling cannot exceed the calibrated error bounds.
2. Sensors can be lost

Let \( S = \{s_i\}_{i=n}^n \) be a set of sensors, \( k = \{v_j\}_j \) be a set of attributes monitored by any sensor si. Let \( \forall s_i, M_{s_i} \) monitor \( A \). At \( t \), \( M_{s_i}(t) \) knows \( k \) (\( k \) being a tuple of size \( m \) of current measurements of \( v_j \)). Then

\[
M_{s_i}(t) = k
\]

But

\[
k = \{v_j\}_{j=1}^m
\]
\( v_j \) are the values of each attribute in the set \( A \).

Hence Equation 2 becomes;

\[
\text{(4)}
\]

Measurements form a matrix of size, where \( n \) is number of sensors and \( m \) number of attributes.

**Target Authentication**

During system calibration a threshold error bound due to sampling and operational hazards is set to \( \delta \). When sensors and relay the measurements, the aggregator normalizes the measurements using and computes the similarity between values using either Equation 5 or 6. We note similarity between any two tuples \( (p,q) \) (for \( p \) and \( q \) representing tuples of sensor reading) as \( \text{Sim}(p,q) \)

**Option I:** Thus target authentication amounts to computing the similarity between two or more readings from a set of sensors monitoring a given set of conditions of a user at a given time \( t \).

\[
\text{Sim}(p,q) = \begin{cases} 
    p - q, & \text{for } i = 1 \\
    \sqrt{\frac{\sum_{i=1}^{n} (p_i - q_i)^2}{\sum_{i=1}^{m} (p_i - q_i)^2}}, & \text{for } i > 1
\end{cases}
\]

Where \( i \) is the number of attributes

\( \text{Sim}(p,q) \) is computed over all combinations of rows in the matrix. If a row is found to have a big similarity variation from majority of rows, it is suspected to be fraudulent and ignored for processing. Otherwise, the care provider contacts the patient using an out of bound channel to verify if indeed the sensors are still in the right place. For identical rows, \( \text{Sim}(p,q) = 0 \)

**Option II:** Let \( C \) be the covariance between any two tuples \( p \) and \( q \). Then is given by;

\[
\text{Sim}(p,q) = \frac{C(p,q)}{(n-1)\delta_p \delta_q}
\]

Where \( \delta_p \) and \( \delta_q \) represent the respective standard deviation for \( p \) and \( q \), \( n \) the size of the tuple. But is computed from;

\[
C(p,q) = \sum_{r=1}^{m} (p_i - \bar{p})(q_i - \bar{q})
\]

Hence, combining Equations 6 and 7 we determine the similarity index between any two measurements. All authentic measurements should generate with a property given by equation 8.

\[
\text{Sim}_i(p,q) \leq \delta, \quad \forall_i
\]
Related work

Hwang et al. [2003], proposes Identity Mass Flow (IMF) based on Joint Probabilistic Data Association (JPDA) [Bar-Shalom & Fortmann, 1988] to maintain an Identity Belief Matrix given the target position estimates. Their algorithm can not be applied to AWSN since sensors worn by a patient have identical geographic positions. Thus, the algorithm is ideal for target tracking applications not verification of data sources or (data association)

Since IMF is computationally expensive, Shin et al. [2005] proposes a Lazy Inference on Object Identities algorithm. The algorithm is based on ac-cumulated log-likelihoods. The core theories are as those in [Shin et al., 2003] with the main difference being the sharing model of local information. In their earlier work, sensors constantly shared local data but in the updated proposal, sensors keep data logs and broadcast updates on demand. Therefore, there is need to develop new approaches that can verify data sources.

Conclusion

The expanding global population, improving life expectancy, increasing natural disasters, changing combat requirements and innovations in electronics mean that AWSN hold a real promise of healthcare delivery for the future. But for AWSN to gain acceptance from both care providers and patients, concerns about data integrity have to be addressed satisfactorily. As a first step in addressing data integrity concerns TAS is proposed. The implementation of TAS will enable the aggregator to validate the authenticity and the integrity of data from a given source. In future we will evaluate the effectiveness and efficiency TAS. We acknowledge that improving security in AWSN might come at a cost of usability, increases in energy costs and system complexity. The next step in our research is to validate the scheme using emulation techniques.

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References


Part Three

ICT for Development
Improving Content Comprehension and Knowledge Retention with Wikipedia

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Abstract
Wikipedia can function as an inter-knowledge domain glossary for identifying technical terms, jargons, acronyms, and abbreviations in documents, with anchor texts serving as the mentioned entities. There are more than ten million anchor texts that cover nearly all known knowledge domains. This wide coverage offers an opportunity for extracting terms from a document in the absence of a manually constructed glossary. This paper discusses how a state-of-the-art method of term extraction (sub-string match) can combine in-coming links overlaps to predict, disambiguate, define and link technical terms using Wikipedia anchor texts for easy knowledge acquisition. Where applicable, Wikipedia images shall be displayed along with the technical term definitions in an effort to improve knowledge retention. It is hoped that term definitions shall improve document content comprehension and facilitate the processes of knowledge acquisition.

Keywords: Document enrichment, term extraction, term definition, term disambiguation, text illustration, hyperlink generation, document comprehension, knowledge retention.

Introduction
Cost effective document content comprehension can be defined as the ability to read and understand the concepts discussed in a document within minimal time possible. The field of document comprehension is widely studied with reference to reading
levels where persons who do not read at college level or higher are said to have a low reading level and therefore cannot clearly understand the concepts of the documents they read [Young et al. 1990]. These studies indicate that education plays an important role in vocabulary level building, which in turn eases understanding of semantically related documents. As an implementation of research findings based on reading levels, vocabularies (or technical terms) that occur in documents are substituted with simpler words or word phrases that have similar semantics [Graves and Graves 2003]. If the substitution is done without considering word context, this venture may not only distort document content meaning but also limit the possibility for students to build their vocabulary level. By technical terms we refer to anything that is a word, a group of words, an acronym, or an abbreviation which designates a special meaning in text context. Although research in reading shows substantial evidence that the meaning of technical terms can be derived from context [Kate 2007], it is also true that in most cases, technical terms are used in text without definition or explanation. This tends to hinder content comprehension for readers who are at low reading levels in certain knowledge domains. Moreover, human languages more especially English constantly change by borrowing, coining, and combining words to represent new ideas, (technology,) and development [Engineer, 2005]. Therefore vocabulary level building becomes a lifetime obligation.

In 2009 the verb twitter was borrowed as trade mark of a social network that provides microblogging services, enabling its users to send and read messages called tweets.

The example above presents three technical terms that were borrowed or coined in the recent years to express ideas related to Short Message Services (SMS) and Internet technology. For a person who is not familiar with these technologies the semantics of the terms twitter, and tweet may be conspicuously revealed by considering them in context. On the contrary the meaning of the term microblogging may not be that obvious from this sentence context.

Technical terms occur in almost all reading material especially those intended for an audience at higher institutions of learning like universities and they may hinder content comprehension if they are introduced without definitions and/or explanations. We assume that easy access to context related definitions and explanations of technical terms found in a document will simplify document comprehension for readers of all levels without depriving them the opportunity to build their vocabulary levels. Therefore, TermPedia was designed with an objective to provide easy access to contextually relevant definition of technical terms that are embedded in documents. In case a technical term definition is obscure, TermPedia contains an option for the reader to obtain additional explanation on the defined technical term by linking to a Wikipedia article that discusses it explicitly.

In cognitive science, comprehension is generally characterised as the construction of a mental model that represents the objects and semantic relations described in text
This suggests that if text strings can be represented by visual aids, content comprehension could be largely improved. Pictures, charts, maps, and other illustrations form powerful object representations of text strings and make important points in document content vivid. When visual aids are coupled with relevant definitions of technical terms, information is received by the reader through two senses, the fruition of which is a clearer and lasting impression on the mind [BEN., 2001], enabling the reader to easily retain knowledge acquired.

Document content comprehension is an essential part of knowledge acquisition and retention without which the process of education is rendered futile. Education is a basic element for sustainable development, an educated population is able to provide sufficient labour for its government and in turn earn adequate income for their support. The subtle objective of this research is to promote sustainable development by facilitating the process of knowledge and retention during education.

The ability to retain knowledge is important in a developing country like Uganda which has limited access to education materials like books. Recently the expansion of ICT facilities at Makerere University increased the library users’ access to electronic information and improved student-book ratio to 1:21 [Namisango, 2010]. Although acceptable, this ratio is still below the ideal of 1:40 as recommended by The National Council for Higher Education in Uganda [NAT., 2006]. Worse scenarios exist in less fortunate universities like Islamic University in Uganda where the student-book ratio is below an unacceptable ratio of 1:13 [Idrisa, 2009].

**TermPedia Technologies**

TermPedia is a document enrichment tool that uses Human Language Technologies (HLT) to provide contextually relevant information for technical terms that are embedded in documents. TermPedia was designed to define technical terms by extracting their meaning from Wikipedia, an on-line encyclopedia. Although Wikipedia offers multilingual documents, we only utilize the English content.

Defined technical terms are linked to contextually relevant Wikipedia articles so that in cases where a term definition does not provide sufficient information for content comprehension, a reader may navigate to the Wikipedia article for additional explanation. The HLTs used in TermPedia include semi-automatic technical term extraction, automatic term definition, automatic term disambiguation and automatic hyperlink generation.

Much as document enrichment (that is to say, incorporation of contextually relevant information into existing text) is the fundamental technology of TermPedia, the tool uses document extraction techniques for semi-automatic term extraction. In addition, a simple string look-up algorithm is used for automatic term definition and a frequency based algorithm is used to generate automatic disambiguated hyperlinks. For details on TermPedia technologies please see [Olango et al. 2009]. In this paper, we present a term sense disambiguation algorithm based on overlap counts of incoming links to

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Wikipedia articles as discussed in section 3. Term sense disambiguation is necessary because most terms are ambiguous with reference to the context in which they occur. For example, `twitter` could refer to a social network as seen in the sentence example above or to the chirpingsound of a bird.

**Related Works**

This section discusses previous research in relation to using Wikipedia for document annotation and enrichment in an effort to improve content comprehension and knowledge retention in addition to reducing time for knowledge acquisition. We also look at work that has been done in relation to improving content comprehension and knowledge retention using illustrations or still images.

From the angle of topic indexing, Medelyan et al. [2008] show that Wikipedia can be used as a controlled vocabulary for identifying the main topics in a document, where article titles serve as index terms and redirect titles as their synonyms. We borrow the idea of controlled vocabulary from this research and use Wikipedia anchor texts for identifying technical terms in documents and the first paragraphs of Wikipedia articles to which the anchor texts point as the definitions of these terms.

Medelyan et al.’s research was extended for identifying significant terms within unstructured text and enriching them with links to appropriate Wikipedia articles using machine learning by Milne and Witten [2008]. They use Wikipedia not only as a source of information to point to, but also as training data for how best to create links. Milne and Witten’s resulting link detector and disambiguator performs with a constant recall and precision of close to 75% on both Wikipedia data and “real world data.” The term detector uses Wikipedia article titles for identifying terms and the disambiguation algorithm considers the links made to articles as a means of comparing possible senses of each term with its surrounding context. The good performance of this approach motivated us to use Wikipedia for training a term detector and disambiguator that uses anchor texts in place of article titles while maintaining the term disambiguation paradigm experimented by Milne and Witten.

Education theories suggest that the use of realistic graphics in teaching material increases the probability of improving comprehension. Willis [2004] acknowledges that graphics have been used to overcome the deficits in patient education material because the comprehension of such material is often impeded by text written at reading levels too high for the patient population. The focus of Willis’ work is on choosing graphics that are not too advanced for patients to understand while providing illustrations for patient educational material. Our perspective is that graphics should be used alongside technical term definitions and explanations. We believe that if text at a high reading level is well explained, comprehension shall be improved which in turn will be enhanced by graphical representations of the difficult text.

Physiologists believe that proficient readers spontaneously and purposefully create mental images while and after they read. They also say that the images emerge from all the
five senses and emotions and are anchored in a reader’s prior knowledge [Keene, 2002]. Therefore a reader without prior knowledge would benefit from image representation of text portions. Graphical representation of text is expected to facilitate the process of creating mental images and therefore improve content comprehension.

Although the question as to whether images facilitate text comprehension is beyond the scope of this paper, various researches have shown the advantage of images in this regard. [Pan Y. and Pan Y. 2009] for example presents results that show that the presence of pictures in text improved the translation scores of low-proficiency Taiwanese English foreign language college students. Their findings further show that the pictures facilitated the comprehension of both simple and difficult text. This suggests that images can be used alongside text to improve comprehension of low-level readers in a particular field without necessarily simplifying difficult text. For this reason, we are confident that Wikipedia images will improve document content comprehension for readers at all levels when presented along with term definitions and explanations.

Research Framework and Methodology

As mentioned in section 1 above, we identified three major problems that exist in document content with specific emphasis on higher education literature. The first problem is that such documents contain difficult terms or vocabulary that may hinder content comprehension if they are used without simple definitions or explanations. The second problem is that terms are ambiguous in relation to the context in which they are used. For example the term tweet may be deemed to mean the following5:

- A type of bird vocalisation
- Tweet (singer) (born 1971), American R&B and soul singer-songwriter
- Cessna T-37 Tweet, a trainer aircraft
- Tweet, a post on Twitter

A third problem is that knowledge acquired from educational literature may be easily lost if it does not make a clear and simple impression in the readers’ minds. To solve these problems, we propose TermPedia, a document enrichment tool that provides technical term definitions, explanations, and illustrations with the help of HLTs and Wikipedia’s special features. The hypothesis guiding this research can therefore be stated as follows:

1. Wikipedia anchor texts can be used to predict difficult terms in documents.
2. Incoming links overlaps can be used to disambiguate terms senses.
3. Term definitions can be provided by the first paragraphs of a Wikipedia article.
4. Wikipedia images can provide relevant illustrations for difficult terms to improve knowledge retention.

TermPedia uses anchor Wikipedia texts to represent terms because this information occurs within the text body and therefore it is more likely to provide correct terms.
in unstructured text. Anchor texts also escape the problem of spelling errors, word stemming, and terms made up of multiple noun phrases and/or multiple word strings. By anchor text we mean the alternative set of characters that are displayed in place of a web address after the creation of a hyperlink. For example blogging is an anchor text in the hyperlink below:

```
```

**Data Collection**

We used a 2010 English dump of Wikipedia which was downloaded on 14 February, 2011. The dump contained important summary information of Wikipedia articles among which were 8,605,586 article titles including their page ids. A database was thus created to hold information about the article titles and their ids. A summary of 10,672,018 anchor text strings also existed in the dump of which only 578,576 anchors indicated the possibility of ambiguity, meaning that they were linked to more than one Wikipedia article. Therefore technically speaking, TermPedia needed to disambiguate only 5.4% of the Wikipedia anchors. A database was created to contain the 10,093,442 unambiguous anchor texts including the number of incoming links to their Wikipedia targets. Yet another database was created to contain the ambiguous anchors including the id of Wikipedia articles to which they are linked. Summarized information for each article and their incoming links from other Wikipedia articles was also stored into a database. The dump also included unstructured text from Wikipedia to the capacity of 4.0 Kilobytes of zipped files. Although these databases require a lot of storage space, the pay-off was a first algorithm that did not overload the working memory with large files.

**Term Sense Disambiguation by Maximum Incoming Links Overlap Counts**

There are three major steps in the incoming links overlap count algorithm that include, categorizing terms into unambiguous and ambiguous sub-sets, finding Wikipedia targets for the terms and incoming links to these targets, and, counting the incoming link overlaps between the unambiguous targets and ambiguous targets. The ambiguous target with the most incoming links overlap count is then selected as a target for the ambiguous term. Given an unambiguous term x and an ambiguous term y, the score \( \beta(x, y) \) for the best target of y was calculated using the formula below:

\[
\beta(x, y) = \text{Max(Count)}|X \cap Y|
\]

Where X is the collection of incoming links to the target of x and Y are the collection of incoming links to targets of y.

A 39 Kilobytes text file was generated from the Wikipedia article on Anarchism and used to train the disambiguation algorithm.
Evaluation
Evaluation of the maximum incoming links overlap counts algorithm was carried out on 151 random Wikipedia articles that belonged to the medical category. Each file was transformed into a plain text file with the Wikipedia links removed and then the algorithm was used to populate the free text documents with Wikipedia links. We were interested in evaluating the performance of the algorithm on accurate term prediction and relevant target allocation.

Discussions of Findings
In this section, we shall discuss results from the evaluation of the disambiguation algorithm and the use of Wikipedia images to represent terms.

Term Sense Disambiguation
By the time this paper was submitted, the evaluation results for the incoming links term sense disambiguation algorithm were not yet ready. We shall include these results in the camera ready copy of the paper. The evaluation results shall be presented using precision, recall and f-score to show how well the algorithm performs at predicting relevant terms for specific Wikipedia articles. Original links in Wikipedia articles shall be used as the gold standard of terms in each article of interest.

Improving Knowledge Retention Using Wikipedia Images
As already mentioned, the scope of this paper does not evaluate the relevance of Wikipedia images for illustrating terms, but we assume that the disambiguation algorithm provides relevant targets for the predicted terms.

Figure 1: Screen Shot of TermPedia User Interface

We are happy to find the first image from relevant target article of a term to illustrate it as shown in Figure 1 which is a screen shot from TermPedia user interface. The user interface was designed to especially extend TermPedia to university students. The interface allows students to read HTML version of annotated text with automatically generated hyperlinks using predicted terms as anchor texts. Each hyperlink has an added

6 Online are: http://www.let.rug.nl/~olango/TermPedia/termpedia.php
Java script functionality which allows definitions of the terms (i.e. the first paragraphs of their target pages) to show in a pop-up window together with an image if available, as soon the mouse is moved over the term. Definitions are retrieved in real-time from the current version of Wikipedia articles with an excellent speed. In addition, all exist

**Conclusion and Future Work**

The challenge of using Wikipedia anchor texts to predict terms is that they are very noisy and it is difficult to filter out anchor texts which may not necessarily depict proper terms. Since we are focusing on improving vocabulary levels of readers at all levels, this is not a problem of our concern. Our concern is to allow the reader to select a level of reading by choosing how much of the text should be annotated. Fever annotations provide relatively good annotations and this take care of over populating the text with text. In turn the reader can still easily use the interface without much destruction.

The images from Wikipedia have been successfully incorporated into text but the quality and relevance of these images is beyond the scope of this research. Terms that have been linked to relevant Wikipedia pages should automatically provide meaningful illustrations from the Wikipedia images if available. We hope that in cases were the images are clear and relevant, they shall improve knowledge retention by the readers since it will allow information to go through the readers mind in two ways, by explanation and illustration.

These improved methods of reading are expected to reduce the time a reader needs for knowledge acquisition and retention, thus leading to improved ways of learning in both higher education institutions and elsewhere. In order to investigate the effect of TermPedia on improving document content comprehension, a user survey shall be carried out at Gulu University. TermPedia term prediction algorithms shall be improved in future by using category information from Wikipedia. This is expected to reduce term ambiguity and provide more accurate definitions of predicted terms including relevant images.

For ambiguous anchors texts, their targets could be used to predict their synonyms or related concepts. An example can be given for the anchor text as well considering the subject domain, it they are very closely related.

**References**


Endiisa: Decision Support Tool for Least Cost Nutritious Feed Combinations for Dairy Cattle in Uganda

Abstract
Studies reveal that low milk yields in Uganda can be attributed to poor feeding methods resulting from not meeting the right nutritional requirements of dairy cattle. Rural farmers therefore need to determine the right combination of feedstuffs in order to ensure that the diet meets the nutritional requirements in order to increase profitability. We present a decision support tool that was developed to advise farmers on the most optimal feed combination that minimizes costs while meeting the nutritional requirements of each animal. Linear Programming techniques were used to develop a computer-based Decision Support tool (DST). Results from this tool were used to obtain dietary requirement for six farms whose baseline data had been obtained. It showed a remarkable improvement of 14% variation in the milk produced.

Key Words: Decision support, Linear Programming, dairy cattle, milk production

Introduction
A common challenge that dairy farmers in Uganda face is low milk production. The current average yield is approximately 2400 kg per cow per lactation from cross-bred (Holstein Friesian Small East African Zebu) cows, which is only about 50% of their milk production potential [MUBIRU 2003]. This low yield can be attributed to poor cattle nutrition resulting from inadequate feeding. Most dairy farmers in the rural parts of the country are small scale (typically keeping 2 to 10 cows) and can hardly afford expensive feeds as this would reduce on their profit margins and make the business unviable. A stakeholder meeting with farmer participation identified the major source of the underfeeding problem as a lack of clear information on how to feed dairy cattle. Farmers indicated knowledge of the high-value cattle feed resources; however, they had no knowledge of the quantities to feed. Advice on feed combinations to meet minimum nutritional requirements with the least costs in order to increase milk production is therefore necessary.
Metabolisable energy (ME) and crude protein (CP) are key components in feeding dairy cattle (HARRIS 1992). ME is critical in providing energy for maintenance and production to the animals while CP contains the vital amino acids responsible for growth and development [EASTRIDGE, BUCHOLTZ et al. 1998; LIN 2003]. Feeds therefore are often assessed against these two feed components when evaluating feed quality. Unfortunately, dairy cattle in Uganda often fail to attain the limit of their production potential due to inability to obtain these feed components in the required amounts. Previous studies show that farmers provide only 59% and 36% of the minimum requirement of ME and CP to their dairy cattle. As a result, milk production from dairy cattle is low, in some cases ranging from 2-5 litres per cow per day [MUBIRU 2003].

Poor feeding practices largely result from limited land for establishment of fodder, inadequate knowledge on feeding regimes and the various feed resources that can be offered to dairy cattle. Previous studies have identified nutritious grass and legume pastures that can be grown for feeding dairy cattle, some being more suitable for paddock grazing and others for zero grazing. The improved tropical grass pastures contain ME ranging from 7 to 9 MJ per kg on dry matter basis and CP from 6 to 12%. ME in legume pastures can be between 7 and 13 MJ per kg on dry matter basis and CP from 17 to 30%. A number of crop residues and agro-industrial by-products can also provide quality feed for dairy cattle. Crop residues such as banana peels and sweet potato vines are valuable animal feeds and are, in fact, often used by farmers who manage their cattle under zero grazing system. Agro-industrial by-products such as brewers waste and bargasse have ME levels as high as 10 MJ per kg of dry matter and CP content of 28%. Clearly, the major problem is not necessarily the lack of feed resources in the country but rather low access to feed resources and inadequate knowledge on their utilisation and appropriate quantities to offer.

Research to address these concerns was therefore conducted in the Ugandan districts of Kayunga and Luwero. The research produced vital outputs in form of (i) information on the status of feeding of dairy cattle, and (ii) a computer based Decision Support Tool (DST), given the name “ENDIISA” by the Project Team, for developing least cost feed combinations that meet the nutritional requirements of dairy cattle.

As such, we developed a decision support tool that helps farmers to be informed directly or indirectly, through their advisors, on quantities of feeds to offer their dairy cattle which were seen as a necessity. This tool is based on the formulation of the nutrition dieting problem as a Linear Program whose objective is to minimise costs. LP models based on the National Research Council (NRC) provides for two kinds of formulation for dairy cattle as least cost and maximum profit [O'CONNOR, SNIFFEN et al. 1989]. Least cost formulation involves specifying the nutrient requirements or constraints for the ration and then finding the combination of feeds that meet or exceed these constraints at the lowest cost. Maximum profit ration program includes a least cost function, incorporates milk price information, and uses a maximum profit (income over feed cost) as one of the constraints or specifications to formulate on change as
feed costs change. Least cost formulations were considered appropriate as compared to Maximum profit because of the difficulty in determining milk yield potential of the dairy cattle since the breeds in Uganda are highly mixed and information about them seldom kept.

The rest of this paper explains how the DST was developed, tested and deployed. Chapter 2 provides materials and methods used in the study, chapter 3 describes the development of the DST tool, chapter 4 describes the development and deployment of the tool, chapter five discusses validation tests and performance and chapter six provides a conclusion to the study.

**Materials and Methods**

A team of scientists (4 female and 4 male) from the National Livestock Resources Research Institute (NaLIRRI), Makerere University (MAK), Kulika Charitable Trust - Uganda, Mukono Zonal Agricultural Research and Development Centre (MuZARDI) and the National Agricultural Advisory Services (NAADS) through a brain-storming process agreed that the prudent solution would be the development of a computer based decision support tool (DST). The team also agreed that the DST should have the capacity to generate least cost feed combinations for the farmers based on available feed resources to enable profit maximization. The DST would benefit the dairy farmers through 3 main channels. (i) Farmers who had access to computers and were computer literate would, using the DST, carry out proper planning of the feeding of their dairy cattle. This would be an option not only for farmers with personal computers but even those living in close proximity of farmers resource centers whose numbers are growing in Uganda. (ii) Extension advisors (government and NGO based) would receive information from farmers on their cattle types and available feed resources and use this information in the DST to generate cattle feeding schedules for the farmers. (iii) Researchers could incorporate all new feed resources and strategies into the DST to evaluate mechanisms for their use.

The team embarked on a process in 2 dairying districts of Uganda namely Kayunga and Luwero. The 4 stage process involved (i) A baseline study, (ii) DST development, (iii) DST testing and (iv) DST uploading onto the NARO website and stakeholder feedback. The baseline study covered 106 representative dairy farms and collected data, using a structures’ questionnaire, on household characteristics and production inputs and outputs with major focus on dairy. Eighty four percent of the study households were male headed with a husband and wife and the rest were female headed households. Data collected from the baseline study was analysed using GenStat (Discovery Edition–Version 3) to establish the proportion of farmers providing less than the required ME and CP to their dairy cows. In addition, t-tests were used to study differences in milk production where feeding was adequate compared to situations where feeding was inadequate. Simple linear regression was done to study the effect of ME and CP, separately, on milk production. In this case, the milk production (Litres per cow-1 day-1)
was the dependent variable and the proportion (%) of the daily requirement of ME and CP provided were the independent variables.

Development of the DST
Data from the baseline survey was also partly used in development of the DST. This incorporated information on feed resources used in the study area. Cattle feed requirements and feed nutritional values in terms of ME and CP were obtained from information generated from previous research in Uganda. Linear programming techniques are considered appropriate for solving the problem identified in this paper and has been widely used (O’CONNOR, SNIFFEN et al. 1989). In order to determine the appropriate solution, there is need to consider animal and feed dependant factors [O’CONNOR, SNIFFEN et al. 1989; EASTRIDGE, BUCHOLTZ et al. 1998].

Animal-Dependent Factors
The NRC model requires information about animal weight and estimates of productive status to be integrated in a linear formulation model. The model requires ME and CP value is dependent on the number of lactations, stage of lactation and weight of the animal (NRC, 2001). Information about daily milk yield, daily body reserve change during lactation, and milk fat or milk protein percentage is required to determine lactation protein requirements. The table below shows the ME maintenance requirements for lactating cows. The number of lactations is categorised as 1st – 3rd, 4th – 6th, 7th and above. For each of these categories, the stage of the cow which could be early, mid and late, bears an effect on the ME requirements.

Table 1: An example of daily cattle ME requirements for dairy cattle

<table>
<thead>
<tr>
<th>Cattle type</th>
<th>No. of Lactations</th>
<th>Stage of Lactation</th>
<th>Cattle weight (Kg)</th>
<th>ME Maintenance MJ/day</th>
<th>ME Milk production MJ/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow lactating</td>
<td>1st -3rd</td>
<td>Early</td>
<td>350</td>
<td>44.98</td>
<td>97</td>
</tr>
<tr>
<td>Cow lactating</td>
<td>1st -3rd</td>
<td>Mid</td>
<td>350</td>
<td>44.98</td>
<td>72.75</td>
</tr>
<tr>
<td>Cow lactating</td>
<td>1st -3rd</td>
<td>Late</td>
<td>350</td>
<td>44.98</td>
<td>48.5</td>
</tr>
<tr>
<td>Cow lactating</td>
<td>4th-6th</td>
<td>Early</td>
<td>350</td>
<td>44.98</td>
<td>121.25</td>
</tr>
<tr>
<td>Cow lactating</td>
<td>4th-6th</td>
<td>Mid</td>
<td>350</td>
<td>44.98</td>
<td>87.3</td>
</tr>
<tr>
<td>Cow lactating</td>
<td>4th-6th</td>
<td>Late</td>
<td>350</td>
<td>44.98</td>
<td>67.9</td>
</tr>
<tr>
<td>Cow lactating</td>
<td>7th and above</td>
<td>Early</td>
<td>350</td>
<td>44.98</td>
<td>97</td>
</tr>
<tr>
<td>Cow lactating</td>
<td>7th and above</td>
<td>Mid</td>
<td>350</td>
<td>44.98</td>
<td>72.75</td>
</tr>
<tr>
<td>Cow lactating</td>
<td>7th and above</td>
<td>Late</td>
<td>350</td>
<td>44.98</td>
<td>48.5</td>
</tr>
</tbody>
</table>

The CP values for lactating cows were also provided. According to [BOGDAN 1976] the CP requirement for dairy cows is 15% of the total feed requirement. The required
intake of dairy cattle is a function of its body weight [LIN 2003]. To determine the overall quantity, in terms of dry matter of the feed requirement, the formula in equation 1 is used, where \( W \) is the weight of the animal, \( \beta \) is an expression of the proportion of the body weight that estimates the dry matter quantity that the animal will consume voluntarily.

\[
w \times \beta \quad \text{................................................................. (1)}
\]

**Feed Dependant Factors**

The amount of CP in each feed was determined. The NRC model provides requirements for proteins in rumen digestive systems. A survey of the common feed types was carried out and the CP and ME of each feed type were obtained from results of previous studies. In addition, the cost in Uganda shillings per kilogram of dry matter was established. Table 2 below shows the feed types. These values were used as parameters in the LP model.

**Table 2: CP, ME and Cost values for common feed types in Uganda**

<table>
<thead>
<tr>
<th>Feed Type</th>
<th>Crude Protein (%)</th>
<th>Me Mj/Kg Dm</th>
<th>Cost Ugx/Kg As Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banana Peelings</td>
<td>6.50</td>
<td>11.63</td>
<td>317</td>
</tr>
<tr>
<td>Banana Stems</td>
<td>3.75</td>
<td>9.60</td>
<td>67</td>
</tr>
<tr>
<td>Bean Haulms</td>
<td>10.00</td>
<td>12.00</td>
<td>73</td>
</tr>
<tr>
<td>Calliandra</td>
<td>23.70</td>
<td>12.60</td>
<td>549</td>
</tr>
<tr>
<td>Cotton Seed Cake</td>
<td>34.78</td>
<td>12.50</td>
<td>500</td>
</tr>
<tr>
<td>Cassava Tops</td>
<td>30.40</td>
<td>14.40</td>
<td>73</td>
</tr>
<tr>
<td>Dairy Meal</td>
<td>18.15</td>
<td>10.20</td>
<td>500</td>
</tr>
<tr>
<td>Desmodium</td>
<td>16.14</td>
<td>12.00</td>
<td>653</td>
</tr>
<tr>
<td>Forage Maize</td>
<td>14.38</td>
<td>10.00</td>
<td>377</td>
</tr>
<tr>
<td>Gliricidia</td>
<td>23.20</td>
<td>12.84</td>
<td>583</td>
</tr>
<tr>
<td>Green Maize Stover</td>
<td>11.31</td>
<td>8.00</td>
<td>73</td>
</tr>
<tr>
<td>Lablab</td>
<td>21.00</td>
<td>12.00</td>
<td>438</td>
</tr>
<tr>
<td>Leucaena</td>
<td>27.10</td>
<td>12.10</td>
<td>621</td>
</tr>
<tr>
<td>Maize Bran</td>
<td>12.19</td>
<td>9.22</td>
<td>300</td>
</tr>
<tr>
<td>Maize Stover</td>
<td>4.00</td>
<td>8.00</td>
<td>73</td>
</tr>
<tr>
<td>Napier Grass/Elephant Grass</td>
<td>9.60</td>
<td>8.32</td>
<td>248</td>
</tr>
<tr>
<td>Natural Grass/Natural Pastures</td>
<td>10.00</td>
<td>8.32</td>
<td>171</td>
</tr>
<tr>
<td>Other Cultivated Grass</td>
<td>8.00</td>
<td>12.00</td>
<td>256</td>
</tr>
<tr>
<td>Roadside Grass (Natural Pasture)</td>
<td>10.00</td>
<td>8.32</td>
<td>57</td>
</tr>
<tr>
<td>S. Potato Vines</td>
<td>21.38</td>
<td>15.98</td>
<td>73</td>
</tr>
<tr>
<td>Sesbania</td>
<td>21.68</td>
<td>13.60</td>
<td>549</td>
</tr>
<tr>
<td>Star Grass/Chloris Gayana</td>
<td>12.52</td>
<td>17.10</td>
<td>495</td>
</tr>
</tbody>
</table>

**Formulation of the Linear Program**

Ration formulation should be designed with the unique requirements of specific species such as poultry, dairy cattle, etc. Linear Programming is a method of determining the
least-cost combination of ingredients using a series of mathematical equations. There are many possible solutions to each series of equations, but when the factor of cost is applied, there can only be one least cost combination [O’CONNOR, SNIFFEN et al. 1989].

The LP model contains three fundamental elements which are as follows [TAHA and GONZALEZ Pozo 2004]:

a) The decision variables that we seek to determine.

b) Objective (goal) that we aim to optimize (maximize or minimize)

c) Constraints that we need to satisfy.

**Decision Variables**

The decision that needs to be made is the proportion of feedstuffs in kilograms to be fed to each animal in order to meet the minimum dietary requirements while minimizing the cost.

**Objective Function**

In formulating least cost diets, the objective is to find the combination of feedstuffs that minimizes the cost of the diet while satisfying the imposed constraints. The objective function below is a summation of the product of the amount of feed stuff and the associated cost of obtaining one kilogram of dry matter. Where refers to the weight of dry matter of feed type in Kilograms and C is the cost of each kilogram of the feed.

\[
\text{Min} \sum F D, X C \\
\sum \text{(2)}
\]

**Constraints**

Table 3 provides the constraints that were used. Feed costs per kilogram of DM are the only non-zero objective function coefficients in the model. In equation (3) we provide a constraint which requires that the total feedstuffs must be equal to the total Dry Matter content. This constraint ensures that we compare the right quantities based on the dry matter as fresh weight may always vary. Equation (4) meets a requirement where the total crude protein in feedstuffs must be equal to recommended CP in diet. Very high or very low protein in the diet is undesirable hence the reason this constraint has been made binding by specifying the equality operator. Equation (5) ensures that the animal is not fed too much high protein concentrated feedstuffs which could cause digestion problems. High-protein feedstuffs are those whose protein value is greater than 18% of dry matter equivalent. The requirement is that the total High protein feedstuff (CP Value > 18%) must be less or equal to a fraction (0.3) of the total feedstuffs. Equation (6) ensures that the ME requirements are met. As explained in section 3.1, the required ME is a function of the weight of the animal. The requirement therefore is that the total ME in feedstuffs must be equal or greater to the recommended ME in diet. In order to ensure that the animal is given adequate variety of feed, an additional constraint requires that the total amount of feedstuffs of each variety does not exceed 40% of the total
feedstuffs (equation (7)). Equation (8) is a non-negativity constraint that is required for all linear programming problems. The requirement is that all values of feedstuffs cannot be less than zero.

Where

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( F )</td>
<td>number of kilograms of feed type</td>
</tr>
<tr>
<td>( M )</td>
<td>dry matter in the diet</td>
</tr>
<tr>
<td>( B )</td>
<td>CP percentage in feed type</td>
</tr>
<tr>
<td>( M )</td>
<td>required CP value for the animal</td>
</tr>
<tr>
<td>( P )</td>
<td>feedstuffs with %CP &gt; 18</td>
</tr>
<tr>
<td>( B )</td>
<td>ME in 1 Kg of feed type</td>
</tr>
<tr>
<td>( M )</td>
<td>required ME for the animal</td>
</tr>
</tbody>
</table>

Table 3: List of constraints

\[
\sum (1.0 \times FD_j) - DM = 0 \\
\sum (A_j \times FD_j) - CP = 0 \\
0.3 \times \sum FD_j - \sum FD_{cpj} \leq 0 \\
\sum (B_j \times FD_j) - ME \geq 0 \\
0.4 \times \sum FD_j - FD_j \leq 0 \\
FD_j \geq 0 
\]

Implementation

Development of the DST tool

The DST was implemented to be used on the web and was developed using PHP/Mysql. Users are able to select the available feedstuff, from the range that they wish to consider. They are then required to enter the cost per Kilogram of each of the selected feedstuffs. In addition, they need to specify the animal category, number of lactations, and the stage of lactation and approximate weight of the animal. If a solution is obtained, the user is able to see the optimal combination of feed types specifying the quantities and total cost. For purposes of providing appropriate values to the farmers, the fresh weight equivalent was computed.
The DST was developed with the capacity to generate feed combinations from 22 different types of feed resources commonly used by dairy farmers. Feed combinations and their costs could be generated for lactating cows of weight 350kg and above. The DST, which was named “ENDIISA” by the research team, generates feed combinations based on the specific cow CP and ME requirements and the CP and ME contents of the feed resources. The word “ENDIISA” means “FEEDING” in Luganda which is the most widely spoken local language in Uganda. The DST can be accessed and used via the internet at the web address http://www.naro.go.ug/endiisa/about.html. The tool was uploaded on the NARO-Uganda website prior to the testing phase.

Results
Testing was done to obtain ideas for improvement of the DST even before its release to the general public for use. Testing of the DST was done on 6 farms selected from those where data was collected during the baseline study. This was done to evaluate selected feed combinations generated from the DST in terms of assessment of the capability of the cows to consume all the feed as well as the effect on milk production. Data was collected on milk production before implementation of the feeding regime developed from the DST was started, and after it was started and the data was differences were tested using paired t-tests in Genstat. After the testing phase, the DST was revised and 2 Stakeholder feedback workshops were held, one in each of the districts of Kayunga and Luwero. The workshops, which were largely attended by farmers, extension advisors and policy makers, were aimed at dissemination of the DST, explaining its mode of use and describing the benefits that could be realized through its use and obtaining the views of the stakeholders on its use.

Two of the feed combinations generated from the DST and fed to the test cows in Kayunga and Luwero districts in Uganda are shown in Table 4. These were developed for a daily ration for a lactating cow of 4-6 lactations in its early stage of lactation (1-3 months) and weighing 450 kg.

Table 4: Feed combinations generated from the DST for cows of 4-6 lactations weighing 450kg and in the early stage (1-3 months) of the lactation cycle

<table>
<thead>
<tr>
<th>Sample Feed option 1</th>
<th>Quantity of feed component</th>
<th>Sample Feed option 1</th>
<th>Quantity of feed component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elephant grass (kg)</td>
<td>53.3</td>
<td>Elephant grass (kg)</td>
<td>53.5</td>
</tr>
<tr>
<td>Maize bran (kg)</td>
<td>2.5</td>
<td>Banana peels (kg)</td>
<td>23.5</td>
</tr>
<tr>
<td>Lablab (kg)</td>
<td>23</td>
<td>Lablab (kg)</td>
<td>23</td>
</tr>
<tr>
<td>Total (kg)</td>
<td>79</td>
<td>Total (kg)</td>
<td>100</td>
</tr>
<tr>
<td>Cost of formulation (Ushs)</td>
<td>1,515</td>
<td>Cost of formulation (Ushs)</td>
<td>1,000</td>
</tr>
</tbody>
</table>
Overall feeding of the DST computed feed combination to cross bred (Zebu X Friesian) cows in the early lactation period (1-3 months) of age (4-6) lactations increased daily milk production by 3.6 litres per cow (24% increase) with the milk production before and after the improved feeding showing significant differences (P<0.05).

The stakeholder feedback workshops in the 2 districts were attended by 120 participants. These included farmers, extensions advisors, NGOs, researchers and policy makers. During these workshops, presentations on the research findings and the description of “ENDIISA” DST were made and comments and questions from the participants were received and where possible addressed.

For further dissemination of the DST, the following were done:
- An article was published in the Ugandan Print Media; in the New Vision daily. The article, “Cows get computerized feeding” can be read from the internet at the web address http://newvisionuganda.info/PA/9/37/696956
- A leaflet on “ENDIISA” was produced for ease of information circulation
- A booklet summarizing the research done and the results including the use of “ENDIISA” was also produced and circulated
- The DST was put on USB disks which were circulated in the major dairying districts where internet access is still a challenge
- A paper which won First Prize at the all Africa Women in Science Competition at the Africa Science Week in Burkina Faso in 2010 was presented
- The work was also published in the AgriForum Newsletter, SPORE Magazine, and the BBC Focus on Africa Programme

Discussion and Conclusion
Dairy cattle feeding in the Central zone is not well done with most farmers offering feed providing less than the minimum nutritional requirement of the dairy cows and as a result milk production is low. Both ME and CP when provided in inadequate amounts will cause reduction in milk production. ME is a critical source of energy for maintenance and production and CP greatly contributes to milk production. Metabolisable energy and CP each individually accounts for 14% of the variation observed in milk production [MUBIRU, EBONG et al. 2001]. It is expected that the rest of the variation is caused by other factors namely cattle breed, age, lactation stage and other nutritional components. Available feed resources if acquired and fed in the appropriate quantities can provide the required crude protein (CP) and metabolisable energy (ME) to dairy cattle and this will cause an increase in milk production.

The “ENDIISA” Decision Support Tool developed as one of the outputs of this project will provide basis for development of feed formulations/mixtures that provide the required nutrition for dairy cows at the least cost in Uganda and similar agro-ecological zones particularly in parts of eastern and central Africa. “ENDIISA” is a valuable tool for policy-making with regard to feeding dairy cattle. Currently, “ENDIISA” can be used for only milking cows weighing 350 kg and above. The tool will be improved over
time to handle more applications using input provided by all users who will take time to post their comments on the website.

The tool will also (i) reduce time wastage through uncertainty on the quantities of feeds to prepare for the dairy cows (ii) enable conservation of feed for the dry season when feed resources are in excess (iii) enable development of long-term feeding plans and programmes and (iv) control feeding disorders such as bloat which results from feeding excess protein.

“ENDIISA”, being computer based, will be particularly attractive to the youth and will provide an incentive for the older farmers to develop computer skills. In addition, the tool has prospects for incorporation into a mobile telephone mechanism of response to farmers communicating their least cost feeding options based on information they would have sent to farmers’ resource centers. This system needs to be extended to allow for the use of SMS so as to increase access to the DST since most farmers have mobile telephones.

References
HARRIS, B. 1992. Nutrient requirements of dairy cattle, University of Florida Cooperative Extension Service, Institute of Food and Agriculture Sciences, EDIS.
A Model for Managing Information Communication Technology User Experience in Rural Contexts

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Abstract

Information Communication Technologies (ICTs) are increasingly being used as enablers to bring positive and sustainable development in impoverished rural communities. The ICT field is rapidly changing. New technologies are being deployed and existing ones are being improved. Such dynamic trends in ICT diffusion impact on the user experience of the people interacting with the ICTs. The change in user experience should be managed to promote positive user experience and ready people to embrace the ICTs. Most ICTs projects in developing countries rural contexts have not been accepted and or well utilised by the users. The attributing cause of
failure has been poor management of change in user experience and lack of user involvement right from the onset of project initiation. The purpose of this study is to propose a theoretical model for managing user experience of the ICT users in the context of developing countries rural communities. The uniqueness of the proposed model lies in its user centred approach and its applicability in an environment that is not bound by organisational based visions and policies. A study of literature on the impact of ICTs in rural communities, user experience and change management was used to establish an initial conceptual framework through which the theoretical model is developed. The proposed model will be empirically validated using a case study to gain more insights on the model applicability. The focus of this paper is to investigate what is needed to establish a user centred model for managing change in the user experience of ICT users. An initial model is discussed followed by the preliminary findings of a single case pilot investigation.

Keywords: Information Communication Technologies (ICTs); Change Management; User Experience; Rural Context; Information Communication Technology for Development.

Introduction

In this paper ICT is defined as a system of devices, services and applications used to capture, store, process and transmit electronic information. ICT adoption has lead to the much noticeable discrepancies in average economic growth between the developed and developing countries [Pohjola 2003]. In the developed world ICT has contributed to economic growth by improving the quality, effectiveness and efficiency and information access [Easterly and Levine 2001; Easterly 2001]. In developing countries ICT is being used as a tool for poverty alleviation and as a development enhancer [Yates eta al, 2010; Donner et al, 2008; Kenny 2002].

There have been some rapid changes and improvements in ICT technologies, diffusion and usage [Yusuf 2005]. Traditional computers were used by large organisations such as governments and universities for data, storage, processing and automation. By then the use of computers was far from changing the lifestyles of the people but rather oriented on a business perspective [Dahlbom and Ljungberg, 1998]. With the progression of time and computer penetration, personal computers were introduced in homes and offices as sources of information and communication. People began to understand and embrace the new technologies leading to a revolutionary wave changing their life styles, interaction and experiences [Sorensen and Gibson 2006]. In the current era, mobile ICTs have gained predominate use mainly because of the flexibility and unconstrained usage with respect to time and location [Kushchu and Kuscu, 2007; Valk et al. 2010; Svanaes et al. 2010].

The rapid inception of new ICTs has not only changed business processes but also transformed the lifestyles of the people [Trim and Sheng 2008]. The transformation is
evident in developing countries where mobile ICTs are used to leapfrog trends in ICT development and bring an end to the digital divide [Valk et al. 2010]. The rural context in the developing communities is characterised by poverty, illiteracy, lack of information and overall lack of knowledge [Britz 2004]. A wide difference exists between the affluent living in urban areas and the poor living in the impoverished developing context rural communities with respect to access to information and utilisation skills of ICTs. The people in rural communities are often marginalised, powerless and voiceless. They lag in computer skills, use, access and use of internet compared to those in the urban and developed societies counterparts [Donner et al. 2008].

The use of ICTs to fight poverty, improve on communication, bring knowledge and information access to the poor and as an enabler for socio-economic development is increasingly being recognised [Haines and Cassells 2004; Easterly 2001; Sachs 2005; Donner et al. 2008]. Information Communication Technology for Development (ICT4D) refers to the use of information and communication technologies to enhance development. ICT4D aims at the application of information and communication technologies to develop and empower the poor and marginalised communities [Unwin, 2009]. The goal of ICT4D is to transform the lives of people in the “un-entered” ICT areas and poverty stricken rural areas.

Multi-purpose community ICT access points have been established to provide information and communication access to the rural communities [Hajela, 2009]. These access points are referred to as telecenters. Colle [2009] define a telecenter as a shared facility that provides public access to information and communication resources. The telecenters have been used for distributing information, promoting local entrepreneurships, cultural enrichment, improving education and health services and strengthening social mobilization [Davison et al, 2002; Curtain, 2004]. An improvement on the telecenter approach was its modification into information hubs. Information hubs exceed beyond offering basic facilities like faxing, proving internet and phone services. They go an extra mile in generating information and proving information with the goal of enhancing and empowering a behavioral change [Haris and Rajora 2006; ESCAP 2006]. Mobile applications are also being developed targeting users in the poor and marginalized rural contexts. Examples of such are mobile banking applications and mobile learning applications [Hughes & Lonie, 2007; Butgereit, 2007].

However, most of these initiatives failed to yield the expected results. The target users did not fully utilize the availed resources resulting in some of the projects being aborted [Attwood & Braathen, 2010; Beeharry & Schneider, 1996; Benjamin, 2001; Robey and Boudreau 1999]. Lack of user needs assessment, poor user requirements elicitation and failure to manage change in the user experience of the people using the technologies has resulted in unexpected abortion and the failure of the projects [Heeks 2002; Benjamin 2001]. To minimize such failures, it is therefore important that the needs of the users be considered in order to implement contextually relevant solutions that fit the needs of the users. Meeting the needs of the users is paramount to the acceptance
and proper usage of any product [Reece, 2002]. Acceptance of the ICTs is improved when the users interact with the ICT with pleasure, joy and satisfaction. Such feelings resulting from the interaction define the user experience [Sharp, Roger and Preece 2007]. Such an approach emphasizes the user centered perspective in managing change in the user experience. The next section presents a discussion on user experience.

**User Experience**

This section briefly informs what user experience is, how it develops and why it is important.

Several authors have defined user experience from various perspectives [Sward and MacArthur 2007; Hassenzahl and Tractinsky 2006; Mashapa and van Greunen 2010; Roto 2007; Sutcliffe 2010]. It can be deduced from the definitions that user experience consists of the following aspects, the user, context and an interactive product. Thus, user experience goes beyond the usability of a product but an intrinsic subjective emotion of a person's interaction with a product in a specified context [Roto et al. 2011]. User experience can be positive or negative [Roto 2007]. Negative user experience is when users find a product to be boring, difficult to interact with it or not fit for the intended use. A positive user experience is developed when the user finds the product to be usable with pleasure and satisfaction (Sharp, Roger and Preece, 2007). A positive user experience and perceived usability of a product is of paramount importance for its acceptance and full usage [Davis 1989; Webb et al, 2003; Roto, 2007].

User experience development is not a once off thing, but rather a process that evolves over time [Roto 2011]. The main difference between individuals is the amount of time they spend in developing user experience. Thus it is important to manage the change in user experience of ICT users for the ICTs to be accepted and utilised to their potential benefits.

**Change management**

The world is in a constant state of change characterised by increase in global socio-economic integration, technological advancement and the scramble for resources. An evolution of ICTs from traditional location fixed computing through to mobile and pervasive ICTs is an example of such change which have fuelled subsequent change in organisations, societies and individuals. The inception of ICT is forcing organisations and societies to change the way people interact and how businesses operate [Oakland and Tanner, 2007]. It is evident that the implementation of ICTs transforms the livelihoods, experiences and socio-economic aspects of people [Trim and Sheng 2008]. The change involves a transformation and replacement of the old and familiar system with an unfamiliar system characterised by uncertainty, fear and a threat to the security of the people [Vahs et al 2010]. It therefore follows that the change in ICTs should promote a positive user experience. For user experience to be positive it has to be managed in a manner which satisfies the needs and requirements of the people. Thus
the technique for managing user experience must be centred on the target users for the ICTs to be accepted and utilised to the full potential benefits.

Various authors have defined change management and proposed models for the implementation and guiding success in managing change [Kotter and Cohen 2002; Jick 2003; Garvin 2000; Mento et al. 2002; Price and Chahal 2006; Hiatt 2006]. In this paper we adopt a change managed definition put forward by defined by Hiatt and Creasey [2003] as “the process, tools and techniques to manage the people-side of change to achieve the required business outcome.”

Critique of the existing models can be summarised thus. Hiatt’s [2006] ADKAR model lacks in assessing the environment for change and evaluating the outcome and impact of change. Price and Chahal’s [2006] model focuses much on managing change from the organisation’s point of view and neglects the needs and requirements of the people. Kotter and Cohen’s [2002] eight steps change management model is aimed at strategic level activities to transform the organisation. In their model they do not consider managing change in human experiences. Mento et al [2002] focus on the role of strong leadership in implementing change in an organisation. Jick’s [2003] model aims at tactical implementation of major organisational change.

**Problem Identification**

ICT applications fall short on usability and do not create a positive user experience. The people readiness of ICT application users is lagging. There is no model for managing change in the user experience of ICT application users, most importantly in the rural contexts. Following this premise, the purpose of the overall study is to develop a model for managing user experience of the ICT users.

Current approaches to user experience focus on how to develop positive user experience and how to evaluate user experience. Despite the fact that user experience researchers and practitioners accept that user experience is important for the acceptance of a product and that user experience evolves, at this point no work has been done on how to manage the transitions in the user experience of people interacting with the products. Available change management approaches focus on the implementation and guidance of change at organisational level [Kotter and Cohen 2002; Jick 2003; Garvin 2000; Mento et al. 2002; Price and Chahal 2006]. Existing models do not cater for managing the feelings of the people and their experience.

**The Proposed Model**

Existing models will be used to inform the proposed model but specific aspects will be incorporated to make the model unique. The model will adopt a user centered approach to manage change in user experience contrary to an organisational centered approach to managing change. The proposed model will focus on the achievement of individual based change where there are no binding organisational policies, vision and objectives and hierarchies of command to be followed. Thus the change aims at promoting ICT acceptance through an individual’s affinity to change.
The proposed model seeks to make the individuals see and feel the need for change for them to take action for change [Kotter & Cohen, 2002; Marshak, 2006]. The model is implementable in a society where there are no organisational policies, watchdogs, authorities to force change. The model will advocate that the needs for the ICT users and their user experience have to be considered from the onset of the ICT projects right through the transition phases until accomplishment of the overall goal. In managing the user experience it is acknowledged that people will adapt to the ICTs at different paces, thus the model should accommodate individuals based on the innovation adoption curve [Rogers, 1995]. For the ICTs to be accepted with positive user experiences, the various groups of the innovation adoption curve has to be catered for and their needs satisfied.

Based on a single case, an initial model outline is presented in Figure 1.

**Figure 1: An initial User Centred Change Management Model**

As depicted in Figure 1, the initial model infers mostly from the components of Awareness, Desire, Knowledge and Reinforcement (ADKAR) model [Hiatt, 2006]. Additional components include scanning of the present environment, formulation of the vision and strategy, consolidation of lessons learnt and evaluation. The next section describes the components of the initial model in detail.
## A Scan of the Change Environment

### Elicitation of the change context

<table>
<thead>
<tr>
<th>Activity</th>
<th>Tools / Methods</th>
<th>Deliverable</th>
<th>Contributing Authors</th>
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<tbody>
<tr>
<td>User requirements elicitation</td>
<td>Interviews, Questionnaires</td>
<td>Context analysis document</td>
<td>[Jick 2003; Mento et al 2001]</td>
</tr>
<tr>
<td>Needs assessment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discovery of the change climate</td>
<td>Environmental analysis, what has to change what are the risks of not changing</td>
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### A test of the wetness of waters

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<tbody>
<tr>
<td>Facilitate informal awareness of the change initiative</td>
<td>Informal channels of communication e.g. the grapevine</td>
<td>Informal assessment of the change vibe.</td>
<td></td>
</tr>
<tr>
<td>Stir up the people to see the urgency of change</td>
<td></td>
<td>Identification of active change stakeholders and potential pockets of resistance.</td>
<td></td>
</tr>
<tr>
<td>Create a visible gap between current state and desired state</td>
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</table>

### Vision And Strategy Formulation

#### Gathering a guiding team

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<tbody>
<tr>
<td>Gather a cross sectional representation of all the people</td>
<td>Consolidation of feedback obtained from the active informal interaction with the stakeholders.</td>
<td>Stakeholder key relation mapping document</td>
<td>[Kotter and Cohen 2002]</td>
</tr>
<tr>
<td>Identification of who has the power, information, the winners and losers</td>
<td></td>
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</table>
### Defining the desired outcome

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<tr>
<td>The desired outcome must fit the needs and requirements of the stakeholders.</td>
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### Crafting the change strategy

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### Awareness

#### Formal communication of the change initiative

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<tbody>
<tr>
<td>Formal communication on what is to be changed, who is to be affected, what is changing and what is remaining unchanged</td>
<td>Meetings, seminars and workshops</td>
<td>User awareness document</td>
<td>[Hiatt 2006; Kotter and Cohen 2002]</td>
</tr>
<tr>
<td>Awareness of the potential benefits of using the ICTs</td>
<td>Seminars, workshops, emails, road shows, posters, television and radio awareness campaigns.</td>
<td></td>
<td></td>
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### Desire

<table>
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<tbody>
<tr>
<td>Make the people see, feel and change to embrace the ICTs</td>
<td>Motivation by telling success stories of ICT adoption.</td>
<td></td>
<td>[Hiatt 2006; Kotter and Cohen 2002; Jick 2003]</td>
</tr>
<tr>
<td>Eliminate pockets of resistance hindering people from accepting The ICTs</td>
<td>Seminars, workshops</td>
<td></td>
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### Impart Knowledge

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<th>Tools / Methods</th>
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<th>Contributing Authors</th>
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<tbody>
<tr>
<td>Training the people</td>
<td>Seminars and workshops.</td>
<td></td>
<td>[Hiatt 2006; Kotter and Cohen 2002]</td>
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### Ability

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<th>Activity</th>
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<tbody>
<tr>
<td>Evaluation of the accomplishment of short term goals</td>
<td>Observe the people interact with the ICTs with intention of improving their user experience.</td>
<td></td>
<td>[Hiatt 2006; Kotter and Cohen 2002]</td>
</tr>
<tr>
<td>Eliminate pockets of resistance hindering people from accepting The ICTs</td>
<td>Seminars, workshops</td>
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### Reinforcement

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<th>Contributing Authors</th>
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<tbody>
<tr>
<td>Strengthen continuous improvement of user experience development</td>
<td>Enshrine an engaging user experience by training and retraining the people for the change to last.</td>
<td></td>
<td>[Hiatt 2006; Kotter and Cohen 2002; Jick 2003]</td>
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</table>
Consolidation of Lessons Learnt

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<th>Contributing Authors</th>
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<tbody>
<tr>
<td>Compare what is on hand with the initial plan. Determining any variances. Identify why it happened that way Formulate what has to be done next to rectify the discrepancy.</td>
<td>Comparison of intended plan with what is on hand.</td>
<td>Lessons learnt document</td>
<td>[Mento et al 2001]</td>
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Evaluation

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<th>Activity</th>
<th>Tools / Methods</th>
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<th>Contributing Authors</th>
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<tbody>
<tr>
<td>Evaluate the level of the user experience of the ICT users.</td>
<td>User testing, observations, User inquiry</td>
<td>Impact assessment document and outcome assessment document</td>
<td></td>
</tr>
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</table>

NB: It is important to note that the stages are not sequential as explained

Research Methodology

User experience development can be likened to a journey. The change in user experience development is an iterative process [Roto 2011]. Thus to there is a need for an appropriate research design and methodology to capture and manage the change phases in user experience. Based on the nature of user experience (which has been defined to be subjective), the authors propose to adopt an interpretivist paradigm to determine how to manage change in user experience. The authors propose a qualitative research approach employing an inductive logic of reasoning to draw meaning on the findings. The research strategy to be used is a case study within which simple cyclic iterations will be followed. The purpose of the case study is to refine the initial theoretical model. The case studies will be conducted in selected rural communities in a typical developing
country context. The data collecting methods to be used will include literature study, user observations, interviews and questionnaires.

**Pilot Study Details and Findings**

A pilot investigation was carried out to test the applicability of the initial model. The investigation was based on an existing ICT community centre located in the South African rural area in the Limpopo Province. The centre consists of ten networked computers, a server, printers and scanners. Currently the centre provides services such as typing, fax, phone, photocopying and access to computers to all community members. The majority of the people in the community do not have computer skills and are unaware of the full capabilities of the available resources. Thus the ICT resources are being underutilized. During the November – December 2010 period we visited the community centre and offered basic computer training skills in Microsoft Office 2007 suite applications, email, internet and potential uses of the computer resources they are having. In scanning the current environment phase of change management we found that the people in the area have resources that are underutilising. We therefore set a vision that by the end of the training, each of the training attendees should have identified an ICT based sociopreneureship project.

Through change management success stories, we made the training participants aware of other projects utilising the ICT centres to generate income. This increased a sense of urgency and created a desire to participate in changing and empowering the lives. The pockets of resistance identified were that the training participants lacked confidence in making the initiative real. They lacked the skills and cited that they did not have enough resources for the start up. From the training, we noted that the participants demonstrated different capabilities. We identified that some were good at teaching others during the training, some proved to be technical and they wanted to do hardware repair and maintenance while others demonstrated interest in filming, video editing and providing ICT services to the community.

Two participants were selected to be trained at Nelson Mandela Metropolitan University. The objective of the training was to empower these selected individuals to be able to train others in the community (train the trainer initiative). Thus these trainers are now the change mentors in the community. They will then demonstrate that they have the ability to make change happen. Thus from the pilot investigation we applied the model to scan the environment and formulate the objective and strategy. We applied the ADKAR elements [Haitt, 2006]. From the scanning of the environment we noted the underutilisation of resources. We made the people aware of what they can do with the available resources, and created a desire that they make maximum usage of the ICTs. Through the training seminar, knowledge was imparted to the participants and they were given a practical opportunity to demonstrate the ability to implement what they learnt.
Research Significance and Future Work

The South African government and various stakeholders are investing in rural development through the use of ICTs. While these developments are the hype, there is noticeably, a greater failure rate of the projects [Heeks, 2002; Beeharry & Schneider, 1996; Benjamin, 2001; Robey and Boudreau 1999].

The proposed model will unmistakably benefit ICT projects’ implementation in the developing countries rural context. The model aims to guide on managing the change in user experience which results in a positive user experience and an overall acceptance and adoption of the ICTs. Another contribution of the research will be in strategies and techniques used to determine the user experience of the rural ICT users. These strategies may be used by future researchers in implementing and managing user experience of the ICT users.

The initial model has not been tested. To refine the model we will evaluate the impact and outcome of the change initiative. We need to examine how the people are utilizing the available resources. Thus future work includes implementing reinforcement of change, consolidation of lessons learnt and an impact and outcome assessment. The model still has to be applied in multiple rural communities implementing ICTs to not only refine the model but to show its applicability. Expert based opinions will be used to validate the credibility of the model.

The challenges faced include that we had limited time to interact with the ICT users in the community and get feedback on their experiences with ICT usage. Another challenge is that we piloted the components of the model in a centre that was already established, thus we could not monitor change during the ICT implementation. There was a language barrier which was overcome by asking the participants to do translations when required.

Conclusion

The purpose of this paper was to explore the components of a model for managing user experience change as a result of using ICTs in a typical rural context. The initial model components are based on an understanding that change management has to be context specific, people centred and based on individual’s willingness to change. The current context of change has to be scanned before the ICTs are implemented. User requirements should be considered from the onset of the project and their user experience managed throughout and after the implementation of the ICTs. Such an approach promotes acceptance and usage of the ICTs. We applied the initial model in a pilot study and the provisional findings indicated the model to be applicable in the rural context.

References


COLLE, R. D. 2009. ICTs, Telecenters and Community Development . USA, Cornell University.


HAJELA, S. 2009. Development of knowledge hubs/ telecentres in India. India


YUSUF, M. O. 2006. Problems and Prospects of Open and Distance Education in Nigeria. Turkish Online Journal of Distance Education, 7(1), 22-29.
RSAWORKS: Things that “Tweet” in South Africa

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Kim Gush and Meraka Institute, CSIR

Abstract
The “Internet of Things” is the phenomenon of more and more “things” being connected to the Internet (as opposed to people getting connected to the Internet). Although the concept of “Internet of Things” includes bidirectional access (“things” giving information about themselves and people or software then controlling those “things”), creating “things” that “tweet” is a common first step in joining the growing “Internet of Things”. This paper discusses a project where researchers in South Africa attempted to get a wide variety of “things” to “tweet” there statuses automatically.

Introduction To “Internet of Things”
More and more objects are becoming embedded with sensors or are becoming labeled with machine readable visual codes. These sensors or codes could be RFID (Radio Frequency Identification) tags, other wireless devices, commercial bar codes, or QR (Quick Response) Codes to name just a few.

With the “Internet of Things”, the objects which are so labeled are expected to become active participants on the Internet. They are expected to become active participants in business, information processes, social processes where they are enabled to interact and communicate among themselves and with the environment [de Saint-Exupery, 2009].

Many “Internet of Things” technologies are already being used. Luxury cars often have satellite tracking systems along with devices to allow security companies to immobilize the car if it senses that the car has been stolen [Mellor, 2007]. Shipping companies use RFID tagging to expedite movement of parcels. Aircraft have transponders enabling air traffic controllers to monitor their movements.
Introduction to Twitter

Twitter is a microblogging service where users can “tweet” about any topic they wish with a 140-character length limit. Users can follow another person or can be followed by other people. Messages sent on Twitter are called “tweets”. Followers receive the “tweets” of the people they follow [Kwak et al, 2010].

As the “Internet of Things” grows, more and more “things” are beginning to “tweet” their status. The Tower Bridge in London “tweets” whether it is open or closed and which ship is passing by [Böhringer and Gluchowski, 2009]:

http://twitter.com/towerbridge

The Lovell Telescope at Jodrell Bank (also in the UK) “tweets” information about what it is observing [5]:

http://twitter.com/lovelltelescope

Enthusiasts have connected toasters to the internet so that they “tweet” their status.

http://twitter.com/mytoaster

And even plants can “tweet” their need for water.

http://twitter.com/pothos

This project, RSAWORKS, is an attempt to get as many “things” in South Africa “tweeting” as possible using a unified platform.

Introduction to Beachcomber

Beachcomber is a Java JEE application which allows Bearer Agnostic Chatter on a wide variety of channels. It is a platform which attempts to allow the “Internet of Things” to communicate with the “Internet of People”. This communication is mediated through a specified business process. Beachcomber has been used in a number of “Internet of Things” applications and it was the obvious choice for this project [Butgereit et al, 2011].

Illustration 1 shows the configuration of Beachcomber. Beachcomber allows three way communication between people (indicated by the bottom side of the triangle), “things” (indicated by the left side of the triangle), and business processes (indicated by the right side of the triangle).

Beachcomber allows for a wide variety of protocols to communicate with people (including XMPP, MXIT, Email, HTTP) and a wide variety of protocols to communicate with “things” (including HTTP, Email, QR Codes, etc). The business processes are easy to write and implement.
For the specific case of this project, only one communication protocol was necessary for communicating with people: Twitter. Other communication channels to people could have been implemented using Beachcomber but that was not the goal of the research.

**Illustration 1: Beachcomber 3-way configuration**

![Beachcomber diagram]

**Research Framework and Methods**

RSAWORKS used a Design and Creation research methodology as defined by Oates [Oates, 2006]. The Design and Creation research methodology is an iterative methodology containing five steps:

1. **Awareness** – the recognition and statement of a problem
2. **Suggestions** – tentative ideas on how this problem might be addressed
3. **Development** – implementation of these tentative ideas or suggestions
4. **Evaluation** – assessment of the developed item
5. **Conclusion** – consolidation of results

This iterative methodology was traversed for each new “thing” which was connected to the platform. For example, when the researchers first attempted to have a laptop “tweet” the status of the battery, the five steps were
1. Awareness – the status of the laptop battery needed to be “tweeted”
2. Suggestions – it was suggested that a script be written that monitored the battery and then used HTTP to transmit the information to the platform
3. Development – the laptop script was developed and the Beachcomber platform was modified to cater for incoming HTTP requests
4. Evaluation – the development was assessed
5. Conclusion – the results were consolidated

It is important to note that the steps are traversed a number of times.

South African “Things” that “Tweet”

At the time of writing this document, there are ten things regularly “tweeting” their statuses on the RSAWORKS project using the Beachcomber platform. These ten things are using four different communication channels to the platform. These four different channels can be summarised as:

1. HTTP client requests by Beachcomber to existing websites
2. HTTP servlet requests from smart objects to Beachcomber
3. Smart objects communicating via private GPRS networks to an intermediary server which then automatically emails the data to Beachcomber
4. Specialised electricity monitoring hardware which communicates via wireless to base stations which forward pictorial information to Beachcomber using TwitPic

Each of these four channels will be described in detail.

It is important to note that RSAWORKS is an ongoing project and additional channels may be available at the time of the presentation of this work.

HTTP Client Requests

The Beachcomber platform can be easily configured to poll other websites which already publish real-world “thing” data. This was one of our first iterations of the Design and Creation research methodology. This input channel was primarily used to test feasibility of using the Beachcomber platform for this project.

Three websites were accessed for “thing” information.

The Global Sea Level Observing System provides coordination for global and regional sea level networks in support of oceanographic and climate research. The Intergovernmental Oceanographic Commission in conjunction with the Flanders Marine Institute have developed a web-based global sea level station monitoring service for viewing sea level data received in real-time [Merrifield et al, 2009]. Five of those sensors are in or near South Africa: Port Elizabeth, Durban, Simonstown, and Marion Island. During the course of our testing, the Durban sensor was offline. Beachcomber was configured to monitor that site and post relevant information on Twitter. Illustration 2 provides examples of those “tweets”.
Another interesting site which publishes relatively real-time data was the Airports Company of South Africa. The status of flights between Johannesburg and Cape Town were updated on their website within minutes. This enabled Beachcomber to get more or less real-time data and forward it to Twitter. Illustration 3 provides an example of such “tweets”.

The South African Weather Service also published weather data for major South African cities. This data was not immediately updated by the Weather Service and was often a few hours old. Illustration 4 provides an example of the weather “tweets”.

By accessing information which was already published on the Internet, this iteration of the Design and Creation research methodology allowed the researchers to work out any major problems with the Beachcomber platform and still profile interesting information about “things” that are working in South Africa.
HTTP Servlet Requests

The subsequent iteration of the Design and Creation research methodology was to allow smart objects to send information about themselves to the Beachcomber platform whenever the smart object deemed it appropriate. This meant that the Beachcomber platform did not have to poll for the information.

This enabled the researchers to plant the idea of a “Green IT” project with friends and coworkers where it would monitor temperatures inside of the laptops around the organisation. Coworkers could voluntarily install additional software on their laptop to monitor these temperatures. This additional software would then automatically send the information to the Beachcomber platform which would forward it to Twitter as can be seen in Illustration 5.

Illustration 5: Laptop temperatures “tweet”

Continuing with the idea of “Green IT”, laptop battery levels could also be monitored as can be seen in Illustration 6.

Illustration 6: Laptop battery status "tweet"

Any smart object which could make an HTTP request would be able to “tweet” its status using Beachcomber.

GPRS to Email

The Digital Doorway initiative addresses the computer literacy needs of residents of South Africa. The Digital Doorways are robust computer kiosks which are placed in areas where the residents do not traditionally have access to computer systems. This includes rural areas and township areas [Gush et al, 2004]. The majority of the Digital Doorways were not connected to the Internet.

The researchers on the Digital Doorway project developed a method for monitoring the installed Digital Doorways without connectivity to the Internet. They installed watch-dog boxes on three of the Digital Doorways. These independent watch-dog boxes which communicated via GPRS (General Packet Radio Service) on a private network to an intermediary server which also had a GPRS modem. This intermediary server was connected to the Internet. This intermediary server would then email this
information to a specific email address which Beachcomber monitored. The circuitous route of the data from the Digital Doorway to Twitter can be seen in Illustration 8.

When the email was received, Beachcomber would then post the information on Twitter as can be seen in Illustration 7.

Illustration 7: Digital Doorway “tweets”

Electricity Consumption
Prior to the implementation of Beachcomber and RSAWORKS, two researchers at Meraka Institute independently began monitoring their electricity consumption of their personal homes. They had previously installed commercial monitoring equipment “Current Cost”. The “Current Cost” monitoring equipment has been used by other organisations for Green IT applications [Mattern et al, 2010].
As can be seen in Illustration 9 the “Current Cost” monitoring equipment included sensors with associated clamps which went around the mains cables (and no electrician was required to install it). Multiple sensors could communicate via a wireless protocol to a “Current Cost” base station.

The base station had USB (Universal Serial Bus) support which allowed the researchers to move the data from the base station to an intermediary server and then on to the Internet. These researchers had already done extensive work in plotting their home electrical consumption. All that was left for the scope of RSAWORKS project was to post the images of these graphs on Twitter.

Illustration 9: “Current Cost” hardware (Image Credit: www.currentcost.co.uk)

This was done through the use of Twitpic. Twitpic is a Twitter add-on application which allows users to email images to a specific address. Twitpic will then store the images and provide links as can be seen in Illustration 10

Illustration 10: Twitpic “tweets”
These links provide the actual home electricity consumption graphs as can be seen in Illustration 11.

**Illustration 11: Electricity consumption graphs**

![Illustration 11: Electricity consumption graphs](image)

**Local Weather Stations**

One of the researchers at Meraka Institute installed a LaCrosse WS2355 weather station at his home which provided more or less realtime information about local weather conditions as can be seen in Illustration 12.

**Illustration 12: Local weather conditions**

![Illustration 12: Local weather conditions](image)
Security

One of the most widely discussed concerns about the growing “Internet of Things” is security of information and privacy of the individuals. This topic warrants a paper all on its own. However, a number of security measures were introduced even for this initial “Internet of Things” project.

These were the measures taken:

1. The IP (Internet Protocol) address of all incoming HTTP requests were validated against a database table. Only requests coming in from IP addresses which had entries on the table were forwarded to Twitter.
2. The email addresses of providers of information were also validated against a database table. Only data received from email addresses which had entries on the table were forwarded to Twitter.

How can these “Tweets” be used?

People use Twitter for different reasons. Java et al [Java et al, 200] determined that there were four major user intentions found on Twitter. These four intentions are:

1. Daily chatter – posts about daily routine
2. Conversations – posts directed to specific other users
3. Sharing information/URLs – posts which share links to other websites
4. Reporting News – posts which report latest news developments

Twitter posts to RSAWORKS could be generally categorized in group 3 – sharing information and links to other websites.

Grouping of “Tweets”

This project was an initial step in learning about the “Internet of Things”. For the scope of this project, all “tweets” were sent to one Twitter Feed, RSAWORKS. Obviously, a more realistic situation would be to group similar “tweets” into their own Twitter feeds. For example, a Twitter feed could monitor house electrical consumption while another Twitter feed could monitor computer temperatures.

Conclusion and Future work

The “Internet of Things” is the next step in ubiquitous computing. More and more smart things are being connected to the Internet.

This project, RSAWORKS in conjunction with Beachcomber, was an initial project to see how many different types of “things” in South Africa could be posting their status on Twitter. This project must be considered to be an entry-level project to the “Internet of Things” because it only collects information. It was deemed to be a learning experience for the researchers involved.

Future work will involve collecting information from many more and different types of “things”. There are ongoing negotiations with organisations and we hope to report positively on this at the presentation of this paper in Kampala.
References


LOWE, S., Jodrell Bank Centre for Astrophysics, The University of Manchester,"


MELLOR, B. 2007. A world of connections," The Economist, 2007,


Tony: Helping People Find Lost “Things” using the “Internet of Things” Technologies

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Abstract

Human beings exert a sense of ownership over the “things” in their lives. They own books, tennis rackets, cell phones, and handbags just to name a few. They transport these “things” from home to the office and, then, to recreational areas. And, in the process, they often lose these “things”. Pupils misplace school books. Adults misplace eye glasses. Often these items are found by other people but these other people have no idea who owns these “things” or how to return the “things” to the original owners. Tony helps solve this problem. Tony is a JEE application running under Mobicents on a Beachcomber platform. It allows users to register various “things”. The users are sent a QR (Quick Response) code label to affix to the registered “thing”. If the “thing” is lost and later recovered, the finder need only take a photo of the QR Code and the original owner is notified that his “thing” has been recovered. Depending on the facilities of the item taking the photograph of the QR Code (for example, it might be a smart phone), then GPS coordinates can also be sent to the original owner indicating where the lost “thing” can be found.

Introduction To “Internet of Things”

As more and more “things” become electronically labeled, the cost of communication decreases and the embedded processing power in “things” increase, the “Internet of Things” grows. More and more “things” can be tracked and, possibly, controlled via the Internet. In the fight against crime, many cars have tracking devices and remote immobilisers. In the fight to preserve the environment, geysers (or hot water heaters) often have remote temperature controls so electrical power utilities can turn down the temperature when demand for electricity is at a peak. In the search for better health, recently, a 61-year old woman had a pace maker embedded into her body which supported a wireless connection to enable her medical practitioner to monitor how her heart is doing [Caruso, 2009].
“Things” communicate with the Internet using a wide variety of protocols. Some “things” communicate using radio frequency identification (RFID) tags or other wireless mechanisms. Some “things” are labeled with visible codes such as bar codes or QR Codes to enable linkage with the Internet. Some “things” are labeled with microscopic codes which are too small for the human eye to see such as microdot technology that can be sprayed onto cars to enable police to track pieces of stolen cars which have been broken down and sold as spares [Stevens, 1983 and Venter, 2010].

Once “things” are connected to the Internet, an opportunity exists to create intelligent value add services and application on the Internet which enhance our private and economic environments.

**Research Question and Objective**

People often lose possessions or “things”. These possessions or “things” are often found by other people but the finders have no mechanism to determine who owns the object which they have found. The research question, therefore, was:

Can Internet of Things technologies be used to reunite people with things they have lost?

**The research objective was:**

Develop a mechanism where people who find objects can easily notify the original owners that their objects have been found.

The research object could be broken into sub-objectives:

1. Develop a mechanism where owners could register their “things”
2. Develop a mechanism where “things” could be labeled
3. Develop a mechanism where people who find “things” can easily inform the original owners
4. Unite these facilities in a unified architecture

**Design and Creation Research Methodology**

A Design and Creation Research Methodology as defined by Oates [Oates, 2006] was used for this project. The Design and Creation Research Methodology is an iterative methodology containing five steps:

1. Awareness – the recognition and statement of a problem
2. Suggestions – tentative ideas about how this problem could be solved
3. Development – implementation of those ideas
4. Evaluation – assessment of the development item
5. Conclusion – consolidation of the results

In terms of this methodology, these steps were:

1. Awareness – awareness of the problem that people loose “things” and need to be reunited with those “things”
Part 3: Tony: Helping People Find Lost “Things” using the “Internet of Things” Technologies

2. Suggestions - “Internet of Things” technologies could be used to assist in reuniting people with their lost “things”

3. Development – Tony was developed using the Beachcomber platform which provided bearer agnostic communication between “things” and their owners

4. Evaluation – Tony was evaluated through the means of a number of small pilots

5. Conclusion – The results were consolidated

It is important to note that this methodology is iterative and numerous smaller cycles of these five steps occurred.

Tony

Tony is an innovative application of “Internet of Things” technologies to assist people in keeping track of their “things”. It is a business service hosted on the Beachcomber platform. Beachcomber provides bearer agnostic communication between “things” and people thereby linking the “Internet of Things” with the “Internet of People” [Butgereit and Coetzee, 2011]. At the time of writing, Beachcomber provides for communication via XMPP (Extensible Messaging and Presence Protocol), POP3 (Post Office Protocol version 3) email, MXit, HTTP (Hypertext Transfer Protocol) servlet and client, Twitter, and JMS (Java Messaging Service). These different protocols are implemented as resource adaptors and more may be added in future.

Communication with the “things” and the owner of the “things” is maintained through Beachcomber. Beachcomber then communicates with Tony using a bearer agnostic message type. Illustration 1 provides a visual representation of this configuration showing how all “things” and owners communicate with Beachcomber and how Beachcomber maintains the communication with the Tony application.
Illustration 1: Overview of Beachcomber and Tony

This type of implementation means that the developers of Tony do not need to know the intricate protocols of RFID tagging, or commercial bar codes, or QR Codes. That type of information is handled directly by Beachcomber. All Tony developers need to concern themselves with is the business logic of tracking and recovering “things”. In addition, the Tony developers do not need to understand the intricacies of communicating with the owners using various chat protocols. That is also handled by Beachcomber. Again, Tony developers only need concern themselves with the logic of labeling, tracking and recovering “things”.

In addition, although this application currently uses QR Codes to facilitate communication between people and “things”, this could easily be changed to a wireless mechanism and the developers of Tony would not have to make major changes. Beachcomber provides a bearer agnostic mechanism for communication between things and business services.

Owner Interface to Tony

The owner of a “thing” could interface with Beachcomber through any XMPP or Jabber chat client. Beachcomber would forward the messages received via XMPP to Tony. This allowed easy access to Tony by owners through either desk top Internet based workstations or chat clients on mobile devices such as cell phones. Illustration 2 shows a list of commands available with Tony.
Illustration 2: Owner commands in Tony

Any number of “things” can be registered with Tony as can be seen in Illustration 3

Illustration 3: Example of Tony Thing list
When Tony registers an item, a QR Code is generated as seen in Illustration 4 and sent back to the user. The Tony user must affix this QR Code to the “thing” which must be tracked.

**Illustration 4: QR Code generated by Tony**

QR Codes are 2-dimensional visual codes which can be attached to physical objects in order to retrieve object-related information and functionality. QR Codes can be printed on paper (and possibly laminated to protect against the weather) or displayed on electronic screens. Additional information about the object is encoded in the visual code. Often the visual code contains a URL which provides even more information about the object [Rohs and Gfeller, 2004].

In the case of Tony, the QR Code had a URL back to the Beachcomber server with a parameter which told the server which “thing” had been found.

**Finder Interface to Tony**

The person who finds the lost thing must merely take a photo of the QR Code with his or her cell phone (assuming the cell phone is configured to recognise these QR Codes). Many high-end cell phones come with QR Code recognition software already installed. If such software is not factory-installed on the cell phone, a number of free and open source QR Code recognisers are available for both Symbian and Android cell phones. By having this software loaded on a cell phone, the cell phone becomes a sensor to identify lost “things”.

Enhancing cell phones with this software provides promise for interesting applications. People usually keep their cell phones nearby, in their pockets or in their
handbags. Modern cell phones can provide continual wireless communication and usually have cameras on board. The ability to detect objects which are identified by a QR Code within the cell phone owner’s vicinity strengthens the role cell phones can play in various scenarios such as education, gaming, m-commerce, in addition to “Internet of Things” applications [Rohs and Gfeller, 2004].

ZXing (pronounced “zebra crossing”) is one example of an open source QR Code processor which does both encoding and decoding of various 1-dimensional and 2-dimensional bar codes include QR Code.

As part of the Tony research project, additions were done to the open source ZXing application. If ZXing detected that the cell phone also had an on-board GPS (Global Positioning System), ZXing queried the GPS to find the longitude and latitude of the cell phone owner. This information was added to the URL which was encoded in the QR Code and sent to the Tony server.

The original URL encoded with information about the found “thing” along with the GPS coordinates where returned to the Beachcomber server. If the GPS coordinates were available (and this was not supported by all phones), Tony would also create a KML file such as:

```xml
<?xml version="1.0" encoding="UTF-8"?>
<kml xmlns="http://www.opengis.net/kml/2.2">
<Placemark>
  <name>Tony Placemark</name>
  <description>Your hockey stick has been found at this location</description>
  <Point>
    <coordinates>
      28.278984,-25.756823
    </coordinates>
  </Point>
</Placemark>
</kml>
```
In addition, Google provides a geocoding platform which is free for less than 2500 queries per day. If the following URL is accessed:

```
```

Google returns an XML file which contains a wealth of information about the physical location. Extracts from this XML include:

```xml
<formatted_address>
Scientia 627-Jr, Pretoria, South Africa
</formatted_address>

<formatted_address>
Pretoria 0081, South Africa
</formatted_address>

<long_name>Faerie Glen</long_name>
```

In view of the fact that this conference is being held in Kampala, Uganda, it is interesting to note that this geocoding information is also available for many African cities:

```
http://maps.googleapis.com/maps/api/geocode/xml?latlng=0.339984,32.558725&sensor=false
```

Google returns an XML file which includes the information

```xml
<formatted_address>Nanfubambi Rd, Kampala, Uganda</formatted_address>
```

**Communication Between Thing Owner and Finder**

Communication between the owner of the “thing” and the finder of the “thing” was mediated by Tony. For research purposes, a number of cycles of the Design and Creation Research Methodology was traversed giving additional functionality to Tony.

1. The initial implementation of Tony merely sent a message to the owner of the “thing” stating that the “thing” had been found. This message was sent back to the owner of “thing” via the same channel with which the “thing” was registered. This could be XMPP or POP3 Email for example.

2. In the second implementation, Tony allowed the finder of the “thing” to voluntarily send his telephone number to the owner of the “thing” so that the two people could communicate about the “thing”. This was for research purposes only. The
Researchers are well aware of the dangers of putting strangers in touch with each other using social media.

3. In a third implementation of Tony, the GPS co-ordinates captured by the modified ZXing application were displayed on Google Earth as can be seen in Illustration 5.

4. In the fourth implementation of Tony, various Google geocoding platforms were queried with the coordinates to find more information about the physical location of the “thing” that was found as can be seen in the red highlighted portion of Illustration 5.

**Illustration 5: Sample Google Earth shot**

![Sample Google Earth shot](image)

**Evaluation**

Tony (along with the Beachcomber platform) was the first project undertaken by the Internet of Things Engineering Group. As such it was primarily a learning experience for the project members enabling them to familiarise themselves with various Internet of Things technologies such as geocoding, QR codes, etc.

However a number of small pilots were conducted. The evaluation includes the following:

1. There are numerous cell phone applications to decode the QR Codes on the cell phone itself. Some applications work better than others. ZXing (as mentioned previously) often crashed with Java null pointer exceptions. A QR Code decoder which is 100% stable needs to be identified.

2. By modifying an existing open source software package to access the cell phone internal GPS, Tony basically required that people finding the “things” labeled
with a QR code needed to have the modified software already installed on their phone. Although this is acceptable in a research project, it is not feasible in real life implementation. The web server application which receives the decoded information from the QR codes needs to return instructions to the phone to automatically bring up the GPS. A way to do this in a phone agnostic manner needs to be investigated. One possible low-tech solution would be to print instructions at the bottom of the QR code when the thing is first tagged.

3. In order to cater for the situation where finders of “things” who do not have cell phones which can decode QR Codes but do have cell phones with cameras, a mechanism which allows the finders to take photos of the QR Codes and then MMS them to a specified number needs to be implemented.

4. The QR Codes often had to be quite large. This project used a 1000x1000 bit matrix for the QR Code and printed it on A4 paper. This resulted in a QR Code which was quite large for small “things”.

Overall, however, Tony worked as designed.

The four sub-objectives of the project were satisfied thereby satisfying the primary research objective. The answer to the research question is affirmative. Internet of Things technologies can be used to reunite people with their lost “things”.

Conclusion

The Internet of Things is the phenomenon of more and more “things” getting connected to the Internet – as opposed to people getting connected to the Internet. There are a number of protocols or methods which are currently used for “things” connecting to the Internet. These include wireless, RFID, wired connections, and QR Codes.

This paper describes a project where “things” were labeled with QR Codes. If the “things” were then lost, the finder could merely photograph the QR Code with his or her cell phone. The finder and the original owner of the “thing” would then be put in contact with each other. In addition, if the cell phone of the finder included GPS facilities, when possible, the original owner of the “thing” was also given coordinates and geocoding information about the current location of the “thing”.

References


CARUSO, J. 2009. The 'Internet of Things' now includes a human heart.


Knowledge Management Research Using Grounded Theory Strategy: Applicability, Limitations and Ways Forward

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Abstract
Knowledge management (KM) is currently an emerging discipline in higher education, and its effective implementation is becoming a precondition for success in an increasingly globalized knowledge economy. Because it is interdisciplinary in nature, carrying out research in KM requires deciding on appropriate research
strategies that should be used to enable objectives of a study to be undertaken to be achieved.

Based on review and analysis of available literature, this paper looks at the paradigms in KM research and examines in details the applicability and limitations of grounded theory strategy in carrying out KM research. Using the explanation that KM research is a human activity system which requires both soft and hard systems methodologies to achieve study goals, a research methodological strategy is proposed for carrying out a research to develop a framework for KM using ICT in higher education in Uganda as part of an on-going study.

As well as contributing theoretically to the literature on KM by providing insights into the applicability and limitations of grounded theory strategy in carrying out KM research, this paper further seeks to propose a methodological strategy that can be used in carrying out similar or related studies.

Keywords: Knowledge Management; Research Strategy; Grounded Theory; Applicability; Limitations

Introduction

Knowledge management (KM) is currently a subject of much debate in both the academic and business communities and is increasingly being seen by the two communities as the key to competitive advantage. In the academic world in general and higher education sector in particular, KM has attracted a lot of interest and a lot of research has been undertaken. A number of these research projects have taken the forms of surveys focusing on success factors and aspects of best practices involving elicitation of general reflections from senior KM practitioners through use of research instruments such as questionnaires and interview methods [Wastell 2001]. Case studies focusing on KM success/failures have also been reported [Storey and Barnett 2000; Shani et al. 2000]. However, these studies often lacked critical depth and/or methodological clarity. Typically, the results often appear as lists of factors, with no clear links to underlying data in term of explicit methods of theory generation and cited evidences [Wastell 2001]. Because it is a developing discipline, KM requires definitional papers that focus on basic theory by defining terms and establishing relationships between concepts [Croasdell et al. 2003; Guo and Sheffield 2008]. Studies carried out on KM contain a rich variety of conceptual papers that build theoretical foundations for KM in the disciplinary fields such as information systems, management and organizational behaviors, and systems thinking. The problems with these theoretical frameworks are that interconnections that may exist among them in terms of KM research and the strategies that can be employed to achieve improved KM results appear to be largely unexplored.

According to Guo and Sheffield [2008], three perspectives on organizational knowledge are discernable that may support such an exploration and how research in KM can be approached. The first perspective proposes that organizations have
different types of knowledge, and that identifying and examining these will lead to more effective means for generating, sharing and managing knowledge in organizations. Orlikowski [2002] uses the example of Tsoukas [1996] characterizing such a perspective as “taxonomic”, with researchers developing classifications of knowledge and then using these to examine the various strategies, routines, and techniques through which different types of knowledge are captured, represented, codified, transferred and exchanged [Nonaka 1994; Nonaka and Takeuchi 1995]. The second perspective proposes that knowledge is inseparable from knowing how to get things done in complex organizational work and that organizations enact a collective capability in organizing. It examines the practices or the situated and ongoing accomplishment that emerge from everyday actions [Orlikowski 2002]. This perspective recognizes the roles and importance of knowledge resources as well as the processes involved in effective KM, but also examines the nature of work practices, and human agency. The third and final perspective proposes that knowing how to accomplish tasks in organizations cannot be separated from politics, that is, how power is attached to knowledge and knowledge is attached to power. Pozzebon and Pinsonneault [2006] expound on this perspective by describing the conflicting views of clients and consultants in customizing complex software artifacts such as Enterprise Resource Planning (ERP) systems. The authors use this example to describe initial configuration of client-consultant relationships, and the way this arrangement evolves through mediation, in term of power relations.

Because of these different perspectives of looking at KM, studies in the subject currently show that KM researchers differ in their definitions concerning the concept of knowledge and there is a general lack of conceptual integration to KM research, which has contributed to confusing variety of approaches, theories and frameworks [Alavi and Leidner 2001]. For example, Earl [2001] summarizes seven different approaches to KM research, including systems, cartographic, engineering, commercial, organizational, spatial, and strategic, with each having its own philosophical underpinnings, research focus and aims. This makes KM eclectic rather than grounded on a specific ideology, resulting in a variety of knowledge definitions and classification schemes [Amidon 1998; Bushko & Raynor 1998; Nonaka & Takeuchi 1995], as well as methods, models, and approaches [Earl 1994; Nonaka & Takeuchi 1995; Martiny 1998]. Giaglis [2003] points out that the interdisciplinary nature of KM renders its detailed epistemological study more difficult, albeit important.

This paper examines KM research and the applicability and limitations of grounded theory strategy in carrying out KM study, with a view to proposing the best research strategy that will be adopted to carry out a study to develop a framework for KM using ICT in higher education. Firstly, the paper starts by examining KM as an interdisciplinary subject; secondly, it looks at the research paradigms in KM; thirdly, it examines the relationships between grounded theory and KM research. This is followed by examination of the applicability and limitations of grounded theory in carrying out a study involving KM framework development. Finally, a proposal is made on the best
research strategy that will be adopted to carry out our study. As well as contributing theoretically to the literature on KM by providing insights into the applicability and limitations of grounded theory strategy in KM research, the paper also seeks to propose a methodological strategy that will be adopted to carry out a study to develop a framework for KM using ICT in higher institutions of education in Uganda as part of an on-going study.

**KM as an Interdisciplinary Subject**

KM efforts have a long history to include on-the-job discussions, formal apprenticeship, discussion forums, corporate libraries, professional training and mentoring programs. More recently and with increased use of computers, specific adaptations of technologies such as knowledge bases, expert systems, knowledge repositories, group decision support systems, and computer supported cooperative work have been introduced to further enhance such efforts. A broad range of thoughts on the KM discipline exists with no unanimous agreement; and approaches to KM research vary by authors and schools. For example, Ponelis and Fair-Wessels [1998] assert that KM is a new dimension of strategic information management. Davenport and Prusak [1998] view KM as the process of capturing, distributing, and effectively using knowledge. Skyrme [1997] suggests that KM is the explicit and systematic management of vital knowledge along with its associated processes of creating, gathering, organizing, diffusing, using, and exploiting that knowledge. According to Pierce [1999] and Klein [1996], KM is interdisciplinary because it involves the exportation and integration of theories or methods to other disciplines; and in the case of KM, to the development of the emerging field of KM.

The variations in the definition of KM by the different researchers point to the interdisciplinary breadth of the subject and one of the most comprehensive definitions has been proposed by Ruggles [1998]. In his definition, Ruggles defines KM as “a newly emerging, interdisciplinary business model dealing with all aspects of knowledge within the context of the firm, including knowledge creation, codification, sharing, learning, and innovation. Some aspects of this process are facilitated with information technologies, but the greater aspect, is to a degree, about organizational culture and practices”. According to Ponzi [2002], a contextual view of Ruggles’ definition demonstrates the popular perception of the claim that KM is interdisciplinary in nature. It also suggests a definitive set of disciplines that KM is developing from, namely, management science, library and information science, management information science, organization psychology, computer science and sociology. Examples in the definition of KM given by Ruggles [1998] include, “business model” representing “management science”, “codification” representing “information science”, “information technology” representing “management information systems/computer science”, and “organization culture” representing “organizational psychology and sociology”. KM as a subject should therefore be seen and understood as a confluence of several sciences and disciplines, each contributing to the understanding of the concept of KM.
Knowledge is currently regarded as one of the key determinant factors of higher education institutions’ survival and growth in the knowledge age. Unlike Drucker [1993], who considered knowledge as a key resource, it is now widely believed that other factors, such as the business environment or political factors are just as important as knowledge to higher education institutions, firms, industries, and countries, and that the configuration of various factors as a whole determines the performance of these institutions. In systems terms, a “whole” can be greater than, equal to, or perhaps lesser than the sum of its parts. Therefore, KM requires an interdisciplinary study to critically and continuously “sweep in” “new” ideas, approaches, models, and techniques in an informed manner, in both theory and practice, to pursue the notion that a whole is greater than the sum of its parts from the perspective of critical systems thinking [Jackson 2000; Gao et al. 2003]. Although there have been several contributions on KM from different disciplines as well as from different professional experiences, somehow, each of these remained isolated for long, and it is only recently that interdisciplinary approaches to the study of KM have begun to emerge [Ponzi 2002]. This diversity of the contributions from the different discipline and the consequent multiplicity of approaches, theories, tools and technologies lead to the need to decide on the most appropriate research strategy to carry out a study like ours to develop a framework for KM using ICT in higher education.

**Research Paradigms in KM**

A research paradigm refers to a broad framework of perception, understanding, and belief within which theories and practices operate. It is thus a network of coherent ideas about the nature of the world and the functions of researchers which, if adhered to by a group of researchers, conditions their thinking and underpins their research actions [Bassey 1990]. There are various categorizations of research paradigms. A four-paradigm scheme consisting of functionalist, interpretive, radical structuralist, and radical humanist, has been proposed for the analysis of social theory and information systems development by Hirschheim and Klein [1989]. The first two paradigms in this scheme (functionalist and interpretive) seek more or less concrete evidence about the existing state of affairs, while the last two (radical structuralist and radical humanist) criticize, and offer radical alternatives to the status quo. This scheme has further been developed into four paradigms for a discourse theory of organizational inquiry and KM, and these are normative discourse, interpretive discourse, dialogic discourse, and critical discourse [Deetz 1996; Schultze and Leidner 2002]. According to Cavana et al. [2001], positivism, interpretivism, and critical inquiry – aligned with normative discourse, interpretive discourse and, dialogic and critical discourse respectively – are frequently identified as the main research paradigms for interdisciplinary disciplines such as social sciences, KM and business research.

As has already been pointed out earlier, KM is an inherently interdisciplinary research field in as much as its implementation depends on technological systems and
its application depends on user acceptance and embracement by both management and employee alike. This implies, according to Giaglis [2003] that research within the field of KM can generally fall under two broad categories depending on the departing point of research questions. On the one hand, one research stream based on hard systems approach draws predominantly on the findings from the fields of computer science and information systems, and sees KM as an application area that extends the traditional realm of databases and information management into so-called knowledge bases and KM systems. In other words, this sub-area of KM is mostly concerned with investigating ways in which technological capabilities can be exploited by organizations in their pursuit of knowledge driven competitiveness. On the other hand, the second stream based on soft systems methodology approaches KM research from a complementary perspective and attempts to tackle the managerial, organizational, and human issues surrounding the successful introduction of KM within organizations. Research under this sub-area of KM is mostly concerned with investigating ways in which the process of knowledge creation, assimilation, communication, and enactment can be managed by organizations.

Based on the positivist, interpretivist, and critical pluralist paradigms, this study will use the research paradigm proposed by Herbamas [1987] in his ‘theory of knowledge-constructive interest and communicative action’ to recommend the best research strategy that will be adopted to carry out our study. In this paradigm, ‘knowledge interests’ provide the key architectural element for carrying out a study. Knowledge interests according to the paradigm direct the phenomenon studied (research interest) and the guarantor of knowledge gained in a particular research paradigm, and each research interest is associated with a tradition of systems thinking (see Table 1). In the paradigm, knowledge interests are used to frame a typology of actions and such typology can be very useful in guiding actions of KM researchers.

**Table 1: Herbamas Research Paradigms**

<table>
<thead>
<tr>
<th>Research Interest</th>
<th>Research Paradigms</th>
<th>Traditions of Systems Thinking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emancipatory</td>
<td>Critical pluralism</td>
<td>Critical</td>
</tr>
<tr>
<td>Practical</td>
<td>Interpretivism</td>
<td>Soft</td>
</tr>
<tr>
<td>Technical</td>
<td>Positivism</td>
<td>Hard</td>
</tr>
</tbody>
</table>

According to Herbamas [1987], in the critical pluralism paradigm, a researcher’s emancipatory knowledge interest motivates a study of personal reality and is adopted for carrying out KM research in the tradition of critical systems thinking. Here, communicative rationality drives the critically oriented science in their questioning of the legitimacy of the status quo and guides their concern about structured contradictions.
and/or exploitation, and the main task of inquiry is to examine the legitimacy of the current system and provide a stimulus for emancipatory change. Pozzebon and Pinsonneault [2006] study is an example of a research conducted using this paradigm. The research is concerned with uncovering the surface illusion that power and knowledge are separate issues.

In the interpretivist paradigm, Herbamas [1987] points out that a researcher’s practical knowledge interest motivates a study of social reality and is adopted for carrying out KM research in the tradition of soft systems thinking. Here, strategic rationality drives the hermeneutic-phenomenological sciences and research on phenomena that are emergent and subject to social interpretation. The main task of inquiry here is to understand the potential ambiguity and uncertainty of social meaning, and knowledge is associated with the understanding of participants in social interactions. Orlikowski [2002] is an example of a research conducted using this paradigm and is concerned about the nature of ‘practice’ which is described as situated and ongoing accomplishment that emerges from people’s everyday actions.

In the positivist paradigm, Herbamas [1987] points out that a researcher’s technical knowledge interest motivates a study of objective reality and is adopted in the tradition of hard systems thinking. Here, instrumental rationality drives the empirical-analytic sciences and research designs centered on measurement, causal relationships, prediction as well as the imposition of control, and knowledge is associated with hard data, mathematics and models. The paradigm is concerned with the discovery of universal laws that can be used to predict human activity, and the physical and technological world. Holsapple and Joshi [2004] is an example of a research conducted using this paradigm and is concerned with enquiries for categories of operations required to manage different types of knowledge.

Grounded Theory Strategy

Grounded theory was developed by Glasser and Strauss [1967] as a research methodology for extracting meaning from qualitative data collected in the field, and is used to generate a theory that explains a process, or processes, about something at an abstract conceptual level in a specific context or setting. The grounded theory strategy, particularly the way Glasser and Strauss [1967] developed it, consists of a set of 7 steps whose careful execution is thought to guarantee a good theory as the final outcome and is an inductive rather than a deductive methodology for carrying out research. The steps include situating unexplained problems, identification of a research area, collecting data, extracting themes, postulating generalization, developing taxonomies, and developing theories (see Figure 1). The whole process aims to develop an account of a phenomenon or phenomena, which identifies its major categories, the relationships between the categories, and the context and processes which are occurring [Becker 1993]. The result is a middle order theory, as opposed to grand theory or a hypothesis, which explains the phenomenon [Alston and Bowles 2003]. Emergence is a key assumption in grounded
theory, and because data, information and knowledge are emergent phenomena that are actively constructed, they can only have meaning when positioned in time, space and culture, and are only relevant in an experiential world [Goulding 1999].

**Figure 1: Steps in Grounded Theory Research**

![Diagram showing steps in grounded theory research](image)

Curry [2003] points out that the purpose of grounded theory is to provide a framework by which theory can be scientifically and methodically generated. Whereas lots of other research is concerned with verifying deductive theory, grounded theory is concerned with insuring that the theory, which is being verified, was methodologically-driven, carefully developed, and purposefully grounded in the trenchant data. In other words, anomalous states of knowledge are explored and scrutinized. Covalesky & Dirsmith [1990] place grounded theory in the category of the symbolic analysis approach to social science research. This approach views “reality as a realm of symbolic discourse, where humans are seen as actors and symbol users; and where information as a network of symbols, does not represent reality but is reality itself. The essential character of grounded theory lies in the generation of theory from data by constant comparative qualitative analysis. It aims at the emergence of theory from the data, rather than exploring the data to confirm existing theory.

Grounded theory proceeds from the assumption that “theory is a process” and this process begins with the collection of raw data which is then qualitatively coded as a first step towards developing prospective theory. From the preliminary coding, major variables emerge, raising further questions. If the answers to the questions are not found in the data, further data collection is indicated. It is this consistent return to the data at each stage of developments that validates the theory. The theory matures as data elements are integrated into the whole and the grounded network of relationships are established – a process called theoretical sampling. Theoretical sampling is the process of collecting, coding, and analyzing data, and includes deciding what data to collect next and where to find them in order to develop an emerging theory, either substantive or formal [Strauss and Corbin 1998]. The research gradually assembles a theory, inductively and iteratively obtained through categorization from the body of knowledge. This is done on a case-by-case basis, rather than through subject-based identification of variables. Comparison of cases and labels should then be able to reveal similarities and differences. The casual
relationships, similarities and differences then lead the researcher to draw conclusions and formulate theories about what is happening. Every cycle will see the researcher test the emerging theory against new cases and categories, and compare that theory against those in the literature to try and explain or reinforce it. With discovery of further labels, the theory may be refined or abandoned.

**Grounded Theory Strategy Applicability in KM Research**

As has already been pointed out, an analysis of the grounded theory strategy and its intellectual assumption shows that it owes more of its approach to the hard systems/interpretivist paradigm based on its emphasis on multiple realities; that researcher and phenomenon are mutually interactive; that causes and effects cannot be separated; that research is value laden; and that the outcome of a research is socially constructed [Brown 1995]. As a methodology, grounded theory was developed for, and is suited to the study of behavior, and given this background, it has considerable potential for the study of the broad range of subjects which have a human dimension such as KM. This is because in KM research, the basic generating functions are to be found in the heads of human beings and the outcomes are represented by actions and decisions, and on whatever level of abstraction we use the concept of knowledge, the outcome is rooted in the individual.

As a methodology that is used for extracting meaning from qualitative data that is collected from the fields, grounded theory assist in generating a theory that explains a process, or processes, about something at an abstract conceptual level in a specific context or setting [Glasser and Strauss 1967]. The fundamental aspect of this methodology that must be adhered to while carrying out a KM research is therefore to ensure that the theory derived is grounded in the data. The theory that is generated may be an abstraction or generalization of the causal relationships found in the study, and can emerge from logical assumptions or is generated from observations [Glasser and Strauss 1967]. The theory can also be developed from research that is either data driven or theory driven [Dick 2000]. Examples of the use of grounded theory strategy in KM research include the work of Ford and Angermeier [2004]; Smith [2004]; Wastell [2001]; and Wong and Aspinwall [2005].

**Limitation of Grounded Theory Strategy**

With regards to the limitation of grounded theory in KM research, the key issue is that the end result of any research carried out using grounded theory strategy is theory. Glaser [1992] emphasized that the theory generation should be through systematic data collection and analysis, arguing that theory verification and testing should be left to others. The methodological thrust of grounded theory is, therefore, towards the development of theory, without any particular commitment to specific kinds of data, lines of research, or theoretical testing. Rather it is a style of doing qualitative analysis that includes a number of distinct features such as theoretical sampling, and certain methodological guidelines such as the making of constant comparison, and
the use of a coding paradigm to ensure conceptual development and density [Strauss 1987]. The aim is to develop representative concept and ultimately build a theoretical explanation by specifying phenomena in terms of the conditions that give rise to them, how they are expressed through action/interaction, and the consequences that result as well as the variation [Strauss and Corbin 1990]. The problem with the strategy as far as KM research is concerned, is that the use of knowledge, based on the process of learning, is not simply a subsumption of cases based on theories only; it is a process of contrasting and discovering the extent to which new situations can be understood and improved through theory building, testing and re-testing of KM systems/frameworks for continuous improvement of knowledge service deliveries.

**Proposed Research Strategy**

The nature of knowledge, and how we use it, is a complex human activity which cannot be reduced to a formulaic and quantifiable process. Thus, any research strategy in KM must adopt an interpretivist and positivist research approach if it is to yield deep insight and provide solutions to address the challenges involved in the development and implementation of KM activities using ICT in higher institutions of education in a real world situation [Guo and Sheffield 2008]. This is because the level of success in the development and implementation of KM framework using ICT in higher education is significantly dependent on the right balance of intervention and reflection on the current practices of KM. Positivist method focuses on the intensive study of a real world instance of a phenomenon through observation and case-studies [Yin 1994], while the interpretivist method aims through action research to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science (KM) by joint collaboration within a mutually acceptable framework [Rapport 1970].

The goal of our study is to develop a framework for KM using ICT in higher institutions of education, with a view to improving KM for enhanced education outcomes, research, competitiveness and innovations. To achieve this, the scope of the study will include carrying out reviews and analysis of available literature to explore and understand the key concepts, theories and models of KM using ICT in higher education, proposing of a conceptual framework to guide the study, carrying out fieldworks using case studies, and finally carrying out testing and verification of the proposed framework through action research for continued improvement. In line with Guo and Sheffield [2008] proposal that a combination of positivism and interpretivism are the paradigms most frequently employed in KM research because they capture much of the fluidity and interconnectedness of knowledge, we proposed to use inductive-hypothetical research strategy as our overall research approach to achieve our research objectives. The approach has been used previously by other researchers to solve “messy”, “complex” or “ill-structured” problems [Sol 1982; Churchman 1971; van Meel 1994; de Vreede et al. 1998]. The strategy will employ a combination of grounded theory (interpretivist/hard
Inductive-hypothetical research strategy combines theory and practice and adopts existing problems by emphasizing problem specification from a multidisciplinary point of view [Sol 1982]. Using hard systems as well as soft systems methodologies, the inductive-hypothetical approach in our study will focus on theory formulation, testing and evaluation of the proposed KM framework and generation of alternatives solutions for continuous improvement. In this research, theory will be formulated based on abstraction from an inductive case study as well as from existing theory using grounded theory strategy. The use of grounded theory strategy will involve using the seven steps processes which are, situating unexplained problems, identification of a research area, collecting data, extracting themes, postulating generalization, developing taxonomies, and generating theories (figure 1). This will be followed by implementation through testing and evaluation of the proposed framework for continuous improvement. The overall study process which will include generating of theories as well as testing and evaluation of the proposed framework will be undertaken following the steps used in the inductive-hypothetical research strategy as outlined in figure 2 below:

**Figure 2: The Inductive-Hypothetical Research Strategy**

As shown above, the inductive-hypothetical research strategy starts with reviewing of literature so that the problem domain of KM using ICT in higher education is elicited, a process called initiation (arrow 1). The result here is expected to be a descriptive conceptual model providing the first understanding of the key issues regarding KM framework development using ICT in higher education as well as the parameters that are required for effective implementation of KM. To substantiate the issues identified during initiation, field explorative studies using case studies in higher education will be undertaken to identify KM approaches, processes, strategies and key challenges through a process called abstraction (arrow 2). Through this process, a descriptive empirical model will be derived where a description of the KM framework requirements for effective KM using ICT in higher education will be made. Using the results from the conceptual and empirical descriptions, theory will be formulated in which the descriptive conceptual model will be made prescriptive (arrow 3) giving rise to a prescriptive conceptual
model. The theory formulated should be able to describe what constitutes an effective KM implementation framework and this will be used to guide the development of a framework for KM using ICT in higher education. The prescriptive conceptual model will then be implemented by testing of the proposed framework (arrow 4). Finally, the prescriptive empirical model will be evaluated (arrow 5) so that further improvements can be made through comparison of the elicited empirical knowledge (arrow 1) with the prescriptive empirical model (arrow 4). In our study therefore, grounded theory strategy will be used for initiation, abstraction, and the theory formulation phases of the study, while soft systems methodology will be used in the implementation and evaluation phases.

In order to transform knowledge into a valuable organizational asset, knowledge, experience and expertise must be formalized, distributed, shared and applied. KM and organizational dynamic process knowledge is viewed as a human activity system which involves real life situations. Real life here involves ill-formulated and ill-structured problems and conditions: real life problems have context, depth, complexity and duration; involve cooperative situations and shared consequences; and are worth solving and can provide benefits when solved [Fitzsimons 2001]. Human activity systems refer to an assembly of knowledge workers occupying a shared space that serves as a foundation for knowledge creation [Nonaka and Konno 1998], and consist of both soft and hard systems resources for managing, organizing, learning and reusing of existing knowledge and, more importantly, for creating new knowledge to realize an organization mission and goals [Gao et al. 2003]. The activities of capturing, coding, abstracting, storing, transferring, converting, sharing, using and reusing existing knowledge and creating new knowledge are the human practical activities. Without these, knowledge cannot be created, used, reused and shared. An organizational KM system/framework is a purposeful human activity system [Checkland 1999] comprising three interdependent components: The people who make up the organization, the activities the people perform, and the technologies that enable activities. Thus any KM research involving systems/framework development needs a combination of soft systems methodology that deals with the analysis of evolving and ill-defined needs as well as hard systems approach to address the needs of design of physical solutions to meet those needs. Inductive-hypothetical research strategy attempts to address all these issues highlighted.

KM research using grounded theory in the interpretivist paradigm regards knowledge, technology and organizational practices as socially constructed. Sahay and Robey [1996] highlight the implications of this social construction, namely that conceptual knowledge about a system is heavily intertwined with the social environment and that this environment influences not only the spread of knowledge, but also the adoption and adaptation of ICT. Because the assimilation process can be viewed as one of organizational learning, knowledge transfer and ICT adoption, Sahay and Robey [1996] further suggest that organizational learning should be a theoretical perspective adopted for research on organizational transformation through ICT. On the other
hand, soft systems methodology which has its foundation in action research and general systems theory is characterized by involvement in a problem situation, learning by doing, trying to see a system from as many perspectives as possible, and seeing a system through the eyes of others rather than the researcher [Checkland 1981] making it useful to complement grounded theory in our study.

The widespread use of ICT in KM embodies social complexity, and the continuous changes in technology within organizations requires a continuing evolution from advancement of ICT tools and applications to cognitive level usually involving messy human problems within the social context in a particular environment. In addition, the level of success in the implementation of KM initiatives in higher education is significantly dependent on the right balance of intervention and reflection on the current practices of the organizations. Using soft systems methodology combined with grounded theory is an attempt to try and address this limitation. Checkland’s [1981] soft systems methodology lies firmly within the tradition of action research and aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework [Rapport 1970]. Organizations with entrenched traditional structures such as higher institutions of learning are under particular pressure to review their working practices in KM. In this context, Elliman and Orange [2000] recommend soft systems methodology as an approach to facilitate effective change and to improve work practices.

Checkland’s soft systems methodology is concerned with human activity systems which he defines as a notional purposive system which expresses some purposeful human activity; activity which in principle could be found in real world. Such systems are notional in the sense that they are not descriptions of actual real-world activity (which is an exceptionally complex phenomenon) but are intellectual constructs; they are ideal types for use in debate about possible changes which might be introduced into a real-world problem situation [Checkland 1999]. According to Durant-Law [2005], human activity systems by their nature are complex. They are considered to be holistic, subjective, process-oriented, in a state of constant flux, and often non-rational. In addition, they act based on interpretation of the world, but there are always several world views because individuals interpret the world differently and there is no single correct answer to a problem situation.

In its idealized form, soft systems methodology refers to a seven-stage process of analysis as shown in figure 3, which uses the concept of human activity as a means of defining the situation for taking actions [Checkland 1981], and these include:

(i) Identification of problem situation by observing the problem symptoms in a situational context;

(ii) Analysis of the symptoms map to identify the real underlining issues and root causes resulting in rich picture of the given situation;
(iii) Analysis of the problem identified in rich picture and developing a root-definition for the transformation processes, which addresses the problem;
(iv) Development of the conceptual model;
(v) Comparison of the conceptual model with identified problems;
(vi) Identification of desirable changes or solutions; and
(vii) Development of final model that can be implemented.

Figure 3: Checkland’s Soft Systems Methodology

Combining Grounded Theory With Soft Systems Methodology
Because of the variation in the definition and understanding of the concept of KM, knowledge has been perceived as either (i) a “discrete, objective, largely cognitive entity” [Newell et al. 2002], susceptible of being classified as tacit (unarticulated expertise and experience) and explicit (formalized and expressed knowledge); or (ii) as socially constructed and embedded in practice (knowledge as a process) [Nonaka & Takeuchi 1995]. These two different, but complementary perspectives are at the root of different approaches to the KM process in organizations [Newell et al. 2002]. An organization embracing the first perspective of knowledge being a discrete entity will use hard systems methodology to develop knowledge stores and will try to capture the organization’s knowledge by software. On the other hand, organizations with the latter perspective of knowledge being a process will use soft systems methodology which gives more importance to the process of knowing and knowledge creation and to the
context that makes possible this creation to ensure effective KM. Our research looks at the two perspectives of KM as being complementary, hence the need to use inductive-hypothetical research strategy based on combining grounded theory strategy with soft systems methodology to achieve the research goals.

According to McLucas [2003], real world activities are “hows” related to a specific “what”, which is usually implicit rather than explicit. In social situations, the “whats” can be difficult to define and many problems might be considered to be “wicked” – that is, they are complex, dynamic, systemic, emergent, difficult to resolve, and confounding to manage. KM represents such a situation. Soft systems methodology addresses this complex situation by modeling the real world “what” as well as alternative “how” for improvement of the situation and lends itself to developing of a set of structured research questions to gain insights into wicked problems. It is also useful in building a road-map to a research project and to show the logical dependencies of the various activities in a multi-disciplinary research project [Hindle et al. 1995], especially where the research process is of itself a purposeful human activity and therefore is part of human activity system. Indeed, Gao et al. [2002] suggest that soft systems methodology is valuable research approach to study KM and that some of its value is to offer inspiration on how to learn continuously and effectively. In the same vein, grounded theory is a useful research methodology for collecting and analyzing research data, and can provide deep insight into the real issues associated with a phenomenon like developing a framework for KM using ICT in higher education. Because of the depth of analysis, grounded theory results in deep understanding of phenomena and is therefore, a sound research approach for any behavior that has an interactional element to it [Goulding, 2005].

A closer look at the two methodologies also shows that they are both seven-step processes with remarkable similarities and complementarities as shown in table below:

**Table 2: Grounded Theory and Soft Systems Methodology Compared**

<table>
<thead>
<tr>
<th>Steps</th>
<th>Grounded Theory</th>
<th>Soft Systems Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>An unexplained phenomena or process</td>
<td>The problem situation considered</td>
</tr>
<tr>
<td>2.</td>
<td>The phenomena or process identified</td>
<td>The problem situation expressed</td>
</tr>
<tr>
<td>3.</td>
<td>Data collection and coding</td>
<td>Root definitions of relevant systems</td>
</tr>
<tr>
<td>4.</td>
<td>Theme extraction</td>
<td>Conceptual model construction</td>
</tr>
<tr>
<td>5.</td>
<td>Postulate generalizations</td>
<td>Model and problem situation comparison</td>
</tr>
<tr>
<td>6.</td>
<td>Develop taxonomies</td>
<td>Feasible and desirable change construction</td>
</tr>
<tr>
<td>7.</td>
<td>Theory development</td>
<td>Action to improve the situation</td>
</tr>
</tbody>
</table>
From the table, it can be seen that there are remarkable similarities as well as complementarities in using the two methodologies to carry out a study. For example, steps 4 and 5 result in similar outcomes, although they are expressed differently. In addition, many of the methods, tools and techniques can be in either methodology. For example, the use of questionnaires, interviews and focus group discussions are common in both methodologies. The two methodologies also share the assumption that the model or the phenomena determines the final model or theory. The main difference between the two approaches is that grounded theory develops theory from data interpretation by the researcher while soft systems methodology values data from the perspective of participants. Using the two approaches in a complementary manner should therefore provide a more holistic approach in carrying out our study. We intend to merge the seven steps of the two methodologies into a five-step process as used in inductive-hypothetical research strategy, that is, initiation, abstraction, theory formulation, implementation, and evaluation.

Finally, Rose [1997] emphasizes the importance of using soft systems methodology to complement grounded theory strategy in carrying out a study like ours due to the roles it can play in achieving the objectives of the study. Firstly, he points out that soft systems methodology is a good-fit research tool that is qualitative, activity-based, interpretative, participative, and systems-based which uses methodological tools that are appropriate to a KM framework study; secondly, that it is a triangulation tool that can be used to confirm, deny, or amplify findings from grounded theory; thirdly, that it is a problem-structuring tool that can serve as a “front-end” to grounded theory strategy by lending structure to a ‘messy’ problem; fourthly, that it is a theory testing or generation tool; and fifthly, that it is a coordinative or directive tool which can help in conceptualizing a research process whether it is a human activity systems. Models may then be built, which may assist in delineating the various research activities and their logical dependencies.

Conclusion

In today’s knowledge driven economy, higher education institutions’ managers are faced with the challenge of how to effectively link KM initiatives and processes with the ever-changing needs of higher education. The problem arises due to the disconnect between KM and the ever-changing organizational needs, which is mainly due to having inappropriate KM framework development and implementation approaches, and adoption of some quick-fix solutions to KM to achieve higher educational goals. If knowledge is to be effectively managed and utilized, KM research and other initiatives should be made to link with institutional goals such as enhanced research, innovations and competitiveness. This paper examines the applicability and limitations of grounded theory strategy in carrying out KM research, and proposes the use of inductive-hypothetical research strategy based on grounded theory strategy, in combination with soft systems methodology based on action research, as approaches to be adopted to
carry out a study to develop a framework for KM using ICT in higher education in Uganda. The proposed approach attempts to address the missing links between KM initiatives and processes and the ever-changing needs of higher education, and presents a holistic view for formulating KM framework development and implementation using ICT by focusing on both technical and non-technical issues including higher education activities, KM processes and human activities within institutions.

Using inductive-hypothetical research strategy based on grounded theory using case studies combined with soft systems methodology using action research provides a systematic basis for developing and verifying theory (the research interest), and in designing and evaluating interventions to serve the interest of KM practitioners in higher education. The degree to which these interventions are successful provides validation for the theory and may indicate areas where further improvements should be made in the implementation of KM using ICT in higher education. Both grounded theory and soft systems methodology have been used to explore and discuss problems relating to KM in complex settings and situations. They offer a flexible approach to a KM research like ours, where solutions to problems can be theorized, tested and re-tested with participants, thus increasing stakeholders’ ownership of solutions and participation in KM framework development and implementation. Although the focus of this paper is in proposing the best approach to be used to carry out our study, it does not help much in promoting good research; good research is not only effected by a strong research methodology alone, but by its conscientious, intelligent and self-reflective application, that must be reflected in how the study is conducted. This will ensure that the objectives of a study are achieved as well as contribute to improved research outcomes.

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References


POZZEBON, M. AND PINSONNEAULT, A. 2006. A study of power and knowledge in the implementation of configurable information technologies, HEC Montreal, 0832-7203.


A Studio Based Approach to Enhancing Decision Making in Sme Start-Up

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Abstract
The start-up phase plays an important role in the success and survival of many enterprises, which greatly depends on adequate and timely services for decision making. However, deciding to startup a mining Small and Medium Enterprise (SME) is a challenging task for many entrepreneurs in Uganda. Research on SME start-up support is limitedly available. Information Communication and Technology (ICT) is envisaged to facilitate enterprise start-ups. However, there are still acknowledged deficiencies in Uganda due to their discrete and isolated approach of technology, stakeholders and processes. There is lack of a generalized and systematic means to carrying out SME start-up that emphasizes constant communication and prioritization to support decision processes. Hence, this design science research aims to enhance ill-structured mining SME start-up decision processes with a decision enhancement studio. This studio consists of services for participants in an interactive environment to enhance the enterprise start-up decision processes by doing an analysis of the decision alternatives. This paper presents a design of the decision enhancement studio for mining SME start-ups. The studio is based on the requirements derived from literature and an exploratory study in Uganda. The future research will be dedicated to the implementation, evaluation, and refinement of the decision enhancement studio for mining enterprise start-ups.

Keywords: Small and Medium Enterprise, Start-up, Decision Enhancement, Studio
Introduction
The Uganda government has turned to Information Communication and Technology (ICT) as a tool to improve access to information as a new medium for social and economic change [Uganda Ministry of Finance, Planning and Economic Development 2010]. There is a strong push for job creation and self employment in Uganda especially as the population of unemployed youth is on the rise. Enterprise ventures are a viable means of dealing with this concern. Small and Medium Enterprises (SMEs) are important for a national economy. An enterprise is defined by the number of employees and its annual sales or revenue turnover. In Uganda, we adopt the following definitions of small and medium enterprises. A Small Enterprise employs a maximum of 50 people, has annual sales/revenue turnover of a maximum 360 million Uganda Shillings (UGX) (USD) 150,000, or Euros (€) 110,000 and total assets of maximum 360 million UGX. A Medium Enterprise employs more than 50 people with a maximum of 500 people, has annual sales/revenue turnover of more than 360 million UGX and total assets of more than 360 million UGX [UIA 2008; Hivos 2008; UBOS 2007; Kasekende and Opondo 2003].

In Uganda, SMEs contribute to more than 20% of the National Gross Domestic Product (GDP) with an estimated 1,500,000 SMEs of which more than 90% are privately owned [Ssebugwawo 2007; Ssewanyana 2007; Ssewanyana and Busler 2007; Hatenga 2007]. More than 150,000 of these are mining SMEs with an estimated one million Ugandan direct beneficiaries [Kato 2010; Hinton et al. 2009]. A study carried out by Uganda Bureau of Statistics, clarified the reason why many SMEs collapse and fail to remain in operation for more than a year. It was attributed to the entrepreneurs’ decision-making challenges since they rely on intuition and lack of information to base their decisions [UBOS 2007]. In Uganda, more than 30% SMEs established do not survive the first year due to limited access to information, lack of appropriate technologies and inadequate opportunities to support technology transfer [Ishengoma and Kappel 2008; Hatenga 2007]. Their survival is greatly influenced by the amount of information availed to the SME stakeholders [Habinka et al. 2009]. To achieve a sustainable enterprise start-up, it is vital for one to understand the start-up process and activities involved so as to decisively establish what is required and the development of the right strategy. Enterprise start-up is defined by GEM [2007] as any attempt by individuals to start a new firm including any attempt for self employment. An entrepreneur is a risk taker who sees an opportunity in the market, gathers resources, creates, grows a business venture to satisfy these needs and is rewarded with profit (an added value if it succeeds) [Kunene 2008]. Starting up an enterprise is a decision or choice a manager makes to start a business or enterprise [Wickham 2001].

Decision processes that lack agility and quality have a tremendous impact on the SME start-ups. In situations where the current decision process is slow, inflexible, fragmented, conflicted, multiple unknown procedures, and highly bureaucratic, chances of crisis and collapse are high [Habinka et al. 2009]. Start-up decision agility is defined
as the ability to swiftly and appropriately adjust a set of related activities performed to achieve a given start-up goal in response to unpredictable challenges that occur in this phase, beyond the normal level of flexibility [Habinka et al. 2009; GEM 2007]. Keen and Sol [2008] argue that, the enterprises that sustain success, develop decision disciplines that are an integral part of their culture. There is need to engage in a more controlled approach to decision making within the enterprise start-up process by systematic identification of the best outcomes to problems as a means of improvement to decisions. This will enable the entrepreneurs to focus on the decision priorities in the enterprise start-up process.

The availability of literature on mining SMEs start-up support is relatively limited. There has been a growing tendency to focus on the use of technology in the optimization of mineral rock cracks, which deal with the operational sector of the mining industry [Vanek and Rueckova 2010; Berglund and Karlton 2007; Everett 2007; Heuberger 2005; Zahiri 2004; Simonsen and Perry 1999; Kaden et al, 1990]. However, a lot has been said on the pre-investment sector but little has been provided on “how to” enable a starting entrepreneur make an informed decision. Various technologies in the mining sector were proposed, however their emphasis was on the use of experts to make decisions without the managers and owners involved thus the need for the fusion of the stakeholders, process and the technology for improved start-up decision processed. In absence of comprehensive integrated models and information systems, incomplete decisions are faced. Emphasis has been put on the use of technology to improve production in the mining sector; however, people handle complex decisions using human judgment, intuition, word of mouth, sixth sense, and experience in starting a mining enterprise in the rural areas of Uganda [Habinka et al, 2009; UBOS 2007]. The current system for carrying out enterprise start-ups are adhoc and not structured hence the need for a guiding framework and services to support the mining SME start-up decision process in rural areas of Uganda. Hence, the main question of this research is: How can we provide support for enhancing mining SME start-ups in rural areas of Uganda? Keen and Sol, [2008] emphasize that technology is to be used for administrative, meeting and analytical support coupled with quality information for enhancement of decision processes. Therefore, in this paper we use the studio based approach to provide support to mining enterprise start-ups in Uganda.

In summary, this research aims to enhance mining SME start-up decision processes with the design of a decision enhancement studio. To address this goal, we first look at decision enhancement services presented in section 2, followed by the research approach in section 3. Subsequently section 4 addresses the mining SME challenges, requirements, and the studio design. Finally section 5 presents the future work and conclusion.

**Decision enhancement services: a studio based approach**

Decision Enhancement Services (DES) utilized a studio-based approach to enhance ill-structured decision processes presented by Keen and Sol [2008]. In this paradigm,
the concept of a “studio” is introduced, and this is defined as a facilitative, interactive environment for decision enhancement [Keen and Sol 2008]. The goal of a studio is to help managers “rehearse the future” by building their comfort with and confidence in directly using appropriate, interactive tools in the decision process. Decision Enhancement Services involves the fusion of tools, processes and people to make an informed decision [Keen and Sol 2008].

The studio environment enhances decision agility by creating opportunities for speedy, adaptive, coordinated, collaborative, and innovative projects among its participants. According to Keen and Sol [2008], decision enhancement services focus on landscaping, orientation and initiation, recipes, suites and processes. Landscaping defines the decision context, stakeholders and governance rules for the decision process. Orientation and initiation ensures that teams with the skills, credibility and domain expertise to attract, motivate coordinate and help the studio participants’ move to a decision commitment. Recipes apply to whatever possible proven guidelines which may include scripts. Suites are the tools and technologies that are designed and implemented within an overall distributed architecture. Process involves making commitment to a decision, the explicit target and agenda.

This approach was used in developing countries like South Africa, and Uganda respectively [Muniafu 2007; and Mulira 2007]. It was used in inter-organizational service inter-dependency [Mulira 2007]; and logistic service delivery [Muniafu 2007]. Muniafu [2007], handled a complex situation of matching supply and demand transport scheduling services in a rural transition country that is South Africa. His aim was to get a solution to conflicting interests of transportation parties using ICT services. Mulira [2007], was able to come up with a studio that supported inter-organizational service systems in volatile contexts. The study was in Uganda handling collaboration within three universities that is Makerere University, Kyambogo University and Uganda Martyrs University Nkozi. The studio was used to enhance decision making within the inter-organizational service systems, among independent actors with divers technical infrastructure and scarce resources. In order to enhance mining SME start-up decision processes, in this research a decision enhancement studio will be developed using the studio based approach following [Keen and Sol 2008]. A set of services delivered with suites that are deployed in a decision process will be developed within the studio for mining enterprise start-ups.

Research Approach

Research strategy
This research was inductive in nature as it derived its problem from the community, abstracted and synthesized it with an aim of understanding contextual issues that cause mining SMES to collapse within the start-up phase. According to Trochim [2007] an inductive hypothetical strategy is suitable for synthesis, multi-disciplinary, attempt, to integrate scientific, ethical and esthetic modes of thought. In addition, it is regarded as a
bottom-up approach in conducting multi-disciplinary research. This approach is suitable when dealing with ill-structured problems or when seeking to define problems.

The inductive hypothetical research strategy consists of five steps namely initiation, abstraction, theory formulation, implementation and evaluation as explained below [Trochim 2007; Sol 1982]. The initiation stage involves gathering information from mining SME owners and managers on the operational, administrative decision issues involved at start-up. The second step involved abstracting the essential aspects. Here, the challenges faced by the miners were analyzed to get the key issues. Requirements were then derived from literature and the challenges. Based on the requirements, the essential components were classified to get their interactions in the global design stage in the theory formulation stage. A studio instantiation comprising a prototype and sets of guidelines from the design will be developed in the implementation phase. This will then be taken back to context for testing and validation in the final phase.

Research Philosophy
In order to design a generic framework for improving the decision process of starting a mining SME, we followed the design science research philosophy. This method consists of three cycles namely: the relevance, design and rigor cycles [Hevner and Chatterjee 2010; Herver 2007]. We chose this method because it aims at handling ill-structured problems by producing artefacts that contribute to the body of knowledge and are relevant to the community [Carlsson 2006; Hevner 2007; Winter 2008]. In this research, design science was used to emphasize the relationships between the environment, existing knowledge base and our research project. A review of theories, methods, practices in mining SME start-ups and information systems was done with an aim of positioning our research. This was done and referenced in the introduction section to ensure innovation and novelty. In the relevance cycle, we explored multiple case studies [Yin 2003] to gain an in-depth understanding of the mining challenges that cause them to collapse. Secondly, the exploratory study was used to identify user requirements for the proposed solution based on the challenges faced by mining enterprise managers.

In the design cycle, the build and evaluate loop, a decision enhancement studio was designed and an artefact will be developed in an iterative way [Hevner 2007; Hevner et al. 2004]. This paper contains the first and second steps in this cycle as to be discussed in section 4. These comprise the artefact that will be deployed together with a prototype to the mining enterprise owners/managers during the testing and validation stage.

Studio design

Requirements of the studio

Challenges and decision needs for mining SME start-ups in Uganda
Seven challenges that mining SME entrepreneurs encounter in the decision process of starting a mining enterprise in Uganda were found, based on an exploratory study. This involved focus group discussions and interview sessions with a total of
ninety (90) mining SME stakeholders from various mining regions of Uganda. These include mining entrepreneurs, mining consultants, mining representatives from the Department of Geology Survey and Mines (DGSM) and potential miners. Documents from government and a countrywide mining workshop added more insights to the regional and major problems faced by miners with potential solutions. Interviews and Focus Group Discussions (FDGs) were used to collect opinions and experiences from the mining entrepreneurs, consultants, DGSM representatives and potential miners concerning decision-making problems in starting a mining enterprise. Interviews were useful in discussing and clarifying issues and doubts. We collected data from four regions in Uganda: Kampala (central), Mbarara (south), Kasese (western) and Gulu (northern). These were selected because they are in the main rift valley wings with lots of mining activities in Uganda.

Based on information from the exploratory study, several needs for the mining SME start-up process were formulated and they were: limited accessibility to information about mineral distribution, lack information on the alternative methods of land ownership, limited access to regulatory and licensing information, difficulty in developing a mining plan as a prerequisite in the legalization process, increased costs as a result of middlemen, limited support for cost benefit analysis and return on investment projections or forecasting, and no interaction with the service providers. These are explained further below.

i. **Limited accessibility to information about mineral distribution**
The miners face challenges of identifying mineral deposits. In cases where decisions have been made on mineral locations, the miners have inadequate information on the quality and quantity of the remaining ore available for exploration, thus the need for stakeholder involvement in directed decision-making on alternative mineral distribution, their quality and quantity.

ii. **Lack of information on the alternative methods of land ownership**
The miners lack information on alternative methods of land possession and costs involved. This affects their decision-making process thus the need for a structured way on disseminating these procedures for improved decision-making when applied correctly. Currently the alternatives known of land ownership is by joint venture with the land owners.

iii. **There is limited access to regulatory and licensing information**
The miners have limited information about where they can acquire licenses more quickly and cheaply due to the bureaucratic procedures involved. There is too much bureaucracy involved in acquiring a mining license. There is no cheap way one can acquire a license directly. The miners attribute their failure to acquire licenses to their distance to the mining headquarters as being far and expensive.
iv. There is difficulty in developing a mining plan as a prerequisite in the legalization process

This is a requirement in getting the mining license. As one of the prerequisites in getting the licensing, a mining plan is needed and the miners need a guide in developing one. The miners have limited information in coming up with a mining plan. This involves plans on production, marketing, and mining method alternatives, therefore, the need for stakeholders to enable decision-making processes when coming up with the mining plan.

vi. Increased costs as a result of middlemen

The miners incur losses as a result of middlemen since they do not have direct contacts with their customers. They have to use middle men or brokers to help out which causes them to get less profit from their products. The operation of these middle men is done in a chain of dealers who also link up with other dealers making a complex chain of dealers. The dealers sometimes fail to remit the money to the miners with worst cases being that of running away with money obtained from customers after making deals with miners. There is a need to get direct access to the customers in a transparent manner hence eliminating the middleman’s role.

vii. Limited support for Cost Benefit Analysis (CBA) and Return On Investment (ROI) projections or forecasting

The mining business is capital intensive and needs huge sums of money which miners usually get from loaning facilities like banks and micro-finance schemes. As time goes by with the mining business and capital intensive mining operational activities, they face problems of paying the loan and systematically counting the expenses in relation to the profits from a mining activity. Hence there is a need for guided procedures, blend stakeholders using appropriate tools and techniques to handle this issue.

viii. There is no interaction between the miners and the service providers

On various issues of concern like request for information, suggestions, complaints, follow-up and contacts. In order to have the miners survive in the mining enterprise field, it is necessary to get a cheap and effective way of interaction between the miners and the service providers.

The above shows that overall a need for a solution that enables mining SME collaboration, coordination, and service sharing as well as for generation and analysis of decisions alternatives clearly exists for mining SME start-ups in Uganda, confirming that the deployment of a decision enhancement studio is a suitable solution to this end.

Theoretical reflection on the findings

Based on the findings and the observations made through the exploratory case study and presented in this chapter, we learnt that it is very challenging to develop mining enterprise
start-up services in rural areas of Uganda especially because of the environmental and technological constraints. The objective of this research is to use the decision enhanced services to support and improve mining enterprise start-up services.

The information on mining enterprises in rural areas is limited or non-existent. The SMEs operate with cash constraints and operate in business environments characterized by fragmented, incomplete and inconsistent information regarding start-up services. The mining SMEs cannot afford information systems to help them compete favourably with the large mining enterprises. Thus it is noted that to develop start-up services, they should not put financial constraints on the managers. It is therefore important to note that the start-up services are best to be developed at the mining knowledge service centers within the infrastructure and attendance of the staff of the Department of Geology Survey and Miners to improve on their support to start-up miners. This contributes to the relevance of the research objective and the need to provide support for the development of mining enterprise services.

**Flexibility:** According to Muniafu [2007], services for rural enterprise managers should be flexible and reusable. The SMEs in the rural areas we studied had unique problems of information needs thus developing start-up services is challenging since they need to be flexible and reusable to suit the activities identified in the exploratory study, thus the need to develop services for each of the mentioned activities. Simon [1977] suggests that this hierarchy (inflexibility) creates costs for example in the form of communication, and motivation towards achieving a goal.

These information quality services include information on mineral distribution to handle the limited accessibility to such information, alternatives to cater for lack of information on the alternative methods of land ownership, regulatory information to cater for limited access to regulatory and licensing information, a mining plan, middlemen intermediation to reduce costs as a result of middlemen, finances to cater for limited support for cost benefit analysis and return on investment projections or forecasting and communication services to handle interaction with the service providers. According to Gonzalez, [2010] Information quality has the following attributes: accuracy [Kontogiannis 1996], timeliness [Atoji et al., 2000], relevance [Adam et al. 2007] quantity [Atoji et al, 2000], completeness [UBOS 2007], format [Jenvald et al, 2001], security [Kim et al, 2007] and consistency [Fisher and Kingma 2001].

**Un-fragmented services:** The review of literature reveals that the major entities involved in decision processes i.e. people, process and technology are often in isolation and treated as separate segments. Usually the people that matter are left out and the process is left to experts [Heuberger 2005]. There is need for stakeholder participation in making start-up decisions. Therefore the services to be developed will consider un-fragmentation as an important issue. This will improve the kind of decisions being made, by creating consensus and uniformity of ideas. Lack of un-isolated services cases the decision makers and stakeholders involve remain un-contented and grambling over
their opinions. In order to view the enterprise as a whole it is important to consider unfragmented workable practical solutions when starting a mining enterprise.

These are classified in four categories: land acquisition, regulations, pricing and communication. This suggests that mining start-ups will be achieved if these issues will be considered and manipulated in favour of the miner. In this section we compare our results against the existing literature. This helps to identify and explain any relevant similarities and or variations from the existing body of knowledge.

Land acquisition issues suggest that miners will be more likely to start-up if they possess land with their desired mineral of interest. In land acquisition, there is a collective result of miners effort in 1) identifying a mineral of interest 2) ensuring alternative nearest resources are known 3) ensuring adequacy of mineral deposit 4) ensuring the quality of the ore in relation to the customers need 5) inquiring from experts on the ore grade and 6) availability of funding. Miners will unlikely collapse at start-up if they acquire land with their desired mineral of interest.

The regulatory category involves the miner formalizing their business with the basic required governmental bodies. These include: 1) registering the enterprise with the registry of companies - Memorandum of Understanding (MOU) and Articles of Association (AOA), Uganda Revenue Authority (URA) for Tax payers Identification Number (TIN) for both the enterprise and individual 2) ensuring that Environmental Impact Assessment (EIA) is carried out with National Environmental Management Authority (NEMA), acquiring a mining license (Prospective Licence (PL), an Exclusive Prospective Licence (EPL) renewable, a Mining Lease (ML) and Mineral Dealers License (MDL)).

We found in the literature, various factors pointing to the importance of the identified issue on land acquisition at enterprise level [Hilson and Banchirigah 2009]. We acknowledge the value of these contributions to enterprise start-up land acquisition implementation. Our results differ from them in one important way, enterprise managers involved in the start-up phase do not have a check-list of factors to help them decide to start or not to start a mining enterprise initiative and also an integration of technology to show the location of various areas with the same mineral, and the involvement of stakeholders at each step. Instead their start-up decisions are influenced by the extent to which an entrepreneur has information. Specifically they mainly use experience and word of mouth on the location of minerals from the indigenous people in the area.

Issues related to regulatory policies literature reveals the need for regulations as mentioned by [Nabukenya 2008; Siegel and Veiga 2009; Hilson and Banchirigah 2009]. However, we differ in the sense that we suggest an interactive environment where the regulatory forms are easily downloaded and explanations and communication from the stakeholders on their importance given and the use of the exact form as what stage. We also differ in a way that we provide a check list of how to achieve each of the important regulatory steps needed for legalization. This can help in decision making by the entrepreneur at start-up.
Considering the pricing and financial strategies [Kazooba 2006; Zavatta 2008] emphasize that such practices are important and we acknowledge their contribution. However, we suggest a checklist of issues to consider in carrying out the financial analysis and pricing comparison to bridge the demand and supply gap. In addition, these issues are looked at in a discrete way which we differ by suggesting a blend of technology, stakeholder involvement and processes. To blend the three identified issues mentioned above, the communication issue is important in a way that the available means are discrete in nature not considering the mix of ICT, methods and stakeholders which we propose as the way forward.

The categorization of service issues presented above is not new, however this approach is similar to that used by [Kunene 2008]. They look at the process partially with emphasis on training as the major component. Our findings further the existing propositions by suggesting generic issues such as usefulness and convenience to access of start-up information with interaction from technology with experts. In addition, the local language is an important issue to consider in the effective reach of miners in the rural areas of Uganda. These languages may include Luganda, Swahili, and Runyakitara as the major spoken languages in Uganda.

Requirements
The theoretical basis of the requirements of the studio developed is this research is derived from the work of [Keen and Sol 2008].

Requirement 1: The studio should allow for start-up request and response services. The studio should contain services that facilitate collecting the details of the service requests and responses from the end user. The studio should provide for a means of categorizing the services according to the similarity of functional services like land acquisition to handle land issues and pricing to cater for pricing and financial analysis services. The request for information in the studio should be considered to enable particular services of interest. Due to the bandwidth problems, it is important to cater for services that need limited bandwidth by providing distributed systems on the local networks that get updated frequently. The stakeholders should be involved from the inception of the start-up initiative and actively involved in the decision-making processes. This is important for consensus and agreement of particular start-up decisions like those concerning issues of land ownership or financial commitment to a particular mineral of interest. The studio should also contain video-conferencing or interactive chatting and discussion virtual environments for stakeholder to meet based on location independence [Glushko 2010]. Literature from Uganda Communication Commission (UCC) report shows that there is an estimated mobile telephone subscription of 13.2 million people in Uganda with an estimated 24.9 million by 2015 [UCC 2011].

Requirement 2: The studio should support distributed and dynamic selection of mining enterprise start-up services.
The studio should be developed on platform and browser independent systems, allowing for flexible and adaptive services. The sets of services in the studio should facilitate creation of services definitions, and modification of services [Muniafu and Van de Kar 2008; Muniafu 2007]. Considering situations where the infrastructure is low, getting feedback may take a long time considering the urgency of the request. The need for decentralized architecture for different locations would be a solution to the centralized kind of system architecture. This will reduce on the service inefficiency.

**Requirement 3**: The studio should facilitate effective combination of service components.

The studio should contain middleware services that blend the different services provided in each of the tools in the studio. The studio should contain middleware that reduces the infrastructure problems and effectively combine the service components. The studio should provide for means of creating value added services for the basic survival of the users and service providers based on the environment. The components should have been tested and free of bugs [Franke and von Hippel 2003; Muniafu and Van der Kar 2008].

**Requirement 4**: The studio should support flexible and adaptive value added services.

The studio should be able to contain services that can be used to identify the start-up service needed from the service provider in a flexible manner. The services should enable the knowledge center managers to enter new services, and update the existing ones whenever necessary. This could apply to entering land availability details, mineral prices and any other regulatory services that are needed to add value to a start-up mining entrepreneur.

**Requirement 5**: The studio should provide a solution space (graphical user interface) for the services.

The studio should contain services that provided on a front end tool, with an easy to use graphical user interface to enable service providers to manually enter new details necessary for a start-up mining entrepreneurs. It should also allow the users to access the services necessary for mining enterprise start-up. Glushko [2010] suggests that an interface allows the service provider and service consumer to exchange requests and responses services.

**Requirement 6**: The studio should facilitate effective means of communication among the different actors involved in the organizational architecture such as with partners offering mining start-up services in order to achieve competitive advantage.

The studio should contain services that enable the knowledge service center managers to adapt mining enterprise start-up services to suite the users and connect to partners in the stakeholder organizations that provide start-up services like company registration (URA), environmental issues (NEMA) and standards (UNBS). These should be in a transparent and flexible way on mutual agreement of the different ministries.
and organization departments. Given the complexity of the multiple services from the actors, it is important for the knowledge service manager to remain focused on the start-up service delivery [Papazoglou and Van de Heuvel 2006].

**Requirement 7:** The studio should provide guidelines for using the studio

The studio must be accompanied by practical and usable sets of guidelines that facilitate the knowledge service center managers, and the users to follow up on the various services. These could be in form of user manuals attached to every suite showing how to use each of the suites in the studio. These should be available to provide support to enable easy navigation and to cater for the expectations of the users.

**Requirement 8:** The studio should be user friendly

The users should be able to operate it using their existing skills and customary design languages [Franke and von Hippel 2003; Muniafu and Van der Kar 2008].

**Studio design**

Based on the requirements and information from the exploratory study, a mining SME start-up design was derived. This diagram below presents a design of the decision enhancement studio for mining SME start-ups. Considering the requirements and the literature reviewed above, we propose a decision enhancement studio consisting of four suites that provide the required functionality. These are the (i) Land acquisition suite (ii) Regulatory suite (iii) pricing suite and (iv) Communication suite as illustrated in figure 1 below. Figure 1 shows the design process design in which the following services are deployed: landscaping, facilitation, recipes, suites and process [Keen and Sol, 2008]

- **Landscaping:** It involves the definition of the decision context in this research which is enhancing mining small and medium enterprise start-ups in Uganda. This involves understanding the decision issues, decision makers, information resources, and the basics to model the mining SME start-up process. These include the four major suites in figure 1.

- **Facilitation:** Here, behavioural knowledge and process skills are major. The role of the facilitator is important in the process of decision enhancement. This involved the assembling of stakeholders coupled with an agenda and followed through a start-up process. In this stage, initiating the guidelines is carried out to ensure that the team supporting the studio participants was alert.

- **Suites:** The tools are to be designed and implemented within a distributed architecture. The aim is to get the prototype easy to access, from any location by making use of the Internet. The appropriate tools were used to provide the services needed during the enterprise start-up process.

- **Recipes:** Recipes are proven, repeatable and transferable specific ingredients and sequencing permit variations and innovations. In this study, we came up with guidelines that were derived as systematic, to the mining enterprise start-up process. These were carefully chosen in line with the government
regulatory body and the mining enterprises coupled with literature and creativity.

- **Decision process**: This involves making a commitment to a decision, the explicit target and agenda.

The *land acquisition* suite is responsible for enabling identification of mineral distribution by giving information to start-up miners on alternative mineral deposit locations during the land acquisition process. This suite also avails alternative methods of land ownership by giving information to the start-up miners on the processes involved such as costs involved and access to the required forms in a timely way hence improving their strategy in land ownership.

The *regulatory* suite enables access to regulatory and licensing information by giving information to the start-up miners on the relevant documents for the start-up phase. It also provides support in the development of a mining plan through giving the miners an improved approach of coming up with a mining plan.

*The pricing and financial analysis suite* provides direct linkage of suppliers to consumers by giving the start-up miner a beginning point for price estimation of their product that will in turn be a source of revenue for the business and thus the financial analysis decisions improvement. It also supports Cost Benefit Analysis (CBA) and Return On Investment (ROI) for projections and forecasts by giving information on investment decision-making. In addition, this suite also provides functionality to link the mining entrepreneurs directly with the customers thereby eliminating the middleman’s role.

The communication suite provides a means to support communication between miners (problem owners) and service providers (problem solvers) by using tools to bridge the gap between the two parties.
Conclusion and future work

In summary, this research aims to enhance mining SME start-up decision process with the design of a decision enhancement studio in Uganda rural areas. Based on a list of requirements, this paper presents a design of the decision enhancement studio for mining small and medium enterprise start-up decision process that consists of a set of services that are delivered in a decision process in which the four suites are deployed. Following the iterative “build and evaluate” of design science, future research will be dedicated to the implementation, refinement and evaluation of the design into a plausible solution space for the decision enhancement studio for mining small and medium enterprise start-up decision process presented in this paper. The evaluation of the solution will be based on the work of [Hevner and Chatterjee 2010].
References


This paper presents preliminary findings from a project aimed at improving the quality of training and producing a critical mass of competent secondary school Mathematics and Science (Biology, Chemistry, Physics, Sports Science and Information and Communications Technology, ICT) teachers by expanding access to training through the Open, Distance and e-Learning (ODeL) mode supported by Information and Communication Technologies (ICTs). The project is an innovative one, currently being implemented by Kyambogo University under the Millennium Science Initiative (MSI) in Uganda. A Methodological Information and Communication Technologies (ICTs) Teaching Approach (MICTTA) has been developed to help demystify the perception that teaching Mathematics and Science subjects is hard. This approach involves several stakeholders who have been tasked to undertake several activities either in parallel or sequentially. It involves four main activities: Infrastructure Establishment, Content Development & Review, Content Delivery and Community Outreach. The project has already realized outcomes from the activities implemented which demonstrate that the methodological approach being proposed is effective. The overall success of the project will be evaluated against its aims at the conclusion of the project and will be reported on in a future paper.
Introduction

Over the last five years, Uganda has registered a high increase in the number of students at the secondary education level [USE Headcount Report, 2009]. This can generally be attributed to the recent introduction of free education at both the primary and secondary school levels by the Ugandan government. Although this initiative has created access to educational resources for the masses, it has also created resource constraints in most schools. There is a growing lack of interest and poor performance in Mathematics and Science within the primary and secondary schools as reflected by the national examinations conducted by the Uganda National Examinations Board, UNEB [UNEB, 2009]. This phenomenon is attributed to several factors that are directly impacting on both the teachers and students. The current shortage of Mathematics and Science teachers in secondary schools is one such factor and is attributed to lack of adequate and well trained motivated staff. These staff have limited knowledge and skills in using ICTs to teach Mathematics and Science.

The lack of ICT knowledge and skills may arise from their initial training but is also a result of a widespread lack of computers and internet connectivity in the schools [Opolot-Okurut et al. 2008]. The related poor performance in Mathematics and Science in secondary schools has led to low enrolment of Mathematics and Science students at universities and other tertiary level teacher training institutions. An average of about 15% of students in all of Uganda’s tertiary institutions take science based courses [Ouma, 2003].

Research has also shown that inefficiency and ineffectiveness in learning is created whenever there is an abrupt influx of students in any learning environment and if the method of teaching is indigested [Adelman & Taylor, 2000]. Such symptoms usually affect the performance of such recipients and it also creates a negative impression on the knowledge domain under examination [Dickson & Bruce, 2004]. This is true when it comes to the increased enrolments of students in secondary schools and the growing lack of adequate staff to teach Mathematics and Science in Uganda. Improving teaching methods for Mathematics and Science subjects at the secondary school level can go a long way in addressing this intriguing phenomenon that is engulfing Uganda. The Association for Development of Education in Africa [ADEA, 2002] has indicated that ICT represents a learning channel with the potential to enormously improve the quality of basic education teaching. World Bank [2002] also notes that there is lack of ICT research in Africa in the areas of effective educational uses and potential impacts on the quality of African education.

The Open, Distance and e-Learning (ODeL) project at Kyambogo University in Uganda is trying to address the intriguing phenomenon by undertaking ICT based
approaches in demystifying the perception that teaching Mathematics and Science is hard. This ODeL research project arose out of the need to increase the enrolment for graduate Mathematics and Science (Biology, Chemistry, Physics, Sports Science and ICT) teachers at Kyambogo University. Advancement in learning technologies has made significant impact and improvements on the conditions of distance learning. Today ICT use is more widespread in the provision of services than ever before. Several higher institutions of learning have developed programs and specifications for integration of ICT in teaching and learning [British Education Communications and Technology Agency, BECTA, 2005]. The integration or use of electronic means for both teaching and learning is termed as e-learning. The purpose of this paper is to share preliminary findings from the ODeL project currently being implemented by Kyambogo University under the Millennium Science Initiative (MSI).

Situational Overview – Odel Project at Kyambogo University

The overall aim of the project is to improve on the quality of training and produce a critical mass of competent Mathematics and Science teachers by expanding access to training through the ODeL mode supported by Information and Communication Technologies (ICTs). This aim can only be achieved through the increased integration of ICT innovations in content development, content delivery and community outreach activities for the various stakeholders. The teachers who enroll for the Bachelor of Education Degree (BEd) program under the project are Grade V (Diploma) teachers qualified to teach Mathematics and Science only at lower secondary school level. At the inception of the project, it was anticipated that a total of 120 teachers would be enrolled each year. So far, there have been three enrollments with a total of 210 teachers as in Table 1. This enrollment has increased access to training for the science-based BEd by 44%.

Table1: Student Enrollment in the Faculty of Science for the Bachelor of Education (BEd) degree.

<table>
<thead>
<tr>
<th></th>
<th>2008-2009</th>
<th>2009-2010</th>
<th>2010-2011</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>ODeL mode</td>
<td>100</td>
<td>12</td>
<td>47</td>
<td>8</td>
</tr>
<tr>
<td>Conventional mode</td>
<td>94</td>
<td>17</td>
<td>79</td>
<td>17</td>
</tr>
</tbody>
</table>
The project’s mandate is to develop effective approaches for equipping Mathematics and Science teachers with the knowledge on how to best teach these subjects using ICT. Once the mandate is fulfilled, the following will be achieved too; improved quality of training and competence of Mathematics and Science secondary school teachers who will participate in the project, increased enrolment of Mathematics and Science teachers that will be achieved by expanding access to training through the ODeL initiative (See Table 1), teachers equipped with skills on how to integrate ICT in teaching and learning, and a sensitized community on how ICT can improve teaching and learning.

The online education being used in the project is a blended approach that combines both traditional and electronic means of teaching and learning. Typically, it involves the use of the internet to access learning materials, interact with the content, the instructor and other learners; and obtain support during the learning process in order to acquire knowledge, to construct personal meaning and to grow from the learning experience as reported by Ally, [2004]. The project activities include an annual Science week that has sensitization and training outreach activities for Mathematics and Science teachers, students, parents and the community at large. This is meant to enlighten people about the usefulness of ICT in the teaching and learning of Mathematics and Science. This outreach activity among others, aims at demystifying the perception that Mathematics and Science subjects are hard to teach and learn.

**A Methodological Information and Communication Technologies (ICTs) Teaching Approach (MiCTTA)**

The project has developed a Methodological Information and Communication Technologies (ICTs) Teaching Approach (MiCTTA) to help in demystifying the norm that teaching Mathematics and Science subjects is hard. This approach involves several stakeholders who have been tasked to undertake several activities either in parallel or sequentially. It involves four main activities: Infrastructure establishment, Content development & Review, Content delivery and Community Outreach. After the infrastructure had been established, the multi-media content developments laboratories set up at Kyambogo University are used for the content development and review process. The content will be packaged for delivery to the students through the Moodle e-Learning Management System. As a way of creating awareness about the project activities and attracting more teachers on to the program, the teachers who are not enrolled on the course are expected to benefit from the output of the project during the community outreach activities. The four activities are illustrated in Figure 1 and each one is explained as follows.
Infrastructure Establishment

During this activity of, identification of the target teacher trainee groups is done and then there is selection of a regional coordinating Upcountry Centre within which to help in directly handling the training, do community outreach and have an access point for the study materials. An Upcountry Centre is a place within one of the teaching institutions in a region that has minimal requirements for handling ICT based teaching and learning. Each of these centers has an established computer laboratory which can be accessed by the students within the region. ODeL’s mandate is to make sure that the established infrastructure adheres to the minimal standards required for an effective ICT teaching environment. ODeL provides internet connection to the Upcountry Centers. The purpose of this is to create a conducive learning environment for the students when they are not at Kyambogo University. Five upcountry coordinating centers have been set up in the different regions of Uganda: Gulu (Northern), Bushenyi (Western), Mukujju (Eastern), Fort Portal (Southern) and Arua (North Western) whereas Kyambogo University acts as the center for the Central region.

The other part of infrastructure establishment involves setting up content development labs at Kyambogo University to be used during the content development process. The project relies greatly on the developed content and therefore effective content is pertinent. The process of also establishing other hardware to be utilized by the ODeL staff is inevitable within this activity.

Content Development and Review

In this activity, a team of lecturers that is competent in using ICT to develop Mathematics or Science content at University level is established. The content development approach
being used is one that results in products that will help learners synthesize information, analyze it and become problem solvers. The design of the contents is based on the Reusable Learning Object (RLO) Concept advanced by Wiley, [2000]. The RLO concept enables the team to configure content to suit individual learners. Thus, learners can request for this personalized content which is dependent on their learning styles [Keefe, 1979; Kolb, 1981].

The content developed is rich in nature in that it has lots of multi-media illustrations in both Mathematics and Science concepts. The multi-media used are in the form of video files, images, voice files, simulations and experiments. After the content development process has been accomplished, the developed content is passed over to two independent reviewers who assess it for its richness and effectiveness in teaching Mathematics and Science. Once the reviewers are satisfied, the content is ready for dissemination to the students.

Content Delivery
This activity involves packaging the content and delivering it in the best way possible to the students. In ODeL, two ways of content packaging, namely the Moodle Learning management System and CD ROMs are used. The Moodle e-learning environment is used to deliver all the content that is developed through the internet. This is to help the students do their learning ubiquitously irrespective of their location. The CD ROMs are used by students who have no access to the internet. Both packaging methods contain the same content depending on the learning level. However, the Moodle e-learning platform is more effective because it allows the learners participate in other interactive activities such as discussion boards.

Community Outreach
This particular activity is meant to sensitize the public about the usefulness of ICT in teaching Mathematics and Science. A National Science Week is organized annually by Uganda National Council of Science and Technology (UNCST) to help the public appreciate the pivotal role of Science and technology in the economic and social transformation of Uganda. It is also a week to reflect on the scientific and technological achievements and assess overall progress towards strengthening Uganda’s Science and technology capability. ODeL project team has participated in the last two consecutive National Science Weeks in 2009 and 2010. Through the Science Week, the community in attendance is taken through illustrations on how very hard concepts of Mathematics and Science can be easily explained through the use of ICT innovations. During the Science Week in Gulu in September 2010, the ODeL staff teamed with the trained custodians of the Upcountry Center and provided the students and teachers opportunities to experience live classroom sessions in either Mathematics or Science where they interacted with the content (See Figure 2).
In an outreach activity in Mbale, Eastern Uganda in November 2010, 186 teachers attended. The ODeL team was able to guide the teachers on how ICTs can be used to ease the teaching of Mathematics and Science. A number of virtual experiments and simulations were used to demonstrate the teaching of several topics in Mathematics and Science. The team explicitly demonstrated to the teachers the usefulness and ease of obtaining extra learning and teaching materials from Microsoft Encarta and EDUBUNTU.

The community outreach activities in Gulu and Mbale were also used to identify those hard concepts in Mathematics and Science that need to be demystified using ICT innovations. This was done by administering questionnaires to the participating teachers. The information from the questionnaires helped the ODeL Team to ensure that during the subsequent community outreach visits, the mentioned hard concepts are demystified through the use of innovative multi-media approaches. During both outreach activities, the developed content was given out freely to the participants. This is expected to help the teachers in demystifying the community’s perception about Mathematics and Science.
Odel Outcomes

The ODeL project has implemented the developed approach through the help of the Millennium Science Initiative funding that was won by the project team. The project has already realized outcomes from the activities implemented which demonstrate that the methodological approach being proposed is effective.

There has been an increased enrollment by 210 students in three years within the Bachelor of Education (BEd) program as a result of the introduction of the ODeL approach. Due to a scholarship scheme for females within the project, there has been an increased enrollment for females studying Mathematics and Science by 38%. Therefore the project has gone a long way in trying to encourage teachers with a Grade V Diploma to train as graduate Mathematics and Science teachers thereby increasing their numbers.

- There is increased access to and improved quality of Mathematics and Science teacher education through the established mode of delivery. The courses previously delivered through the conventional, traditional face – to – face mode of teaching/learning are now supported by the use of ICT at the six (6) regional coordinating centers. The centers have been equipped to support the activities of the program like practical work, internet access, and distribution of print material and CD ROMs. They also act as community outreach centers. The face – to – face support is organized at specified times during the year to coincide with school holidays.

- The established community outreach activities have helped to sensitize communities within the different regions of Uganda about the use of ICT in teaching Mathematics and Science. During the Science weeks, demonstrations and presentations were made to the public on how ICT can be used to demystify the norm that Mathematics and Science are hard to teach.

- Free content for both Mathematics and Science teaching has been developed by the ODeL team. Instruction that is rich in multi-media has been included for example simulations, videos, audios and images. The content has been packaged for both online delivery through the Moodle e-learning platform and the CD ROMS. Therefore the students can access the content irrespective of the location. Some of the content developed is illustrated in Fig.3, Fig. 5 and Fig. 6.

Mathematics: The Mathematics team has developed online content for the various course units including Elements of Mathematics cited in Figure 3.
Biology: During the outreach activities in Gulu and Mbale, the Biology team made presentations of the respiratory, digestive, reproductive, circulatory and excretory systems of the human body. Informative simulations of the various processes that occur in the systems were presented. In addition, online content on microarray experiments has been developed for the gene expressions of two cell populations. For example, in an experiment involving normal cells and cancerous cells, microarray technology determines which genes are expressed (or repressed) in each cell population in order to find which genes are responsible for the abnormal condition. Microarray technology does this in several steps as shown in Fig.4.

Figure 4: Screen shots of DNA microarray animation.
Physics: In Physics, a number of virtual experiments were carried out before the audiences which were heavily composed of school teachers, secondary and primary school pupils and students from technical institutes. Demonstrations on how to vary the experimental conditions of the various virtual experiments and thereafter plot suitable graphs were carried out. These demonstrations included experiments in Waves and Wave Optics, Sound, Atomic Physics, Heat, Electricity and Magnetism and Mechanics. The Waves illustration below has been adopted from the Physics online content.

Figure 5: An excerpt of the Physics online content developed by the ODeL team

Chemistry: The Chemistry team has developed content used to demonstrate and allow teachers to perform online practical experiments. One such experiment is illustrated in Fig. 6. The teachers who attended the outreach activities appreciated the use of ICTs in practical lessons as an alternative method of performing experiments.

Figure 6: Chemistry online content virtual experiment illustrating volumetric analysis
Sports Science: In the outreach activities the Sports Science team presented to teachers the use of ICT in Physical Education teaching and learning in secondary schools. The presentation aimed at helping the teachers to think about the need and how to use ICT facilities available to improve teaching of PE and sports. A fifteen minutes’ discussion followed. Demonstration of use of a computer to measure jumping strength of athletes, collecting and interpreting the data obtained using graphs, use of a digital camera and laptop to capture, and analyze student’s performance in a practical physical activity session, throwing, passing, catching and ball passing skills were used for the demonstration. The teachers were actively involved and excited about the demonstrations and called for longer time to be given next time.

Discussion and Conclusion
One of the aims of the ODeL research project was to increase the enrolment of undergraduate Mathematics and Science teachers at Kyambogo University in Uganda. This objective has been achieved with a 44% increment in BEd student enrolment in the Faculty of Science. These students have benefitted from the use of the Moodle e-learning environment to interact with the content through the internet while CD ROMs have been provided to students who may have no access to internet connectivity. Thus, as Broadbent [2002] appreciates, e-learning has enabled pre-packaging of essential information for all the students to access through the Moodle Learning Management System. According to Cole [2000], such online learning allows for flexibility of access from anywhere, at any time and at the learner’s wish. The students enrolled with the project have been able to continue working, and staying together with their families.

A total of 210 Grade Five teachers have enrolled onto the ODeL mode of training. The introduced scholarship scheme for females within the project has increased enrollment for females studying to become graduate teachers of Mathematics and Science. Twesigye [2007] concurs that the shortage of Mathematics and Science teachers who need further professional training as they continue in their employment may be alleviated through ODeL as it provides a wider access to university education.

With increased access to Mathematics and Science teacher education through ODeL, courses previously delivered only through the conventional face – to – face mode are now supported by use of ICT at six regional coordinating centers. The centers have been equipped to support the activities of the program like practical work, internet access, distribution of print material and CD ROMs. They also act as community outreach centers. The students attend face – to – face support which is organized during the school holidays. The introduction of the ODeL mode of training mathematics and science teachers will increase Kyambogo University’s annual output of well trained teachers which will in turn lead to increased production of well trained scientists, technicians, technologists and engineers that Uganda needs for its industrialization, socio-economic development, environmental sustainability as well as health and food security.
The National Science Weeks on the other hand demonstrate to the public the pivotal role of science and technology in the economic and social transformation of Uganda. It is also time to reflect on the scientific and technological achievements and assess overall progress towards strengthening Uganda’s Science and technology capability. The community outreach activities have through the use of innovative multimedia approaches, equipped teachers and students with the necessary skills to become change agents and demystify the notion that Mathematics and the Sciences are hard to teach and learn. This has also encouraged more students to do mathematics and the sciences. The outreach activities further provide opportunities of informal networking where teachers, students, school administrators, education officials and communities surrounding the schools share their experiences, ideas and new information.

For the government and Ministry of Education and Sports in Uganda, achievement of Education for All goals of Universal Primary Education (UPE) by 2015 and the introduction of Universal Secondary Education (USE) requires that the education system attracts, educates and retains a sufficient number of well qualified teachers. MICTTA has been developed to help demystify the perception that teaching Mathematics and Science is hard. It presents an important strategy for improving the quality of training as well as equipping secondary Mathematics and Science teachers with ICT skills for use in technology supported teaching/learning environments.

Acknowledgements

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References


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The grid as a Driving Force for E-learning and OERs

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Abstract

The advent of grid and cloud computing is slowly reshaping the learning ecology from individual learning to collaborative learning via Internet, resulting in new e-pedagogy. Introduction of GRID technology in institutions of higher Learning in the recent times is bound to bring realignment in conceptual and technical aspects of electronic learning. The model of Learning GRID and group modeling is being extended toward knowledge GRID, GRID Intelligence, and distributed artificial intelligence for effective knowledge communication, building and management. We investigate the role of grid computing as a driving force for e-learning and open educational resources in Africa for the development of the knowledge community in the learning space, within the educational context. In this paper, we also attempt to survey Africa’s effort in developing internet connectivity infrastructure, grid technology and discuss the various grid projects, emerging trends, future prospects and the potential for the said technology in facilitating e-learning as well as development and delivery of OERs.

Key words: e-pedagogy; e-learning; grid computing; knowledge society; open educational resources (OERs);

Introduction

The demand for education in Africa has skyrocketed in the recent times overstretching the facilities available in Higher Education Institutions (HEIs). While this situation can be remedied by embracing e-learning, e-learning systems are resource intensive and
there are numerous educational institutions that cannot afford the high investments required in terms of hardware and software. However e-learning paradigms can leverage the various grid projects currently being funded by donors such as European Union, UNESCO and HP to offer quality education and collaborative research [Karume and Omieno 2010] while at the same time saving on cost.

At the same time, open content in education and learning has increasingly gained attention in recent years. Its importance has been acknowledged by stakeholder organizations, and recent international initiatives are fostering the creation and sharing of such resources. However the investments made in ICT-enabled teaching and learning in Africa has not yet brought about the profound changes in educational practices that would better align educational institutions with the requirements of the open knowledge resources. Since grid computing enables sharing of various types of resources including knowledge [Hai Zhuge 2002], the grid initiatives can further be used by researchers and educators to establish a knowledge grid. In view of current development, E-learning paradigm is bound to systematically shift to knowledge management behaviors based on Knowledge Grids operations [Zheng et al. 2003].

Permeation of the sharing notion in the context of computer technology in the modern society has resulted to a consumer empowered and democratic market place. Alongside grid computing, Web 2.0 tools like blogs, Wikis, podcasts and other social networking tools are used so naturally by the younger generation to communicate and to form communities of interest. Unfortunately, these activities happen almost exclusively outside the classroom and thus outside the traditional learning environment. These have created a gap between current educational practices and the online networking and sharing tools. By exploiting the grid initiatives to establish e-learning grids that incorporate social networking tools this gap can be narrowed if not eliminated.

**Objectives**

The objective of this paper is to investigate the status of internet connectivity infrastructure and the various grids computing initiatives in Africa. The paper also explores the need to exploit improved and affordable regional and international connectivity provided by the emerging optical fiber links. The researchers envision a service oriented architecture e-learning platform that is empowered by grid computing as an appropriate solution to education demand and open education resources in Africa. The paper seeks to demonstrate that penetration of grid technology in Africa will provide African HEIs with a grand opportunity to embrace e-learning grids.

**Basic Fundamentals**

In this section we discuss the fundamentals relevant to our study which include grid computing, e-learning and the open education resources.
Grid computing concepts
Grid computing is a term referring to the combination of computer resources from multiple administrative domains to reach a common goal [Ian Foster 2002]. What distinguishes grid computing from conventional high performance computing systems such as cluster computing is that grids tend to be more loosely coupled, heterogeneous, and geographically dispersed. Although a grid can be dedicated to a specialized application, it is more common that a single grid will be used for a variety of different purposes. Grids are often constructed with the aid of general-purpose grid software libraries known as middleware [Wikipedia 2010].

Grid computing uses middleware to coordinate disparate IT resources across a network, allowing them to function as a virtual whole. The goal of a computing grid is to provide users with access to the resources they need, when they need them. Grids address two distinct but related goals: providing remote access to IT assets, and aggregating processing power. The most obvious resource included in a grid is a processor, but grids also encompass sensors, data-storage systems, applications, and bother resources. Grid architecture has a 5-layer basis as depicted in Figure 1.

Figure 1: e-Learning Management System Using Service Oriented Architecture [Mohammed et al. 2010]
1. Fabric Layer constitutes all the shareable resources such as: processors, memories, sensors and actuators.

2. Connectivity Layer constitutes protocols related to communication and authentication.

3. Resource Layer comprises common actions related to network parts such as negotiation, initiation, monitoring, control, accounting and payment.

4. Collective Layer comprises collaborative operations in the shareable resources.

5. Application layer comprises the user applications ported to support specific tasks.

HEIs can develop intranet Grid portals to reap from internal organizational infrastructure and then have a global Grid connectivity. The connection itself is more important [Berman et al. 2003; Adelsberger et al. 2003]. Through the grid portals a user navigates to the portal page, and afterward, the portal presents the appropriate applications that the user may interact with, derived from their identity and the authorization policies. Like this, a virtual organization may be formed.

Grid service-based infrastructure allows academic institutions to enhance e-learning technologies and innovate e-learning experiences through the provision and mutualisation of various services. Grid computing enhances e-learning by providing the following capabilities:

1. Ability to create virtual labs using the power of distributed computers in grid network which is more cost-effective use of a given amount of computer resources.

2. Ability to create a completely customized class for learners using distributed content.

3. Collaboration between education resources, contents and services within grid network [Hall 2003].

E-Learning Systems

Considering that most of current e-learning systems are based on client-server or peer-to-peer model, they have some limitations such as scalability, share ability [Berman et al. 2003], accessibility [Foster and Kesselman 2004], availability, distributed computing and storage. Most e-learning systems consist of 4 parts [Mohammed et al. 2010] namely:

1. Role management.

2. Authoring system.

3. Learning Management System (LMS)

E-learning systems often do not address just a special kind of learner, but may rather be implemented in such a way that a customization of features and appearance to a particular learner’s needs is supported. Learners vary significantly in their prerequisites, their abilities, their goals for approaching a learning system, their pace of learning, their way of learning, and the time (and money) they are able to spend on learning. Thus the target group of learners is normally heterogeneous; e-learning system is ideally able to provide and present content for all these groups. And as such, a learning system ought to integrate a variety of materials, the potential deviation from predefined sequences of actions [Carsati and Dayal 2002], personalization and adaption, and the verification of work and accomplishments.

**Open Educational Resources (OERs)**

Open Educational Resources (OER) comprise content for teaching and learning, software-based tools and services, and licenses that allow open development and reuse of content, tools and services [Thomas 2006]. OER are teaching, learning and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use or re-purposing by others. They include full courses, course materials, modules, textbooks, streaming videos, tests, software, and any other tools, materials or techniques used to support access to knowledge [OERs in Africa].

From a pedagogical perspective, the key aspects of ICT-supported lifelong learning and OER are that self-directed learning is emphasized, and that there is much potential for novel approaches of collaborative knowledge development [Guntram and Schaffert]. Such approaches are more likely to evolve in learning settings other than traditional forms of formal education, which still show few signs of abandoning the teacher-centered paradigm of education. The importance of OER has been acknowledged by many stakeholders including both research and educational organizations in the
creation and sharing of such resources. It stems from the fact that these resources are fundamental to the knowledge society and economy. Open Educational Resources can make a difference in teaching and learning, especially where there is inclusion of images and audio clips.

Participating in creating Open Educational Resources by higher educational institutions focuses on 5 fundamental points of agreement: (1) to share knowledge is a good thing to do (2) educational institutions are often funded through public monies (by governments) and their products should be publicly available, (3) it provides a platform for the institution to showcase what they have and attract new students and funding – and interestingly mirrors the increasing use of online student portfolios as a record of achievement, (4) HEIs could experience increased enrollment, and (5) open sharing will speed up the development of new learning resources, stimulate internal improvement, innovation and reuse and help the institution to keep good records of materials and their internal and external use.

Integration of Grid And E-Learning
E-learning platforms that exploit resources and computing power of Grid infrastructure define the concept of “e-learning Grid”. This is depicted by the figure 3 below.

Figure 3: The scheme and function of learning GRID Technology [Okamoto & Kayama 2004]

Just as the World Wide Web has changed the way that society deals with information, researchers and educators now expect the grid to change the way that they deal with computing resources and, ultimately, how they deal with knowledge. With advanced functionality of e-learning grids, Africa HEIs’ can design a grid-based solution for leveraging learning and reaping from the benefits of grid and e-learning platforms. The e-learning grids can be able to support computational intensive applications such as
complex real-time simulations or photo-realistic visualizations amongst others. Thus, e-learning Grid is positioned to be a one-stop-hub for the growing community of e-learning practitioners [E-Learning Grid 2011].

Web-based learning systems give students the freedom to determine what to study based on each individual student’s learning goals. These systems support students in constructing their own knowledge for solving problems at hand. However, in the absence of instructors, students often need to be supported as they learn in ways that are tailored to suit a specific student. Adaptive web-based learning systems are suited to such situations. In order for an adaptive learning system to be able to provide learning support, it needs to build a model of each individual student and then to use the attribute values for each student as stored in the student model to determining the kind of learning support that is suitable for each student. Examples of such attributes are student knowledge level, learning styles, student errors committed during learning, the student’s program of study, gender and number of programming languages learned by the student of programming. It’s at this point that HEIs can initiate intranet Grids as a potential and viable tool for knowledge creation, sharing and management and especially in the context of open education resources. These tools can in fact result in strengthened e-learning and e-management in these HEIs.

Anatomy of Grid Initiatives and Status of Connectivity In Africa

International grids

International grids cross national boundaries, spanning cultures, languages, technologies and more to create international resources and power global science using global computing [Grid projects, 2010] as depicted in table 1.

Table 1: Taxonomy of international grids by regions/continents

<table>
<thead>
<tr>
<th>Project name</th>
<th>Aim</th>
<th>Continent/Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia-Pacific Grid (APGrid)</td>
<td>Share technologies, resources and knowledge.</td>
<td>Asia-Pacific region: 15 countries</td>
</tr>
<tr>
<td>D4Science grid</td>
<td>create grid-based and data-centric e-infrastructures to support scientific research</td>
<td>Europe</td>
</tr>
<tr>
<td>DEISA</td>
<td>accelerate scientific research</td>
<td>Europe</td>
</tr>
<tr>
<td>EELA</td>
<td>scientific collaboration between Europe and Latin America</td>
<td>Europe and Latin America</td>
</tr>
<tr>
<td>Enabling Grids for E-sciencE (EGEE)</td>
<td>multi-disciplinary grid infrastructure</td>
<td>Europe</td>
</tr>
</tbody>
</table>
Volunteer computing projects

Volunteer computing uses computers belonging to ordinary people or institutions, to create a computing grid that can rival the most powerful supercomputers in the world. Upon joining a volunteer computing project, the researcher or institution concerned agree to donate the idle cycles of their computer to specific research projects. The implication of this is that while a computer is not in use by the owner, someone else is using it for their research. Volunteer computing software uses the leftover computer power to solve calculations, perform simulations and otherwise contribute to some amazing projects. Table 2 below summarizes international volunteer computing projects and their areas of concern [Grid powered projects 2010].

<table>
<thead>
<tr>
<th>Project name</th>
<th>Aim</th>
<th>Continent/Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>European Grid Initiative</td>
<td>Research</td>
<td>Europe</td>
</tr>
<tr>
<td>Design Study(EGI_DS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EUAsiaGrid</td>
<td>e-science</td>
<td>Europe and Asia.</td>
</tr>
<tr>
<td>EU-IndiaGrid</td>
<td>e-science</td>
<td>Europe and India.</td>
</tr>
<tr>
<td>GÉANT</td>
<td>Networking research</td>
<td>Europe</td>
</tr>
<tr>
<td>GridPP</td>
<td>Particle physics research</td>
<td>UK</td>
</tr>
<tr>
<td>LHC Computing Grid</td>
<td>Energy physics research</td>
<td>Worldwide</td>
</tr>
<tr>
<td>NextGRID</td>
<td>research, industry and the ordinary citizen</td>
<td>UK</td>
</tr>
<tr>
<td>NorduGrid</td>
<td>free grid middleware</td>
<td></td>
</tr>
<tr>
<td>Open Grid Forum</td>
<td>distributed computing and grid technologies</td>
<td>Europe</td>
</tr>
<tr>
<td>OGF-Europe</td>
<td>Standardization of grids</td>
<td>Europe</td>
</tr>
<tr>
<td>Open Science Grid</td>
<td>Collaborative science</td>
<td>USA</td>
</tr>
<tr>
<td>PRAGMA</td>
<td>grid-enabled applications</td>
<td>Pacific region</td>
</tr>
<tr>
<td>WINDS</td>
<td>ICT research</td>
<td>Europe, Latin America and the Caribbean</td>
</tr>
</tbody>
</table>
Table 2: Taxonomy of international volunteer grid projects by research area

<table>
<thead>
<tr>
<th>Project</th>
<th>Research Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climateprediction.net</td>
<td>Climate research</td>
</tr>
<tr>
<td>Compute Against Cancer</td>
<td>Cancer research</td>
</tr>
<tr>
<td>FightAIDS@Home</td>
<td>HIV/AIDS research</td>
</tr>
<tr>
<td>Folding@Home</td>
<td>Disease research</td>
</tr>
<tr>
<td>GridRepublic</td>
<td>Many exciting and different research projects</td>
</tr>
<tr>
<td>LHC@home</td>
<td>High energy physics</td>
</tr>
<tr>
<td>GIMPS</td>
<td>Mathematics</td>
</tr>
<tr>
<td>SETI@home</td>
<td>Extraterrestrial intelligence</td>
</tr>
<tr>
<td>World Community Grid</td>
<td>Many different projects all with humanitarian aims</td>
</tr>
</tbody>
</table>

Grid Activities in Africa and Knowledge creation and sharing in HEIs

The impetus to grid computing activities in Africa was being curtailed by the lack of terrestrial infrastructure leading to a strong dependence on expensive narrowband satellite links [Adelsberger 2002]. However deployment of submarine cable has greatly improved interconnectivity. This has to a large extent favored HEI which are the major consumers of internet. With improved connectivity speeds, the grid activities in Africa have been re-energized. This scenario has led to previous grid activities aggressively publicizing their activities e.g. the South African Grid lead by Dr. Bruce Backer of Maleka Institute. Other initiatives have expanded their mandate and included more institutions for instance, the UNESCO-HP Brain Gain Initiative has expanded the initiatives Grid project to cover 20 [UNESCO and HP, Brain Gain Initiative 2009-2011] more HEI from the previous 5 [UNESCO and HP, Brain Gain Initiative Pilot projects in Africa 2006-2009]. Other grid initiatives such as HP catalyst initiative have seen African HEI submit quality proposals that have been selected and are being implemented [HP catalyst 2010]. Table 3 below gives a summary of grid activities in Africa, the HEI’s involved and their respective research projects.
### Table 3: Grid activities in Africa and HEI’s involved

<table>
<thead>
<tr>
<th>Grid project</th>
<th>African HEI’s involved</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UNESCO-HP Brain gain Initiative:</strong>&lt;br&gt;By providing universities with advanced technology, the project allows top quality researchers to play a key role in international research and contribute to economic development in their home countries.</td>
<td>Algeria: Centre de Développement des Energies Renouvelables (CDER)&lt;br&gt;Senegal: Cheikh Anta Diop University, Dakar Computing Centre, Cheikh Anta Diop University (UCAD) Senegal&lt;br&gt;Nigeria: University of Nigeria, Nsukka&lt;br&gt;Ghana: College of Engineering, Kwame Nkrumah University of Science and Technology&lt;br&gt;Zimbabwe: Chinhoyi University of Technology&lt;br&gt;Burkina Faso: Ouagadougou University&lt;br&gt;Cameroon: Douala University&lt;br&gt;Cameroon: Yaoundé I University&lt;br&gt;Côte d’Ivoire: Cocody University&lt;br&gt;Ethiopia: Mekelle University&lt;br&gt;Kenya: Masinde Muliro University&lt;br&gt;Kenya: Nairobi University&lt;br&gt;Kuwait: Kuwait University&lt;br&gt;Lebanon: Saint-Joseph University&lt;br&gt;Morocco: CNRST:&lt;br&gt;Tunisia: Université de la Manouba&lt;br&gt;Uganda: Makerere University&lt;br&gt;Uganda: Mbarara University&lt;br&gt;Senegal: Gaston Berger University</td>
</tr>
</tbody>
</table>
| **HP catalyst initiative:**<br>Kenyatta University (Nairobi, Kenya)<br>Cairo University,(Giza, Egypt) "Cairo Cloud Computer”<br>Masinde Muliro University of Science and Technology (Kakamega, Kenya) “computational chemistry infrastructure”<br>University of Fort Hare (Alice, South Africa) “ STEM+ Innovations for under-represented rural-based schools”<br>North-west University (Gauteng, South Africa) “ Using machine learning to measure student learning” | |}

Other ongoing and proposed projects focusing on e-Infrastructure development in Africa include:

South Africa’s Cyberinfrastructure program, EPIKH project, proposed CHAIN project, EUMed Support, UbuntuNet Alliance, EUMEDCONNECT2, and FEAST. However, it is clear that the grid computing agenda is gaining momentum in Africa. This means that the education and research arena in HEIs in Africa is gradually being reengineered. Establishment of dedicated research and education networks (REns) using the
e-infrastructure is giving rise to increased collaboration nationally and internationally thereby enhancing knowledge creation and sharing in HEIs. Figure 4 offers comparison of Africa’s grid infrastructures compared with rest of the world.

Figure 4: Grid infrastructure in the world – a global computing platform for global collaborations (source Bruce Becker, for Sigrid JRU and Ops | BBecker@csir.co.za | www.sagrid.ac.za)

From the above preview of grid infrastructure in the world it is clear that only part of North Africa and South Africa are fairly covered by grid infrastructure while European countries are adequately covered by grid infrastructure.

Africa’s HEIs have adapted 2 semesters for an academic year in nordeHamid et al. (2010)

Africa’s Status of Connectivity

Figure 5: provides information regarding planned connections from the rest of the world to the African mainland. So far TEAMS, Seacom, EASSy, and SEAS have been rolled out.
The emergence of optical fibre will provide Africa with improved and affordable regional and international connectivity. This will enable African tertiary education and research institutions to generate a proportionate amount of intellectual property goods to achieve parity with the rest of the world. Though Africa is behind in this development this is changing rapidly as several submarine cable systems are being deployed on both sides of Africa, as well as regional and national terrestrial backbones, often part of other infrastructure projects, such as the electrification, roads, railways and pipelines of different sorts. While waiting for more dense electrical and optical fiber grids to penetrate the rural areas, the rapidly developing mobile phone networks offer alternatives to the satellite links.

In line with the internet connectivity increasing, the Africa universities stand to reap the benefits for Grid portals including but not limited to: Change in learning style, enhanced collaboration among students in their design and developing a courseware. Grid learning framework helps to lower cost, and encourages innovation besides facilitating free exchange of ideas, knowledge, information and creation of open educational resources. More importantly, researchers can partner with colleagues in more advanced faculties, and perform joint collaborative research and development with the use of the emerging global GRID computer networking technology [Hamid et al. 2010].
Conclusion

Any technology that empowers, enables and connects people such as grid computing and other related technologies is a catalyst for change. Organizations that ignore this will definitely wallow. In view of this, the grid initiatives in Africa will therefore catalyze change in the education sector alongside other sectors. For a world that is Web based and uses multiple implementation platforms, the e-learning grids have to embrace Service Oriented Architectures (SOA). Grid learning presents a new approach for procuring e-learning services and OERs. On the other hand SOA supports the integration of disparate data sources, combining existing web services into new applications while allowing development of durable e-learning contents regardless of changes or evolutions in technology. As people become massively networked, the scale, even within niche communities, reaches a critical mass and the ability to access and leverage the wealth of human knowledge across varied disciplines is boosted considerably.

References

CONNECTIVITY IN AFRICA: http://www.manypossibilities.net accessed 12 February 2011
GRID POWERED PROJECTS http://www.gridcafe.org/grid-powered-project.html
GRID POWERED PROJECTS http://www.gridcafe.org/grid-powered-project.html accessed 10 April 2010
HAI ZHUGE. 2002. acknowledge grid model and platform for global knowledge sharing, Expert systems with applications Elsevier journal Vol.22, pp 313-320
KARUME S.& OMIENO K.. 2010. OERs and Research: The Role of Grid computing for Knowledge creation and Sharing. ANIE conference, Kamapala, Uganda, 2010 http://www.anienetwork.org/node?page=0%2C0%2C1


OKAMOTO T & KAYAMA M. 2004. IADIS International Conference e-Society 2004, Japan

THOMAS PFEFFER (2006). Open knowledge resources for higher education: Scholarly publications, course materials, academic Software, Thomas pfeffer, University of Klagenfurt, Austria


What is the Grid? A Three Point Checklist Ian Foster Argonne National Laboratory & University of Chicago foster@mcs.anl.gov July 20, 2002


Towards the Development of a Framework for Open Courseware for Emerging Economies: the case of Kenyan public Universities

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Abstract
Open Courseware (OCW) refers to university course materials which may include lecture notes, presentations videos, syllabi and course outlines that are shared on the web for free. This is a concept that has gained popularity especially in developed countries. The purpose of this study was to develop a framework for implementation of open courseware for Kenyan public universities. The research set out to investigate the factors that discourage and/or encourage open courseware in Kenyan public universities and what needs to be done to improve the implementation. A survey was conducted on three public universities to find out the factors influencing implementation of Open courseware in public universities in Kenya. Data was collected mainly through questionnaires administered to students, lecturers and university administrators. To a lesser extent interviews and observation were also used. In total, six hundred and thirty (630) questionnaires were distributed to the three public universities, with five hundred and twenty two (522) valid responses received. The result of the survey was used to propose a framework for open courseware suitable for Kenyan public universities. The framework was validated by use of data collected from ninety one (91) students, twenty three (23) lecturers and eight (8) administrators selected from across the three public universities. The findings show some significant factors that influence implementation of open
courseware in public universities in Kenya and provide a generic framework for adoption by similar institutions in the developing nations.

**Key words:** Open Courseware (OCW), Open Educational Resources (OER), Generic Framework for Implementation of Open Courseware, and Content Management System (CMS).

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**Background to the Study**

Open Courseware (OCW) refers to university course materials that are shared for free on the web. OCW is a fast growing phenomenon in the tertiary education arena especially in the developed world. Unfortunately African higher learning institutions, especially those in Kenya, have not been enthusiastic to adopt it [Materu, 2004]. The primary characteristics of OCW include the fact that they are offered for free, do not lead to a degree or diploma certification, and do not grant access to faculty. They facilitate availability, development, and distribution of the best available learning materials in a cooperative and collaborative manner, thereby tapping the best brains around the world for the benefit of all, with continuous improvement. Unlike distance learning programs that charge tuition fees and provide formal instruction with limited participation, Open Courseware offers all course materials for free to everyone with online access. Educators may upgrade their classes, students may enhance their coursework or pursue self-study, the general public may glimpse the depth and breadth of what leading universities are offering, and benefit from reading materials and lectures. The development of open courseware is a recent phenomenon initiated by Massachusetts Institute of Technology (MIT) who posted its course contents on the Web [MIT, 2007c].

OCW is based on the philosophy of sharing knowledge. Knowledge is infinitely scalable because it grows with reuse. Fortunately, when we share knowledge, we still have it for ourselves to use. Sadly, much of the world's knowledge is locked behind copyright and consequently access to this knowledge is restricted, especially for the less privileged citizens in the developing world.

The fact that the present conventional classroom-based approaches to teaching and learning will not be capable of meeting the escalating demand for higher education in the knowledge society, represents a major leadership challenge. Universities, especially in developing countries, rely on funds they generate from conventional training to finance their respective educational programs and development projects in their institutions. There are a number of challenges that discourages adoptability of OCW in developing countries such as Kenya as the we sought to find out.

**Problem Statement**

The open courseware concept has been adopted in various models in developed nations such as USA, Japan, China and others. However, even through the benefits are enormous, developing nations have not been very enthusiastic about it. Despite
numerous campaigns of open sharing, Kenya as one of the developing nations, has not embraced the concept of open courseware.

**Research Objective**
The overall objective was to develop a conceptual framework for adoption of open courseware, suitable for Kenyan public universities. The study therefore sought to determine the extent of popularity and usage of Open Courseware in Kenyan institutions of higher learning and examine the issues surrounding their implementation. We also sought to establish the level of ICT preparedness of the universities in readiness for open courseware adoption.

**Literature review**
Literature from fields of studies that directly address Open Courseware in universities was reviewed. In addition, sources that focus on addressing issues of Open courseware of early adopters were explored. Across the fields of literature, relevant documents were identified from existing extensive research databases, updated with summary information from recent publications. This process generated a structure which was interrogated in order to facilitate the development of a synthesis of literature, and hence a theoretical framework of the research.

**Massachusetts Institute of Technology (MIT) Experience**
MIT is the inventor and the main promoter behind Open Courseware. However, many other universities from all over the world are now issuing Open Courseware. The MIT initiated the OCW concept in the year 1999, as an alternative to traditional distance-learning programs [MIT, 2007c]. MIT OCW is a free publication of course materials of what is taught at the university [MIT, 2007a]. The original intention of MIT OCW was to spread teaching material amongst academics with the aim of comparing and enriching course materials. What transpired is the heavy use of OCW by self-learners [Olaf Resch, 2007]. The MIST OCW offers students a rich set of lecture notes, problem sets, labs and more. They can also watch lecture videos and demonstrations and study a wide variety of subjects.

**MIT OCW Publishing Technology**
The MIT OCW technology solution supports a complex publishing process. This is a large-scale digital publishing infrastructure that consists of planning tools, a content management system (CMS), and the MIT OCW content distribution infrastructure (MIT, 2007c). Figure 1 below depicts this infrastructure.
The MIT publication Model is highly ambitious, complex and expensive to use for universities especially in developing countries such as Kenya. However, a lot can be borrowed from the MIT experience. MIT has set the pace and institutions keen to adopt courseware have the choice of either using the MIT framework or designing their own based on their environment.

**Intellectual Property Rights**

According to MIT online publication [2003], OCW usually has open copyright licenses similar to that of OSS (open source softwares), in order to enable the public to access, copy and distribute the content materials. A set of well-defined open copyright licenses, such as those provided by Creative Commons, allows the users to confidently use the resources in the designated manner. For example, MIT OCW uses four of the eleven available Creative Common licenses: attribution, share alike, non-commercial and exceptions.

Creative Commons is an initiative of the law School of Stanford University. Under the initiative (established as a non-profit organization), a set of licenses for regulating collaboration in OCW has been developed. These licenses take the place of similar ones in the commercial software industry but are available for free to developers and users of open source courseware. Altogether, there are types of licenses. For each of these licenses, the author retains the copyright of the courseware but offers some of his/her rights to others under certain conditions.
Issues surrounding implementation of Open Courseware

Some of the issues that need to be addressed for open courseware implementation to be realized in Kenyan Universities, based on the experience of early adopters and relevant to Kenyan situation, include the following:

a) Meeting the cost of Open courseware- Set up and maintenance cost for OCW is high. Cost will be incurred in planning, setting websites, preparing materials, hosting and publishing materials, and supporting and maintaining the sites. Sustaining the economic viability of OCW in the long term so that they remain freely available in an open marketplace. According to the report by study conducted by Materu [2007] one of the unresolved issue is that cost of support and maintenance of open courseware which is considerably high.

b) Handling copyright issues:- Open courseware raises questions of how the intellectual property right of authors will be protected. According to JOCW[2007] consortium, educators can usually find relevant resources in the Web that they may want to incorporate into their courses. However, copyright consideration is a serious roadblock even if the original intention of the content author was meant to provide the resource for free access and use. The OCW materials should be intellectual property-cleared, meaning that the university has the rights to make the materials available under open terms and that nothing in the materials infringes the copyrights of others.

c) Technical support - Finding suitable infrastructures and technologies to convey OCW in a feasible, useable, effective and economically viable way is sometimes a challenge. Issues of resource interfaces, resource interoperability and integration also often arise.

d) Institution policies- Do the Kenyan institutions’ policies and mission statements provide for open courseware? What institutional, national, or regulatory policies are necessary to remove barriers to the success of open courseware? What practical and feasible initial steps should be considered? According to forum by UNISCO Paris 2002, one of the core issues to consider is the institutional commitment and policy structure.

e) Instructor motivation- OCW provide no clear incentives of engagement to the faculty. There is no reward system for instructors who publish their material on OCW[Kubayash, 2008].

f) Quality of materials- This raises the question of whether the OCW contents can be utilized if it is posted for public use. Another question is whether people can trust the quality of open contents given that it is provided for free (UNESCO, 2005).

g) Best practice – lack of good practice models to follow can make adoption difficult, with a high risk of failure. Other than existing OCW websites, there is limited documentation on good and bad practice related to OCW, which require each university to either simply copy what has been done by others or re-invent the wheel. Neither option is entirely satisfactory [UNU, 2008].
Conceptual framework
In pursuit of suitable framework for open courseware for Kenyan public universities, the AVU framework of OER was reviewed. AVU-MIT pilot studies conducted in East Africa and AVU Gap Analysis [2005] conducted in 17 Africa countries elicited four fundamental challenges inhibiting participation in the Open education resource movement: sensitization, technological infrastructure, capacity enhancement and governance structures.

Figure 2: AVUU OER Architecture: Adopted from discussion paper presented to world summit in Tunis in November 2, 2005

One of the strengths of AVU is that OER framework considers open courseware challenges especially eminent in Africa. Awareness, capacity building, technology and policies or institution structures are the main concerns. The framework shows that to participate in Open Courseware, the four elements of creation, organization, dissemination and utilization are building structures of Open courseware implementation. However some weaknesses have been identified by the researchers such as failure to lay emphasis on the quality and relevance of open courseware materials. Moreover, the model does not show how the adoption process will be implemented. The sequence of adoption is necessary for seamless and successful implementation of open courseware and it does not clearly articulate the various roles involved.
We however used AVU framework as benchmark of our study.

**Methodology**

This is a field survey study whose objective is to disseminate findings regarding factors that discourage or/and encourage open courseware in public universities of Kenya with a view to developing an implementation framework. The target population for this research was public universities in Kenya.

Questionnaire approach was the primary data collection instrument. It was divided into four parts based on the four AVU OER framework elements namely organization, creation, dissemination and utilization. Most parts of the research presented as quantitative data which involved making inferences or generalizations, while the rest of the study involved qualitative approach which focused on in-depth information gathering. A target sample size of 450 students and 150 lecturers was selected using the (Mugenda & Mugenda, 2003) theory of sample size considerations.

Purposeful, judgmental and snowball sampling methods were used to draw samples from target population. The study adopted a 5 – point likert for most of the questions. To ensure validity and reliability of instruments data was collected from reliable sources. The survey questions were based on literature review, and piloted using 40 students from KEMU and 10 lecturers. The questionnaire was pre-tested using CVI (Content Validity Test) for semantics and meaning. The result of CVI using 4-point scale of relevance was 0.875 which was above 0.5 that qualify the instrument. Finally, the reliability analysis on field data was performed using Chronbach’s alpha and gave an alpha coefficient of 0.7252 which exceeds 0.7, that is the lower limit of the acceptable reliability coefficient, thus demonstrating reliability.

**Data Analysis**

**Data collection**

Data collection from three (3) public universities took place in August 2009. The University of Nairobi, Kenyatta University and Jomo Kenyatta University of Agriculture and Technology participated in this study. The sample was made up of 450 students and 150 lecturers at the three public universities. Useful responses were obtained from 392 students representing a response rate of 87% and 111 lecturers representing a response rate of 74%.

**FINDINGS**

Data collection and analysis was divided into four parts based on the four elements of conceptual framework. These were utilization, organization, creation and dissemination.

**Utilization**

Items explored under utilization element were as follows:
a. Internet Access-This investigated the Internet usage at the public universities of Kenya.
b. Access of free contents on the internet-This assessed the extent to which usage of free contents is available on internet.
c. Awareness of OCW-What is the degree of awareness of open courseware concepts at the public universities of Kenya?
d. Relevance of open courseware material-If what is offered by the universities is published, would it be relevant to the consumers?

Internet Access is a strong indicator of universities preparedness to embrace innovations and technologies such as open courseware. The researchers were mainly concerned with how often students use Internet and what they use it for at public universities in Kenya. Results indicated that Internet usage amongst students at the university is generally high and students utilize free contents for their research. Buying of Books online scored very low. It was surprising that 73% of students contacted were not aware of the open courseware. However, in general terms, majority of students contacted also felt that the contents used at the university were relevant to the general public.

**Creation**

Items explored under element creation were the following:

a. **Intellectual property rights**: Here we sought know how much lecturers use copyrighted contents in their instructions and willingness to share materials under open licenses.

   Majority of lecturer respondents use copyrighted contents in their instructions. Similarly, an equally high number is willing to share contents under open licenses. This means that they allow use, reuse, adoption and distribution of their content for non-commercial purposes.

b. **Motivation of lecturers**: This aspect sought to establish whether lecturers are willing to participate in creation of contents. Findings included the following:

   • Lecturers are generally comfortable to share their academic work with the public
   • Lecturers strongly accept audio and video recording of their lessons
   • Lecturers generally accept that OCW boosts their reputation as content developers

However, participation was subject to some condition of engagements such as the requirement that there should be some rewards system in place, publishing process being very clear and that lecturers may not have sufficient time to fully participate in the initiative. Finally, majority of lecturers contacted felt that their materials were not well published for open courseware.

c. **E-contents development**: These set of questions sought to find out the level of preparedness in terms of developing electronic contents. Findings from the study show that 49% of lecturers material were in electronic format and 67%
of lecturers contacted have not attended any training in E-content development although informants from the universities visited indicated that curriculum for E-content development was already in place.

Organizing

a. Institutional policies
The study investigated the existence of institutional policies that encourage open courseware. Information from the three public universities administrators contacted indicated that content sharing is within their mission statements but is not well defined within the universities policy documents. Kenyan universities intellectual right policies do not provide for open sharing.

b. Financing the project
The study sought to find out from the university administrators and other informants, options available for meeting costs. Opinion of senior managers in three universities suggested that open courseware is a good idea but universities may not have enough financial resources to sustain the project. Some of the suggestions sampled on costing included the following:

- Most of the administrators and other informants suggested that government and non governmental organizations could sponsor the project.
- A number of university administrators also felt that the university could solicit support from international OCW movements while others felt that universities can work in collaborative mode.

Dissemination
The underpinning of open courseware is ICT. With the right implementation, infrastructure institutions will be able to leverage open learning resources, foster greater user interaction and usher in a higher quality of learning experience. The study sought to find out existing ICT infrastructure suitable for open courseware implementation.

One of the indicators of university ICT readiness for open courseware is the existence of online learning. Interviews with e-learning directors of the universities and observations revealed that all the three visited universities have online learning in different forms. Nairobi University and Kenyatta University online learning systems were at the time of data collection very active.

The internet bandwidth for the visited universities was above 10 mbps and their buildings were sufficiently connected.

It was also revealed that online materials available at the universities was mostly in textual format. However Kenyatta university had already embarked in collecting lesson videos from some of its departments. Kenyatta and JKTUAT university was using moodle CMS while University of Nairobi used Chisimba Wedusoft for contents management. One of the problems experienced across the three universities was that off-campus access of their online content was very slow.
Open Courseware Framework

Figure 3: Open Courseware Framework
### Framework Dimensions

#### Table 1: Framework Dimensions

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Components</th>
<th>Processes</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Governance &amp; Management</td>
<td>-Planning</td>
<td>-Setting up taskforce</td>
<td>-No OCW in public University of Kenya. -No comprehensive plan.</td>
</tr>
<tr>
<td>Partnership and collaboration</td>
<td>Building alliances and consulting OCW partners</td>
<td></td>
<td>-Public universities have established some local and international links on open contents provision.</td>
</tr>
<tr>
<td>Institutional policies</td>
<td>Creating policies that support open courseware</td>
<td></td>
<td>-Universities policies do not cater for open content sharing e.g IPR</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Establish ways of meeting the setup and maintenance cost</td>
<td></td>
<td>-Difficult to direct university limited funds to OCW project. -Low support from Government and NGOs</td>
</tr>
<tr>
<td>Developing knowledge &amp; sharing culture</td>
<td>Faculty sensitization and advocacy</td>
<td></td>
<td>A number of workshops and conferences have been held</td>
</tr>
<tr>
<td>Capacity building</td>
<td>-Improve ICT literacy among lecturers</td>
<td>-Training of faculty in E-content development</td>
<td>-Majority of faculty are ICT literate. -Majority of lecturers have not attended training in E-content development -Most of lecturers contents is not in electronic format</td>
</tr>
<tr>
<td>-Dealing with copyright issues</td>
<td>-Adhere to IPR</td>
<td>-Set up open sharing licenses</td>
<td>-Majority of lecturers obtain materials from copyrighted sources -No clear IPR policies that cater for open sharing.</td>
</tr>
<tr>
<td>Attitudes</td>
<td>-Developing positive attitudes towards open sharing materials</td>
<td></td>
<td>Negative attitude towards open sharing</td>
</tr>
<tr>
<td>Motivation</td>
<td>-Establish ways of motivating lecturers</td>
<td></td>
<td>Low motivation of faculty</td>
</tr>
<tr>
<td>Creation</td>
<td>Prepare digital materials for publishing in OCW sites.</td>
<td></td>
<td>Materials not well organized for publishing in open courseware site.</td>
</tr>
</tbody>
</table>
## Validation

<table>
<thead>
<tr>
<th>Validation</th>
<th>Action</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copyright clearance</td>
<td>Perform copyright clearance</td>
<td>Majority of lecturers obtain contents from copyrighted sources.</td>
</tr>
<tr>
<td>Contextualizing of contents</td>
<td>Perform relevance check</td>
<td>Some of the materials are not relevant to the public.</td>
</tr>
<tr>
<td>Quality Assurance</td>
<td>Perform quality assurance</td>
<td>Some of the instructors materials do not meet quality standards for OCW.</td>
</tr>
<tr>
<td>Accreditation of materials</td>
<td>Get official approval and seek authorization for publishing from faculty</td>
<td>No policies available to support accreditation of open materials.</td>
</tr>
</tbody>
</table>

## Utilization

<table>
<thead>
<tr>
<th>Utilization</th>
<th>Action</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Awareness</td>
<td>Public sensitization</td>
<td>Low awareness level</td>
</tr>
<tr>
<td>-ICT Literacy</td>
<td>Improve ICT literacy</td>
<td>Majority of learners at public university are ICT literate</td>
</tr>
<tr>
<td>-Access</td>
<td>Improve internet access</td>
<td>Internet usage level is generally high by university students</td>
</tr>
<tr>
<td>-Relevance</td>
<td>Maintain high standards and quality in production of OCW materials</td>
<td>Some of the materials are not useful to public</td>
</tr>
</tbody>
</table>

### Framework Validation

The proposed framework was tested so as to assess whether it can be used by universities in Kenya to evaluate readiness for Open courseware adoption. This was done by developing a questionnaire based on the framework elements. The questionnaire contained a perception test item for each of the elements of the framework.

A total of 100 questionnaires were distributed to students and 30 questionnaires to lecturers in the three public universities. There were 91 valid responses from students and 26 responses from lectures giving a response rate of 91% and 87% respectively.

**Framework Validation was performed using Regression Analysis.**

Validation of the framework was performed using regression analysis tests. Regression analysis is a statistical method that deals with the formulation of mathematical models that depict relationships among variables. This approach can be used to predict values of dependent variables, given the values of the independent variable.
Regression Test Results

In this analysis, it is typical to use R^2 to describe the quality of the relationship between the actual response variable and the predicted response variable. Values for R^2 range between 0 and 1, with values closer to 1 indicating a better fit. Our research model when subjected to regression analysis yielded an R^2 value of 0.840 indicating a good research model. The Sig. Value, indicates whether the variable is making a statistical significant unique contribution to the equation. If the Sig. Value is less than 0.05, then the variable is making a significant unique contribution to the prediction of the dependent variable.

Utilization Regression Model

The construct of awareness did not have significant influence on utilization although it was greatly expected it would. Indeed, awareness of open courseware is a determinant of utilization. The outcome is as a result of futuristic kind of approach since the open courseware is not already implemented in Kenyan public universities. That means even those who are not aware about open courseware indicated that they can utilize open courseware if it is implemented in public universities. The intention of utilization in this case is not based on earlier experiences rather on futuristic expectation of the users.

However, Internet access shows significant influence on awareness of open courseware and internet access also has significant influence on utilization of open courseware. This is explained by the fact that users whose frequency of Internet access is high are more likely to be aware of open courseware than those whose frequency is low. It also shows that those who access Internet frequently are more likely to utilize the open courseware if open courseware is implemented in Kenyan public universities.
Based on the regression test above, constructs attitudes and intellectual property rights influence construct creation, while capacity does not seem to indicate influence on the creation which was not our expectation. It shows that creation of open courseware contents depends so much on the attitude of the lecturers and also adherence to intellectual property rights.

The lack of significant influence of construct capacity was associated with the reason that most of the instructors are already computer literate and are able to create electronic content, therefore other factors seem to strongly influence creation of contents.

Demographic factors seem to influence the construct capacity. This was interpreted to mean experience, education level and faculty of the instructor determines ICT readiness. From the study it was clear some of lecturers with long working experience are not keen to engage in digital contents development.

**Conclusion and Recommendations**

**Popularity of Open courseware in Kenya public University**

From the study there is no particular university in Kenya that has so far implemented open courseware. However, the concept of open courseware is not an absolutely new phenomenon to some of the university stakeholders. The study also shows that there is low awareness of OCW in Kenyan public universities. In addition, it was observed that ICT literacy and Internet access influence awareness of open courseware.

**Recommendation**

There is need for rigorous campaign and sensitization to raise the awareness level if a university wants to embark on implementation of open courseware. ICT Literacy and Internet access level needs to be further improved.
Issues surrounding implementation of open courseware in public Universities in Kenya

The study identified a number of issues that affect the implementation of open courseware in Kenyan public universities. Intellectual property rights and attitude of faculty towards open courseware have shown significant effect on creation of open courseware materials while quality or relevance of materials and access of materials have shown significant effects on utilization of open courseware.

a. **Intellectual property rights:**
The study revealed that the majority of lecturers utilize copyrighted contents in preparation of their lecture materials.

**Recommendation**
The study identified IP clearance as one of the solutions to coping with issues of non adherence to copyright laws. IP clearance is the process that ensures the open courseware publisher has the rights to make the materials available under open terms and that nothing in the materials infringes the copyright of others. It may involve getting approvals from authors whose content has been copied and/or removing such contents. It may also involve making sure fair use of other authors contents which may involve ensuring that the original authors are properly acknowledged. However, IP clearance can be time consuming and expensive depending on amount of contents to publish.

**In summary**
There are three dimensions of Intellectual property rights considerations:

- Getting permission (a “license”) from faculty or other contributors of course materials to publish them on open courseware
- IP clearance-Clearing(remove/replace) embedded third-party elements from materials to be published to avoid trouble
- Granting a license to open courseware end-users to use, reuse, adapt, and redistribute materials for non-commercial educational purposes, in accordance with the open courseware concept.

b. **Motivation and attitudes towards open courseware**
There is no clear incentive to participate in open courseware by the faculty. The greatest concern is the time that is required from academics to prepare elements of a course that will be available, monitored, maintained, updated and perhaps re-formulated for new settings and different uses. Open content enthusiasts may be prepared to devote time to creating and adapting materials to a form suitable for open distribution. However, in the case of a large-scale institutional initiative that engages the majority of the teaching staff, any substantial time commitment would be a major barrier to participation.
Recommendation

Instructors should be encouraged to devote time and effort in the open courseware; even on voluntary basis. However, from the study, it is clear that for lecturers to effectively participate in creation of open contents there should be a form of reward system in place. Some of the respondents expressed very negative attitudes towards the whole issue of sharing content. Others expressed fear that the end users may take absolute ownership of their materials. For success in implementation of open courseware, there is need for thorough sensitization to demystify the whole issue of open courseware.

In conclusion, the decision for implementation of open courseware may follow top-down approach but the actual drivers of real operation and maintenance of open courseware is the faculty members. Therefore motivation and attitudes of instructors is critical.

c. Sustainability of the open courseware project

Open courseware does not generate revenue to the university, it only incurs cost and main beneficiaries are meant to be people outside the university. Setup cost and maintenance of open courseware project is high. From our observation, Kenyan public universities may face problems especially in sustaining large-scale open courseware projects. From the study, most of the early adopters of open courseware have relied on grants from their respective governments. For instance, non-governmental organizations or educational foundations such as the Vietnam Open Courseware are funded by Vietnam Government; while the MIT OCW was partly funded by Mellon foundation.

The setup and maintenance cost of open courseware is high and it might be difficult to maintain budget lines for open courseware. However, the cost of open courseware may depend on a number of factors such as the following:-

- Scope of the intended open courseware publication: number of courses to publish over what period of time
- Pre-existing availability of course materials in publishable digital formats
- Feasibility of using existing resources (for example, department-based teaching assistants) to aid in the preparation of faculty materials for publication
- Availability of other in-house services that may reduce the need for or scope of a separate open Courseware publishing organization
- Capabilities of the existing technology infrastructure for managing open Courseware content and for hosting the distribution of that content over the web.
- Availability of open source framework to support open courseware dissemination.
- Whether it employs a producer-consumer model or a co-producer model. Producer-consumer model is more centralized and relies only on the university while co-producer is decentralized and involves collaborations of universities, volunteers and other stakeholders.
In conclusion, based on the above factors, universities which already have an existing and well established online learning infrastructure can easily and cheaply migrate to open courseware. If the university offers online learning for a number of years, over time, published materials will be continually refined. Since online learning is income generating, return on investment will be achieved.

**In summary**

It is important to set up an adequate business model in order to guarantee sustainability of the initiative. Although this is a non-profit initiative, resources must be made available and sustained.

**d. Quality and relevance of open courseware materials**

Course materials published on OCW are subjected to public scrutiny. End users will constantly evaluate the quality of content offered by the university. Therefore, quality of content can positively or negatively impact on the reputation of the institution. Therefore, the university cannot afford to compromise on the quality of what it avails to the public.

It is difficult to achieve synergy of Open courseware content in the face of the diverse thematic areas of research and training, and the different approaches and modes of delivering content. However universities should strive to make the content relevant to majority of the public.

**Level of ICT preparedness in Kenyan public universities**

Public universities in Kenya are already enjoying undersea fiber optics cable which considerably improved the bandwidth. It is encouraging to note that the universities are working on fiber-based local access infrastructure and WIFI networks to improve bandwidth and connectivity for local access.

Our observation suggest that public universities of Kenya have not yet matured in online learning. It is therefore our recommendation that once universities achieve great success in offering online courses they can easily and cheaply migrate to offering open courseware.

It was encouraging to note that the number of lecturers participating in development of content for online learning is on the increase. Universities have also set up repositories for storage of content. For instance, the University of Nairobi and Kenyatta University has each two servers for storage of content and backup respectively. Indeed, one of the unresolved issues is delivery methods for remote access, which includes off campus accesses. The scope of our study did not carry out assessment on the network infrastructure outside the university. But, results from other studies indicate that, it may be difficult to maintain high speed connection in most of places in Kenya especially the remote areas. One of the solutions is to set up distributed systems or mirror servers in various parts of the country. In summary, the content delivery should not only cover the universities but should sufficiently cover the whole country.
From the study, it was observed that the ICT infrastructure facilities in Kenyan public universities are impressive, but need to be improved so that they can handle the scalability, greater access and flexibility of open courseware. The implementation of open courseware site requires dynamic interactions with search, feedback and self evaluation mechanisms. Due to scalability of content, metadata information should be given consideration. Open courseware technology infrastructure consists of several other components, including desktop tools for building course web sites and file conversion, web authoring tools, and publication tools, content publication infrastructure, and content repositories implementation.

Universities should also embark in more rigorous training and sensitization campaigns about development of e-content.

Limitations And Suggestions For Future Research
Some limitations or challenges were encountered in undertaking this research project. Lack of funds hindered the research to the extent that the study only concentrated in public university in which students, lecturers and university management were involved leaving out the public who includes students from other institutions, academicians and the general public who are also the target users of open courseware contents. This could have brought about some bias to the findings of the research especially on some of construct of research such as internet access, awareness and relevance of content from the university. For instance, Internet access level was high which only involved students in the university but this would be different if all targeted users of open courseware were involved.

Lack of experience of local open courseware implementation made the research to adopt a futuristic approach which could have brought about bias in our findings concerning the actual perception of people towards implementation of open courseware. Construct such as awareness, which was found to be insignificant to the utilization of open courseware would infact be significant.

The applicability of the constructs proposed in the framework for open courseware implementation needs to be explored in future research. We further suggest future research on the impact of open courseware in Kenyan education system and also on the design of materials for open courseware.

References

Japan Open Course Ware Consortium (July 2006), A Case Study In Open Educational Resources Production And Use In Higher Education.


KARIE L. KIRKPATRICK, 2006. Open courseware an “MIT Thing” by Senior Production Editor, MIT Press.


Niel Butcher(2009). Leveraging the value of openness and collaboration in Health Education: The value proposition of Open Educational Resources in South Africa. OER Africa project South Africa.


VOCW, 2006.- Making Open Courseware rich, useable, reusable, and accessible at no cost to academia and then to others in Vietnam -www.vOCW.edu.vn. Lastly accessed on 7th July 2009.
Part Four

Information systems
Evaluation of Pathways for GeoG2Gs Development and Delivery in the Public Sector in Africa

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Abstract
Whereas many studies have addressed the transformative potential of ICT in the development process, very little is known to-date on how ICT is practically transforming the public sector in Africa. This paper addresses how cooperative efforts with ICT in the public sector in selected African countries are changing. A literature review hypothesizes that the development of these efforts depends on three factors: the contingent organizational structure of the cooperation, the way each organization is handling uncertainties and the perceived role of the ICT. The hypothesis is tested in cases of cooperative efforts with geoICT, referred to as geoG2Gs, in central and eastern Africa. Data collection entailed two methods (a) Focus Group Discussion (FGD), and (b) two rounds of bipolar surveys. The empirical data collection relied on translating the three causal factors and the resultant development of geoG2Gs into 4 dependent and 12 independent variables, and inferring from the observed extent of relations between the variables. Results indicate that decisions underlying the development of geoG2G strongly relate to either three of the development causes. There is a strong connection between contingent organizational structures and the degree to which staff members in geoG2Gs develop innovations. In particular the influence of the social networks in which the experts play a role, and the politico-organizational role that geoICT
can play for individual partners determines whether a change is actually realized. Similarly, there is a strong relation between the uncertainty handling and the handling of external demands. The study signifies context specific protocols for effective and efficient implementation of ICT in the public domain to realize the desired benefits. However, given the explorative nature of this article, further research may be necessary, particularly looking at the relations between the political and social connotation of geoICT and the potential for organizational innovation on the other hand would require further longitudinal data.

Keywords: G2G, development, public service, geo-information, geoICT

Introduction

Despite numerous accounts of innovative and transformative potential of Information and Communication Technology (ICT) for development in Africa [Mansell, 1999], the utilization of ICT in the public sector in Africa is hardly ever reported as a major driver of change of any part of the public sector in Africa. Heeks [2002] argues that ‘alongside the successes-- many information systems in developing countries can be categorized as failing either totally or partially.’ They fail because most e-government projects, i.e. projects aimed to construct ICT for public sector services and for public sector information integration, rely on ‘imported concepts based on imported designs’. He argues that researching the failure should however not be sought in a stereotypical dichotomy between so-called ‘western’ and ‘African’ e-government models, but in the acknowledgement of specific contexts in which the ICT needs to fit, and the historical contingencies of the national and international governance processes. Just as Germany is different from France, Uganda is different from Tanzania. Basu [2004] in addition notes that e-government is an unlikely key for bridging the digital divide between the developing and developed countries. Even if technology could transform government, it would still require much more national commitment and the need to bring ‘national e-strategies into overall development and governance practices.’ Any impact thus relies on the willingness to adopt, sustained commitment and compliance.

Miscione et al. [2010] note that there is a discontinuity between African context and the ICT for development (ICT4D) mainstream paradigms, and that there is a need to reframe the strategies of ICT implementation and use in Africa, and beyond. In other words, whereas some of the ICT innovations in Africa may be crucial, they are either hardly reported, or they do not fit the current mainstream paradigms. One of the ICT domains concerns geoICT. GeoICT refers to the collection of Information and Communication Technologies (ICT-) based systems that allows the study of natural and man-made phenomena with an explicit bearing in space [de By, 2004]. Lance and Bassolé [2006] see a clear link between ICT developments and policies in Africa and similar geoICT initiatives in Africa. Policies are available, but the execution and monitoring of these policies is often fragmented. Specifically to geoICT in central and eastern Africa [de
Vries and Nyemera, 2010] provide evidence of the presence of many, often redundant, geospatial datasets in Uganda, of which many are handled and utilized in public inter-organizational arrangements. So, where most policies often emphasize responsibilities of individual organizations, in many cases the actual implementation occurs in inter-organizational networks. For the domain of geoICT, de Vries and Miscione [2010] introduced the term geoG2Gs, to evaluate how practically such networks develop. A geoG2G is a kind of Government-to-Government (G2G) arrangement. G2Gs have been defined and evaluated by [Flak, 2007; Joia, 2004]. Flak [2007] and Joia [2004] define G2G as applications supporting ‘horizontal and vertical integration of agencies and competing stakeholder interests’. The applications consists of technology, which is structured in a domain of the public sector with different organizations at different levels (hence the “G” or ‘government’ connotation). Furthermore, the analogy concerns an ICT application through inter-organizational cooperation (hence the “2” connotation, similar to ‘B2B’). A geoG2G has the adjective ‘geo’, to reflect the focus on geoICT. Hence, a geoG2G is an inter-organizational public sector arrangement constructed to work cooperatively with at least one type of geoICT.

Whereas a lot of emphasis in literature is on how public organizations individually or jointly handle technical geoICT developments in Central and Eastern Africa, it is largely unknown what this handling means for the development of the individual and/or joint public organizations, and what it means for the role that staff has in these organizations. Therefore, the research objective was to evaluate how geoG2Gs develop and change in Africa, and to evaluate what influences this development. Such an evaluation could shed light on why policies of ICT development and actual developments do not seem to match.

**Conceptual Model**

From literature we found that three main factors potentially change geoG2Gs. First, Ciborra and Hanseth [1998] argue that inter-organizational arrangements involving ICT involve the handling of the historical organizational characteristics and choices of each of the partners in handling their own ICT. This is the so-called contingency of inter-organizational ICT (Ciborra and Hanseth, 1998). Therefore it is likely that the contingent organizational structure of geoG2Gs will affect any development of geoG2Gs. The contingent organizational structure is visible through the number of partners involved in the geoG2G agreements, the contingencies of the application domain (legal, institutional requirements), and the type of inter-organizational contracts used in those application domain.

A second factor relates to the political perspective. Public sector collaborative efforts are ‘not without conflicts and power issues’ [Agranoff, 2006]. The power differences and (potential) conflicts bring about different kinds of uncertainty among partners [Koppenjan and Klijn, 2004]. As a result, Koppenjan and Klijn [2004] reason that in inter-organizational arrangements with ICT, partners are constantly actively seeking
ways to deal with the different kinds of uncertainties about each other and about the inter-organizational arrangement itself. Such power issues and uncertainties equally exists in collaborative efforts with geoICT [de Vries, 2008]. Hence, the development of geoG2Gs also depends on how individual partners handle uncertainty. Uncertainty is visible in the extent of negotiations which occur between geoG2G partners and number of meetings which are necessary for these negotiations. Furthermore, it is visible in the extent of rules which are necessary to maintain the geoG2G activities, and the amount of risk mitigation activities which partners undertake.

A third factor comes from the geoinformatics perspective. GeoICT is not value-neutral. Georgiadou et al. [2009] frame that the use of geo-information encompasses the values that people aspire when using geo-information. Moody [2010] finds in addition that (access to, or availability of - ) geoICT may in some occasions be a political instrument in policy negotiations. Hence, the perceived role that geoICT and the associated geo-information can play influences the way that organizations act in cooperative activities. Lance et al. [2009] argues that economic motives play a role. Partners may thus foresee different roles of the geoICT in their mutual relationship with each other. The mutually accepted geoICT in geoG2Gs may thus have a political, social, organizational or economical connotation.

In summary, the development of geoG2Gs depends on the contingent organizational structure of geoG2G, the handling of uncertainty of individual partners and the perception on the role of (geo)ICT. Figure 1 provides this relation schematically.

**Figure 1. Conceptual framework on geoG2G development**

The development of geoG2G itself may take several forms. Development and organizational theorists provide many models of inter-organizational development and change in the public sector [Bauer and Stickel, 1998; Bekkers, 2007; Layne and Lee, 2001]. We choose to look at four types of developments and changes on which geoG2G partners can make mutual decisions: handling external demands, geoICT harmonization (and standardization), innovation and economic regulation. Each type of development is further elaborated below.
First of all, geoG2G contributors may change a geoG2G in the way they collaborate in the provision of services to external parties (clients, customers, stakeholders, beneficiaries, etc.). Ramessur [2009] finds that ICT is often increasing the internal organizational processes relevant for government services, but is not leading to improved access to the services itself, or improved reliability that the service is provided. The relations that each partner has with external parties are often forgotten, even though it is a crucial component of joint transformations. Handling external demands is thus a change based on mutual decisions.

Secondly, it is important to evaluate how the agreements within geoG2G’s change on the use of new geospatial technology and the form of geospatial data and content [Albrecht, 1999; Belleflamme, 2002]. The decisions on standards and the process of harmonizing geospatial technologies of individual partners often follow a long track of partner interactions. Both gradual and punctuated changes in adopted standards alternate, but both are a manifestation of the change in standards.

A third component of change concerns how the agreements change within geoG2Gs on how they seek innovations and alternative solutions [Bekkers and Homburg, 2005; Patrascoiu and Olson, 2007]. Similar to standards, innovation may develop gradually or may emerge at a seemingly random discrete moment in time. However, adopting an alternative technology, shared by all geoG2G partners, constitutes a change for all partners in the agreement.

A fourth and final change component concerns the changes the partners make in the distribution of the geoG2G costs and benefits [Lance et al., 2009]. This is foremost a question of agreeing on new economic rules. Such changes are most manifest in new pricing policies and new geoG2G supported budgets.

Operationalizing the causes of geoG2G change with the four type of geoG2G changes leads to the following relation of dependent and independent variables (Figure 2):

**Figure 2. Dependent and independent variables**

<table>
<thead>
<tr>
<th>Independent variables:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of partners</td>
</tr>
<tr>
<td>Type of application domain</td>
</tr>
<tr>
<td>Type of contract</td>
</tr>
<tr>
<td>Number and intensity of meetings</td>
</tr>
<tr>
<td>Influence of social networks</td>
</tr>
<tr>
<td>Extent of hierarchical rules</td>
</tr>
<tr>
<td>Extent of risk management activities</td>
</tr>
<tr>
<td>GeoICT connotation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dependent variables: (of change)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handling external demands</td>
</tr>
<tr>
<td>GeoICT harmonization</td>
</tr>
<tr>
<td>Innovation</td>
</tr>
<tr>
<td>Regulation</td>
</tr>
</tbody>
</table>
Data Collection Methods

The empirical approach of data collection was qualitative and explorative and relied on two methods:

1. Focus group discussion. The focus group had twenty participants from seven African countries (Ethiopia, Kenya, Tanzania, Uganda, Malawi, Zambia, South Africa). Through discussions and comparisons they identified geoG2G cases in their respective countries, and discussed the values of the variables in each of these cases in groups until an agreement was reached among the group members.

2. Bipolar survey. Forty-eight African practitioners responded to a survey with sixteen questions. The sixteen questions were 20 sets of dichotomous, opposing, propositions. The 20 sets of dichotomous propositions represented the values of the variables. Each respondent had to indicate individually the degree to which he or she agreed with two opposing propositions. In addition, each respondent could explain the reason why they opted for their answers. The extent of agreement to one proposition was following 5 point Likert scale, but the results should be interpreted qualitatively, because each respondent had the opportunity to explain their choices.

Results

The group discussions identified 4 types of organizational structures of geoG2Gs in Africa. These types could be differentiated on the basis of the number of partners involved in each geoG2G, and the type of contracts governing the agreements. The four types include:

- Bilateral (1-to-1) geoG2Gs. Such geoG2Gs rely on contracts or MoU’s between two partners. These partners have sometimes equal shares and interest in the geoICT that they manage jointly, but the relation is often guided by one specific organization (in most cases a Ministry). Examples include the agreements over the collection and sharing of administrative boundaries between the bureau of statistics and the Survey department of the ministry of Lands in Zambia; the sharing arrangements of land use and land cover maps between the survey department and physical planning department in Kenya; the arrangements on the sharing of data on international water boundaries between the Survey department and the ministry of water in Tanzania.

- Hierarchical (1-to-many) geoG2Gs. Such geoG2Gs have one particular organization who takes the lead in a specific geoICT activity or a specific product. Other organizations follow this single organization, or are entirely dependent on such an organization. Usually, there are agreements on the local collection and centrally maintained databases, governed by regulations between a central, national organization (such as a cadastral or topographic
mapping organization) and organizations working at lower administrative levels (such as local governments). Examples include the arrangements of cadastral information production and sharing between the Department of Land Affairs and the local governments in South Africa.

- Small networked (few-to-few) geoG2Gs. These geoG2Gs rely on a partnership of a relatively small number of organizations, usually around one thematic or operational field. Examples include the geo-information sharing partnerships in the field of road infrastructure, such as the sharing arrangements between the Ethiopian Utility organizations (water, power, telecom & road), and, the sharing of land use data between the departments of Physical planning, Surveys & lands and Disaster preparedness and rehabilitation in Malawi.

- Large networked (many-to-many) geoG2Gs. These partnerships either rely on MoU’s between many organizations, or on specific nation-wide applying regulations. An example of the former includes the ‘spatial data infrastructure’- like policy in Uganda (aimed to facilitate sharing all kinds of spatial data among all ministries). An example of the latter are the regulations to share cross municipal data in Ethiopia.

The application domains relying on geoG2Gs varied. Respondents indicated that practically all government domains were included in one or more geoG2G. Most prominent in all countries were the domains: land and water management; health; surveys and statistics.

Despite being involved themselves in one or more geoG2G few respondents could indicate a pattern of organization within any geoG2G. Most indicated that the number and intensity of meetings, the organizational and coordinational instruments used to monitor and manage progress, and the degree of progress made were highly idiosyncratic, and strongly dependent on individuals working in the specific geoG2G. Especially in bilateral (1-to-1) geoG2Gs, one organization takes the lead in joint activities, and the other partner is compelled to follow. Addressing uncertainty in the partnership is usually done by soft compliance (to the MoU) tactics, rather than sanctioning or enforcement through hierarchical rules or laws, or bilateral regulations. Contrastingly, the management of uncertainty between partners (regardless of the origin of the uncertainty) in large networked (many-to-many) geoG2Gs relies much more on regulation, and stricter enforcement of the regulation.

With regard to the geoICT connotation there is a sharp distinction between the different types of geoG2Gs. The group participants perceived a strong association between the independent variables ‘number of partners involved’ in the geoG2G and the geoICT connotation, as shown in Table 1. As a result the number of partners was no longer included as a factor in the further survey.
Table 1 Perceived relation between geoG2G type and geoICT connotation

<table>
<thead>
<tr>
<th>geoG2G type</th>
<th>geoICT connotation (geoICT seen by partners as ..)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bilateral (1-to-1) geoG2Gs</td>
<td>(Political) Instrument of power – i.e. access and ownership of geoICT has a political function</td>
</tr>
<tr>
<td>Hierarchical (1-to-many) geoG2Gs</td>
<td>(Social) Instrument of social change – i.e. geoICT is necessary to foster changes in society, and bridge the gap with citizens</td>
</tr>
<tr>
<td>Small networked (few-to-few) geoG2Gs</td>
<td>(Economical) Instrument of economic production and servicing – i.e. geoICT is necessary to improve the efficiency of the public sector back office operations</td>
</tr>
<tr>
<td>Large networked (many-to-many) geoG2Gs</td>
<td>(Organizational) Instrument of coordination - i.e. geoICT is necessary to enable a joint language and a joint needed in coordination and cooperation within a network</td>
</tr>
</tbody>
</table>

Whereas the group discussions primarily highlighted the above mentioned values for the independent variables, the survey focused on the possible relations between the causes of change and the perceived effects of change. Results from the bipolar survey are given in Table 2:

Table 2. Summary of results of bipolar survey

<table>
<thead>
<tr>
<th>Proposition</th>
<th>Degree of agreement</th>
<th>Counter-proposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of application domain influences geoICT harmonization</td>
<td></td>
<td>Type of contract influences geoICT harmonization</td>
</tr>
<tr>
<td>The type of application domain influences regulation</td>
<td></td>
<td>The type of application domain does not influence regulation</td>
</tr>
<tr>
<td>The type of contract influences the geoICT harmonization</td>
<td></td>
<td>The type of contract does not influence the geoICT harmonization</td>
</tr>
<tr>
<td>The influence in / from social networks influence innovation</td>
<td></td>
<td>The type of application domain influences innovation</td>
</tr>
<tr>
<td>Innovation depends on involvement in social networks</td>
<td></td>
<td>Innovation does not depend on involvement in social networks</td>
</tr>
<tr>
<td>Influence in/of social networks influences handling of external demands</td>
<td></td>
<td>Social connotation influences handling of external demands</td>
</tr>
<tr>
<td>Extent of hierarchical rules have not changed geoICT harmonization</td>
<td></td>
<td>Extent of hierarchical rules have changed geoICT harmonization</td>
</tr>
</tbody>
</table>
### Table 2: Propositions and Counter-Propositions

<table>
<thead>
<tr>
<th>Proposition</th>
<th>Degree of agreement</th>
<th>Counter-proposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hierarchical rules facilitate handling of external demands</td>
<td></td>
<td>Hierarchical rules make handling of external demands more complex</td>
</tr>
<tr>
<td>Hierarchical rules increase geoICT harmonization</td>
<td></td>
<td>Influence of social networks increase geoICT harmonization</td>
</tr>
<tr>
<td>Hierarchical rules determine geoICT harmonization</td>
<td></td>
<td>The extent of hierarchical rules do not influence geoICT harmonization</td>
</tr>
<tr>
<td>A small number of risk management activities lead to harmonization</td>
<td></td>
<td>A large number of risk management activities lead to geoICT harmonization</td>
</tr>
<tr>
<td>Political connotation leads to / influences innovation</td>
<td></td>
<td>Political connotation does not lead to/ influence innovation</td>
</tr>
<tr>
<td>Economic connotation is main factor for changes in handling of external demands</td>
<td></td>
<td>Economic connotation is main factor for changes in innovation</td>
</tr>
<tr>
<td>Economic connotation leads to innovation</td>
<td></td>
<td>Economic connotation does not lead to innovation</td>
</tr>
<tr>
<td>Economic connotation influences geoICT harmonization</td>
<td></td>
<td>Economic connotation does not influence geoICT harmonization</td>
</tr>
<tr>
<td>Political connotation influences geoICT harmonization</td>
<td></td>
<td>Political connotation does not influence geoICT harmonization</td>
</tr>
<tr>
<td>Organizational connotation leads to innovation</td>
<td></td>
<td>Economical connotation leads to innovation</td>
</tr>
<tr>
<td>Organizational connotation leads to innovation</td>
<td></td>
<td>Political connotation leads to innovation</td>
</tr>
<tr>
<td>In geoG2Gs with an organizational connotation the geoICT harmonization increases</td>
<td></td>
<td>In geoG2Gs with an organizational connotation the geoICT harmonization decreases</td>
</tr>
<tr>
<td>In geoG2Gs with an organizational connotation the handling of external demands increases</td>
<td></td>
<td>In geoG2Gs with an organizational connotation the handling of external demands decreases</td>
</tr>
</tbody>
</table>

**Discussion**

The Table 2 results shows a number of remarkable relations in the eyes of the respondents:
The application domain in which the geoG2Gs are formed, and the hierarchical rules under which the geoG2G partners are operating are strongly influencing the regulations which the geoG2G have to follow. This applies in particular to the standard setting and other harmonization efforts. Contrastingly, the social networks in which the geoG2G professional are working are more influential in the internal rules of the geoG2Gs than the application domains. Furthermore, the political, organizational and economic connotation of geoICT are determining the developments in innovation, yet the organizational needs and developments are more likely to influence the actual innovation paths than the political use of geoICT. Finally, standardization and harmonization are strongly linked to organizational issues. Linking this back to the earlier described relation between the number of partners involved in geoG2Gs and the connotation, it would seem that larger partnerships, with an organizational reason to cooperate, clearly have difficulties with innovation trajectories.

Results from the group discussions and bipolar survey lead to several associative relations between variables. Table 3 indicates for which relations these associations exist.
Table 3. Associative relations between variables

<table>
<thead>
<tr>
<th>Organizational</th>
<th>Economical</th>
<th>Social</th>
<th>Political</th>
<th>Activities</th>
<th>Risk</th>
<th>Management</th>
<th>Intra-organizational networks</th>
<th>External networks of social</th>
<th>Externally oriented meetings</th>
<th>External demands</th>
<th>Partners</th>
<th>Domain</th>
<th>Application</th>
<th>Types of contract</th>
<th>Contract</th>
<th>GeoICT harmonization and innovation</th>
<th>Regulation</th>
<th>Innovation</th>
<th>GeoICT harmonization</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Role of geoICT in partnership</strong></td>
<td><strong>Uncertainty handling</strong></td>
<td><strong>GeoG2G changes:</strong></td>
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</tbody>
</table>
Last but not least, also the hierarchical rules and the degree to which any hierarchical rules can be enforced plays a role in the harmonization of geoICT. This conclusion clearly refers to the effective or non-effective enforcement of geoICT standards to local agencies, while the standards are agreed upon by national agencies.

Conclusions

The objective of this article was to evaluate how and why current cooperative efforts with geoICT in the public sector in Africa are changing. Given the resource limitations for conducting extensive and longitudinal fieldwork, we used a qualitative, explorative approach to identify a number of causes for particular types of changes in geoG2Gs. We found that both the application domain and the hierarchical rules in which geoG2Gs are formed influence the formal standard setting in geoG2Gs. This applies however only as long as the geoG2Gs are operating under such rules, and in very specific domains. As soon as more partners become involved, and as soon as the applications become more multidisciplinary, then cooperation and innovative trajectories become more difficult. Furthermore, the uncertainty arising from the external environment is influencing both the external and internal alignment of partners. These difficulties show that geoG2Gs are often set up to address a particular need at a particular time, yet have difficulties to change when the needs are changing. At that time there are too many internal rules preventing an easy transformation.

The explorative findings provide a useful direction for further research in this field. First of all, the extent to which actors use (geo)ICT for strategic political reasons could be further explored. A comparison with the findings of de Vries [2008], which focused on the political nature of geoICT in geoG2G cases in the Netherlands would be useful to analyze whether strategic use of ICT is contextual or universal. Secondly, inventorying the role of the societal connotation of geoICT would need further understanding. Such a research could shed further light on the extent to which (geo)ICT is really embedded in other societal developments.

References


Field Investigations into Adoption of Business Process Design and Analysis Techniques in Ugandan Organisations

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Abstract
The need to adopt businesses to the changing customer needs is the major rationale for business process design and analysis [BPDA]. In order to expedite this process, it is relevant to use BPDA techniques like Petri nets, Business Process Modelling Notation and system dynamics among others. Such techniques are used to simplify, illustrate and document BPDA. For Ugandan organizations, these techniques are not adopted to full scale usage. Thus, this study is aimed at developing a framework that can be used by such organizations to successfully adopt BPDA techniques. The study also sought to explore the challenges that impede BPDA techniques adoption and these formed a basis for the requirements of the framework to be designed. To achieve this, we followed the design science approach.

Keywords: Business Process Design and Analysis, Adoption.

Introduction
Industry market changes drive organisations to seek means to remain competitive. This has resulted into adoption of process centric approaches like Total Quality Management [TQM], Just in Time management [JIT] and Business Process Reengineering [BPR] that call for change in business processes to meet customer needs [Kim et al., 2006]. Changes
must be implemented effectively and at an increasing rate [Giesing, 2003], while paying attention to activities that make up business processes.

A business process is defined by Hammer and Champy [2000] as “a set of activities that, taken together produces a result of value to a customer”. Other authors [see for example Talwar, 1993; Davenport and Short, 1990] defined a business process with emphasis on the set of activities that lead to achievement of a goal. A business process evolves through phases of the business process life cycle [BPLC] like design and analysis, configuration, enactment and evaluation [Weske, 2007]. This study pays attention to business process design and analysis [BPDA] as an important phase in designing and implementing new processes in organisations.

Business process design and analysis [BPDA] involves the study and testing of business activities [Jay et al., 2000]. It is a method by which organizations understand and define their activities that enable them to function. Cousins and Stewart [2002] define BPDA as being composed of two phases, i.e. analysis and design. Analysis phase helps analysts to understand how processes of a business function and interact with each other whereas design aims at improving the way processes operate and interact. BPDA involves the use of process modelling, validation, and simulation techniques to develop process models that represent business processes [Weske, 2007]. It ensures that business processes are optimized to meet customer needs and support organizational growth through improved operational performance, integrated and automated processes, reduced cost, and, creation of new business opportunities [Jay et al., 2000]. The opportunities are a result of organizational and technical changes intended to improve business operations by integrating software systems [Cousins and Stewart, 2002]. BPDA caters for testing and evaluating of existing processes to identify current system state, clarify process characteristics, identify possible bottlenecks and their sources, compare any potential process alternatives, measure key performance indicators for proposed changes and suggest potential improvements [Thome et al., 2007; Boekhoudt et al, 2000].

The use of BPDA techniques improves the quality and agility of BPDA [Aalst, 2006]. In the developed world, BPDA techniques have been adopted and used by organisations along with key success factors [Jarrar, 2007]. For developing countries like Uganda, little or no evidence exists about adoption and use of these techniques in business process design and analysis. Even then, fewer organisations in Uganda review or redesign their business processes; for those that do so, it is not known whether they use BPDA techniques to reengineer their processes. This may be attributed to lack of knowledge of their existence or lack of skills to use these techniques. More so, we cannot generalise or guarantee that these techniques can be adopted in Uganda. We therefore seek to explore if Ugandan organizations have adopted BPDA techniques from which a framework to facilitate their adoption will be designed.

Adoption is defined by Rogers [1995] as the acceptance of new innovations. Rogers explains it as the use or none use of new technology at a given period of
time. To contextualize the adoption concept, different models have been put forward, for instance; adopter centred process oriented model [Pereira, 2002] that deals with individual perceptions and attitudes that form part of the adoption process; diffusion of innovations model [Rogers, 1995] that deals with user perceptions and attitudes towards adoption; theory of planned behaviour [Fishbein and Ajzen, 1975] that deals with behaviour, attitude and subject norm that can be used to determine adoption; theory of reasoned action [Ajzen, 1985] that deals with the attitude, subject norm and behavioural control that determine intention to adopt; and the technology acceptance model [Davis, 1986] used to predict adoption of technology based on the ease of use and usefulness of the technology. These models have been used in the developed world to successfully adopt technology in agriculture [Paarlberg, 2003], software development [Umarji and Seaman, 2005] and business process management [Jarrar, 2007]. For developing countries adoption models are too broad and generalised to cater for problems and issues that are specific and unique to developing countries.

To this end, there is need for a BPDA adoption framework to facilitate adoption of BPDA techniques by organizations in developing countries like Uganda. In other words, what are the challenges that impede adoption of BPDA techniques by Ugandan organizations, and what requirements can be derived to meet these challenges that can be used to facilitate their adoption? Thus far, the study aims at designing a customised adoption framework that can be used to fulfil this effect. In the section that follows, we explore the state of practice of BPDA techniques and IT adoption models with an aim of positioning our research problem. Section 3 describes the research approach followed to undertake the exploratory study and the design of the BPDA adoption framework. This is followed by a description of the exploratory study in which the state of practice with respect to BPDA techniques in Ugandan organizations were investigated, analyzed and discussed in section 4. In section 5, the derived requirements that lead to the design of the adoption framework are presented and discussed and finally provide a way forward on future work based on the research outcome in section 6.

**Types of BPDA Techniques**

There has been a rapid evolution and adoption of BPDA in the developed world as opposed to developing countries. This was explained by the failure to adhere to the critical success factors [Miers, 2006]. Little to no evidence exists about application of BPDA techniques by Ugandan organizations in business process design and analysis. That explains why endeavors by some organizations to redesign their business processes have not been fruitful. Thus, this became the driving factor for this study, i.e. to highlight some of the existing BPDA techniques, that Ugandan organizations could adopt to improve business process design and analysis.

**The IDEF family:** Integrated definition [IDEF] is a suite of methods for BDPA [Mayer et al., 1995]. The series of IDEF techniques include: IDEF0 functional model, a structured representation of functions and processes within a modeled system; IDEF1
information model which represents the structure and semantics of information within a system. IDEF1X; Extended IDEF1. IDEF2 dynamic model shows the time-varying behavioral characteristics of a system. IDEF3 process description captures domain-expert knowledge about behavioural aspects of a system. IDEF4 object-oriented develops component-based client/server systems. IDEF5 ontology description capture method provides a language for visualisation of ontology.

**Petri Nets:** Petri nets technique makes use of tokens to represent the dynamism in the nature of a process [Aalst, 2004]. It is a graphical and mathematical tool used to represent procedures, processes, machines and organizations by providing the analyst with the ability to describe, analyze, study and design various business processes [Aalst and Hee, 1996]. Hierarchical coloured Petri nets are an extension of classical Petri nets used to portray, simulate and analyse large systems and processes [Aalst, 2006].

**Role activity diagrams [RAD]:** RAD represents business process dynamism [Bal et al., 2000]. It analyses the interaction between different roles during process execution, along with external events and the logic that determines sequence of activities to represent states and events. A role is a sequence of activities carried out together as a particular responsibility [Bal, 2000]. RAD is suitable for organizational contexts in which the human element is a critical organizational resource that process change aims to address. RAD supports simulation and visualization of processes to cater for experimentation before process implementation [Aalst, 2006].

**State-Transition Diagramming [ST]:** ST diagrams are applicable in systems design [Giaglis, 2007] to analyse and design real-time systems. They overcome limitations that arise from the static nature of Data Flow Diagrams [DFDs] and Entity Relations Diagrams [ERDs] by providing explicit information about time-related sequence of events within a system. ST diagrams make use of rectangular boxes and arrows to represent states and changes in states [transitions].

**Success Factors for BPDA Techniques in Organizations**

The above BPDA techniques have been successfully applied in various organizations in the developed world [Jay et al., 2003] to conduct business process analysis and design. The required resources [time, money, skills] to carry out BDPA make it imperative for us to study past experiences of other organisations to learn from their practices. There is scanty literature regarding success factors for adoption of BPDA techniques in process design and analysis, more so for developing countries. Nevertheless, BPDA being a phase in BPR, we consider success factors for successful implementation of BPR. Jarrar et al., [2000] conducted a survey on critical success factors [CSFs] and established that all the CSFs fall under four major categories, i.e. commitment from top management, reengineering existing business processes, IT infrastructure, and deploying change management as seen in figure 1.
Top management commitment - management must advocate and support adoption of BPDA techniques. Once top management is committed to the effort, then the whole organisation will be aligned to support BPDA [Jarrar, 2000].

**Change management**: human resources should be redesigned to support information sharing and decision making [Vakola and Rezqui, 2000]. People’s mindset should be prepared to support rather than resist change [Jarrar, 2000].

**Training and Education**: according to Al-Mashari et al., [2005], organizations that undertake BPR projects need to increase their training budget by 30-50 percent. That includes training of stakeholders in process design related skills, techniques, interpersonal and IT skills.

**IT infrastructure**: this involves software, hardware and IS that support process design activities [Michael et al., 2006]. Adequate IT infrastructure is required to enable open communication, information sharing and collaborative team working [Attaran, 2003].

Despite the successes above, BPDA challenges are often experienced in terms of failure to align BPDA with process objectives and organizational goals, lack of proper methods of analysis [Bal, 2000] and rejection to use BPDA techniques [Maholta, 1996]. This has led to failure of BPDA projects when outcomes deviate from requirements. We note that Ugandan organizations need to adopt BPDA techniques for proper alignment of process outcomes with process requirements. To effect this, we design a BPDA Framework based on derived requirements and IT adoption models that have been applied in the developed world.

**Adoption models: State of the art**
The developed world has applied adoption models to adopt technology [Jarrar et al., 2000] as opposed to developing countries. This study does not intend to discuss all models, but rather refers to those that relate to the subject under study, i.e. technology
adoption [in our case BPDA techniques]. Besides, the models’ variables provide insights that form a basis to study what impedes BPDA techniques adoption in Uganda.

**Theory of Reasoned Action [TRA]** [Fishbein and Ajzen, 1975]: TRA was intended to provide a distinction between beliefs, attitudes, intentions and behaviours. It highlights attitudinal beliefs as the best predictors of intention to adopt. The authors argue that intention is the mediating variable between attitude and subjective norm to predict adoption behaviour of an individual as illustrated in figure 2.

**Figure 2: Theory of reasoned action [Source: Jackson et al., 2006]**

![Diagram of Theory of Reasoned Action](image)

**Theory of Planned Behavior [TPB]:** TPB [Ajzen, 1985] is an extension of TRA intended to overcome the limitation of uncontrolled behavior. The theory uses Intention and Perceived behavioral control constructs to enable measurement of the extent to which an individual believes that the outcomes of a behavior can be controlled.

TPB uses knowledge of attitudes, subjective norms and perceived behavioral control to understand beliefs and thus predict behavior to adopt. Regarding this discussion, TPB does not cater for rejection during the adoption process which may come as a result of sudden change in behavior. Thus, this becomes a challenge as well as a requirement that could be put into consideration by this research.

**Technology Acceptance Model [TAM]:** TAM predicts usage of an Information System [Davis, 1986]. The model argues that acceptability of an IS depends on the users’ perceived usefulness [PU] and perceived ease of use [PEU], where attitude and behavioral intention act as mediating variables. Ease of use refers to “the degree to which the user expects the target systems to be free of effort” where as usefulness is “the user’s subjective probability that using a specific system will increase his or her job performance within an organizational context” [Davis, 1986]. Attitude is defined as the user’s evaluation of desire to use a system.

The model further argues that usefulness is influenced by ease of use and both have an effect on attitude, but attitude and usefulness together influence behavioral intention to use a system as demonstrated in figure 3.
**Figure 3: Technology Acceptance Model. [Source: Davis et al., 1989]**

Adopter centered model: This is based on the adopter’s mental framework by considering the adopter as a “black box” to model adoption using a sense-making approach. Sense-making refers to the cyclical process of taking action, extracting information from the stimuli resulting from that action, and incorporating the information and the stimuli from that action into the mental frameworks that guide further action [Pereira, 2002]. It is used to form anticipations and assumptions, and subsequent interpretation of experiences that deviate from the anticipations and assumptions. Adopter centered model is used to determine individual perceptions and attitudes that form part of the adoption process.

Unified theory of Acceptance and use Model [UTAUT]: UTAUT was developed by Vanketesh et al., [2003] using constructs chosen after examining eight models of technology acceptance and use. It was intended to improve the predictive powers of behavior of intentions to use technology. According to Vanketesh et al., [2003], performance expectance, effort expectance, social influence and facilitating conditions are used to determine behavioral intention to use technology as illustrated in figure 5.

**Figure 4: The UTAUT Model [Source: Vanketesh et al., 2003]**

Gender, age and experience moderate the key variables of performance expectance, effort expectance, social influence and facilitating conditions [Vanketesh et al., 2003].
In summary, we observe that the models present factors that are relevant for adoption. However, as discussed in the preceding sections, each of these models has strengths but also challenges [see table 1] that impede their direct application to adopt BPDA techniques in developing countries. Thus, for developing countries, these models cannot be adopted wholesomely. Therefore, this study was intended to overcome such challenges by establishing requirements that could meet them and thereby develop a customized framework for adoption of BPDA techniques in the developing countries, more specifically Ugandan organisations.

Additionally and from the discussion in the preceding sections we also observe that to construct a useful BP model, one needs to make use of BPDA techniques that simplify the process and offer a range of other benefits like speed, quality and agility. On the other hand, these techniques have not been fully utilized by organizations in Uganda. We also observed that adoption models have been used in developed countries but hardly in developing countries. As such they cannot be generalized to aid adoption in developing countries like Uganda because they do not address issues that are specific to them, for example the models do not take into consideration factors like collective organisation efforts towards adoption, need for training before introduction of a technology, the financial discrepancy between organisations and regions, divergences in levels of understanding between adopters, the factors that affect adoption like time and limited ability, and rejection of technology at some point due to limiting factors. These issues present challenges that create a gap between models and their direct application to adoption of BPDA techniques by Ugandan organisations.

To this end, this research intended to fill the gap by deriving propositions that could act as requirements for the BPDA techniques adoption framework i.e. consider adoption as a collective organisational effort, sensitise and train users before adoption of technology, consider organisational/regional divergences and imbalances, consider factors that limit adoption like time, limited ability and funding, and finally cater for rejection of technology at some point in time.

The above requirements were used to design a customized framework that provided a set of guidelines to enable direct adoption of BPDA techniques by Ugandan organisations.
<table>
<thead>
<tr>
<th>Model Name and Description</th>
<th>Strengths</th>
<th>Limitations</th>
<th>Model Loop hole(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Diffusion of Innovation</strong></td>
<td>Presents adoption stages that indicate the process through which adoption can be achieved. Highlights Relative Advantage, Compatibility and Complexity as factors relevant to adoption that need to be taken into account.</td>
<td>Puts attention on individual adoption and ignores collective adoption and ignores social factors like attitudes and beliefs. Assumes the adopter to have complete knowledge of the innovation, which is not always the case.</td>
<td>Ignoring collective organizational adoption. Does not provide for collective adoption and ignores collective behavior.</td>
</tr>
<tr>
<td><strong>Adopter-centered Model</strong></td>
<td>Uses Sensemaking to form anticipations and assumptions on an individual's perception, attitude and behavior. Considers individual attributes and organizational attributes.</td>
<td>An individual's perception, attitude and behavior may be influenced by non-work or non-organizational related factors like language.</td>
<td>Differences between adopters disregard the financial and geographical learning. Does not provide for collective adoption and ignores collective behavior.</td>
</tr>
<tr>
<td><strong>Theory of Reasoned Action</strong></td>
<td>Attributable attitudes, beliefs and perceptions influence the adoption process. Considers adopter attributes and organizational attributes.</td>
<td>Attitudes can be taken as norms and vice versa. Confusion between attitudes and norms. Assumes the adopter to have complete knowledge of the innovation, which is not always the case.</td>
<td>Assumes the adoption process is influenced by individual social factors like attitude and beliefs.</td>
</tr>
</tbody>
</table>

Table 1: Comparison of Adoption Models
<table>
<thead>
<tr>
<th>Model name and description</th>
<th>Strengths</th>
<th>Limitations</th>
<th>Model loop holes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory of planned behavior</td>
<td>Intention to use a technology</td>
<td>Intention to use a technology</td>
<td>lapses in scales used to measure and interpret data that need to be improved.</td>
</tr>
<tr>
<td>Behavioral control aspect helps the adoption implementer to influence everybody in the organisation to support adoption.</td>
<td>The adoption implementation helps the adoption implementer to influence everybody in the organisation.</td>
<td>Like the theory of reasoned action, TPB is limited by conflict between norms and attitudes.</td>
<td>The adoption implementation helps the adoption implementer to influence everybody in the organisation.</td>
</tr>
<tr>
<td>Technology Acceptance Model (TAM)</td>
<td>Perceived usefulness and perceived ease of use of a technology</td>
<td>Perceived usefulness and perceived ease of use of a technology</td>
<td>TAM prescribes the variables of perceived usefulness and perceived ease of use of a technology.</td>
</tr>
<tr>
<td>The Unified Theory of Acceptance and Use (UTAUT)</td>
<td>Performance expectancy, effort expectancy, social influence and facilitating conditions are used to determine behavioral intention to adopt a technology.</td>
<td>Performance expectancy, social influence and facilitating conditions are used to determine behavioral intention to adopt a technology.</td>
<td>The variables of perceived usefulness and perceived ease of use of a technology.</td>
</tr>
<tr>
<td>Unified Theory of Acceptance and Use (UTAUT)</td>
<td>Does not provide for ways through which system acceptance can be improved.</td>
<td>Like the Theory of Planned Behavior, TPB is limited by conflict between norms and attitudes.</td>
<td>The adoption implementation helps the adoption implementer to influence everybody in the organisation.</td>
</tr>
</tbody>
</table>

Note: The table is incomplete and some cells are missing data or information.
Research Approach

This research intended to create new knowledge in form of a framework that is to be used by Ugandan organizations to adopt BPDA techniques, that is, to explore challenges to adoption of BPDA techniques by Ugandan organizations and derive requirements from which the adoption framework was designed. To achieve this, a research method that supports the creation of new knowledge [artifacts] and its application to the environment was appropriate. To that effect, this research was conducted following the design science research method. Design Science [DS] is a “problem solving approach that entails a rigorous, systematic study of the deliberate ordering of components in the Universe” [Fuller, 1983]. DS aims at producing artifacts that contribute to the body of knowledge and are relevant to the community [winter, 2000]. It also aims at developing methods of a system for a given set of user requirements represented as models [Hevner, 2007].

Data was gathered through the use of interviews, questionnaires and existing requirements documents. The cases organisations were purposely selected to represent the different application domains and experiences in BDPA in Uganda. The cases were selected from both government parastatals and the private sector that included the social sector, banking and revenue collection. Respondents were IT officers, system analysts, business analysts, IT managers as well as system administrators.

Case 1: National Social Security Fund [NSSF]: this is a social security saving scheme mandated by government through the NSSF Act, Cap 222 [Laws of Uganda] to provide social security services to employees in Uganda. It was established by a Parliamentary Act [1985] to provide for its membership, contributions payment to, and payment of benefits out of the Fund. It is a scheme instituted for the protection of employees against the uncertainties of social and economic life.

Case 2: Uganda Revenue Authority [URA]: this is a government tax body set up in 1991 by the Uganda Revenue Authority Statute No. 6 of 1991. The authority is a central body charged with the roles of assessing and collecting specified tax revenue, administering and enforcing laws relating to such revenue and to account for all the revenue to which those laws apply. URA is as well an advisory body to the Government on matters of policy relating to all revenue.

Case 3: Barclays Bank Uganda: Barclays bank is a global financial services provider, engaged in retail and commercial banking, credit cards, investment banking, wealth management and investment management services all over the world. Case organizations were selected because of their active involvement in business process review and because they are the leading service providers in their respective sectors.
Field study and analysis of BPDA techniques practices in Uganda

Exploring BPDA techniques used by Ugandan Organizations

In order to explore the various BPDA techniques used by Ugandan organizations and the challenges that impede their adoption, it was imperative to start by finding out whether organizations conduct BPDA and how it is conducted. Findings revealed that that the case organizations are involved in a range of business processes as presented in table 2.

Table 2: Existing organizations’ Business Processes

<table>
<thead>
<tr>
<th>Organisation</th>
<th>Business Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSSF</td>
<td>Contributions collections, Beneficiary payment, statement balance inquiry, member Registration</td>
</tr>
<tr>
<td>Barclays Bank</td>
<td>Loan Management, Cash Management Service, Letters of credit and guarantee, Money Transfers</td>
</tr>
<tr>
<td>URA</td>
<td>Tax Payer Registration, Tax Claims, Tax Assessment, Payment processing, Revenue collection, Etax and Asyuda</td>
</tr>
</tbody>
</table>

In order to explore the techniques used by the selected case organizations during BPDA, we first established whether case organizations conduct BPDA and if so, find out the techniques they use to accomplish the BPDA process as seen in table 3.

Table 3: conducting BPDA by case organizations

<table>
<thead>
<tr>
<th>Question</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organization conducts BPDA</td>
<td>100.0%</td>
</tr>
<tr>
<td>Aware of any ways to improve BPDA</td>
<td>75.0%</td>
</tr>
<tr>
<td>Do you know any BPDA techniques</td>
<td>40.0%</td>
</tr>
<tr>
<td>Organizations make use of BPDA techniques</td>
<td>10%</td>
</tr>
</tbody>
</table>

Table 3 revealed that all [100%] case organizations conduct BPDA either internally or externally through a combination of internal committee and consultants. After establishing that organizations conduct BPDA, the study was set to find out whether organizations are aware of ways to improve BPDA. The findings showed that 75% of respondents were aware of such ways, one of which was the use of BDPA technique and methods. Findings further showed that only 40% of the respondents knew about the existence of BPDA techniques but only 10% were using them. As an alternative, organizations use other business analysis methods like PEST [Political, Economic, Social and Technology], SWOT [Strength, Weaknesses, Opportunities and Threats] and MOST [Mission, Objective, Strategy and Tactics] to review business processes.
The study also established challenges that impede adoption of BPDA techniques as summarized in table 4.

**Table 4: Challenges that impede adoption of BPDA techniques**

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>The techniques are difficult to use</td>
<td>43.8</td>
</tr>
<tr>
<td>The techniques require a lot of training time</td>
<td>12.5</td>
</tr>
<tr>
<td>The techniques lack documentation</td>
<td>9.4</td>
</tr>
<tr>
<td>There is lack of institution support towards use of BPDA techniques</td>
<td>34.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

Findings in table 4 indicated difficulty in use of BPDA techniques as the most challenging factor [43.8%]. Other notable challenges included: lack of institutional support towards the use of the techniques [34.4%], higher learning curve, i.e. techniques require a lot of training time [12.5%] and, lack of documentation [9.4%]. After presenting the challenges, the study was set to determine measures that could be necessary for the design of the BPDA adoption framework as presented in table 5.

**Table 5: Challenges and Derived Requirements**

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Requirements derived</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difficulty in use of a technique</td>
<td>Need for training</td>
</tr>
<tr>
<td>Too much time required to learn how to use a technique</td>
<td>Need to plan for training, conduct workshops and seminars.</td>
</tr>
<tr>
<td>Lack of supporting documentation</td>
<td>Use BPR software tools</td>
</tr>
<tr>
<td>Lack of organizational commitment and support</td>
<td>Need for sensitization and change management programs</td>
</tr>
<tr>
<td>Lack of critical success factors</td>
<td>Benchmarking, research and development</td>
</tr>
<tr>
<td>Lack of a defined procedure for choosing appropriate BPDA technique</td>
<td>Need for collective and collaborative decision making</td>
</tr>
</tbody>
</table>

**Discussion of Findings: Challenges and Requirements derived for the adoption of BPDA techniques**

Findings revealed a set of challenges that have created a negative attitude towards adoption of BPDA techniques. Measures to overcome the challenges were established as requirements necessary to develop a framework for successful adoption of the techniques.

**Difficulty in use of a technique:** This impacts on the usability of the technique in two ways, i.e. it affects the attitude towards the technique and also leads to resistance against adoption of such technique[s]. This challenge was found to be verified by literature about the perceived ease of use of specific technology as a factor that
Part 4: Field Investigations into Adoption of Business Process Design and Analysis Techniques

Determines adoption [Davis, 1986]. Attitude determines the user’s evaluation to use a technique [Davis, 1986], once the system is perceived to be free of effort [i.e. easy to use], then chances of adopting such a system are much higher. Therefore training before implementation of BPDA techniques is a key success factor that should be put into consideration in the framework.

Too much time required to learn how to use a technique: This challenge impedes adoption of techniques in such a way that it extends the time it takes to make a decision to adopt. Notwithstanding, Rogers [1995] stages of adoption, findings differed from the assumption that the user has complete knowledge about the technique. This is coupled by lack of a training variable in all models reviewed in the preceding section. To this effect, there is need for planning procedure that details when and how to conduct BPDA. The created plans include budgets to be used to source funds for BPDA. Once put together, plans and budgets provide a basis for BPDA performance measurement.

Lack of supporting documentation: This challenge creates lack of a reference point when faced with problems while using BPDA techniques. This challenge deviates from the expected benefits of the BPDA techniques [Kemsley, 2008]. Such a challenge as well implies absence of facilitating conditions towards adoption [Venkatesh et al., 2003]. To address this challenge, the study derived a need to use BPR software tools to enhance BPDA techniques [Bal, 2000] documentation. The tools would improve the design process by improving the documentation that lacks in some existing BPDA techniques.

Lack of organizational commitment and support: This challenge as well exposes lack of facilitating conditions [Venkatesh et al., 2003] that favor adoption of BPDA techniques. Organizational and management commitment is a key factor to adoption and use of any system. Management must advocate and support adoption of BPDA techniques [Jarrar, 2000]. Commitment should also be expressed in terms of financial support to finance BPDA activities like training. To effect this, there is need to create sensitization and change management programs in organizations before introduction of any new system.

Need for collective and collaborative efforts during BPDA: Lack of collective efforts during BPDA was witnessed as a setback to adoption of BPDA techniques. This was realized from the point that where the BPDA techniques were used, it was at the discretion of the unit Head to choose a technique to be used. This meant that choice was dependent on the intuition and experience of the selector with no regard to appropriateness of the technique to the situation. This therefore called for a need for collective efforts to reach a consensus before a decision for a technique is reached and providing justification for the choice.

Benchmarking, research and development: The study revealed lack of critical success factors for adoption of BPDA techniques in Uganda. This meant that organizations that have no experiences to learn from. Therefore, overcoming such a challenge calls for a need to benchmark with developed countries that have adopted the
techniques. This can be enhanced by conducting research and development in the area of BPDA techniques adoption so as to learn from past experiences.

**Design of the BPDA Adoption Framework [BPDAAF]**

In this section, we present the design of the framework based on the proposed requirements. BPDAAF is essential for organisations that conduct BPDA but do not use BPDA techniques to enhance their process. It enables organisations to adopt BPDA techniques by providing a set of guidelines that followed logically towards adoption as described in the proceeding steps.

**Step I**

**Sensitise and manage change:** Change management is an approach undertaken to divert minds of individuals from their current state of thinking to a desired state. Whereas sensitisation is the process of creating awareness about existence of something that an individual might not have had knowledge about. Step I addresses the challenge of lack of institutional support towards use of BPDA techniques within the organizations. In addition, Step I enables the adopter to study the entire BPDA process in order to understand the processes being reviewed and the requirements needed to conduct BPDA so as to pave way for actual adoption of BPDA techniques. Success for sensitisation and change management guideline requires adopters to work with subject matter experts who are knowledgeable about organisations operations.

**Step II**

**Plan and benchmark:** This involves planning for BPDA techniques adoption and benchmarking with other organisations that have already adopted the techniques. Planning is the process of formulating programs for a definite course of action, while benchmarking refers to copying from experiences and practices of other organisations / individuals about a certain phenomenon. To that effect, planning would involve the process of drawing up plans to be followed in order to adopt BPDA techniques. Planning takes the form of setting the vision, aims, objectives and strategies for adopting BPDA techniques. Benchmarking provides an alternative to planning by enabling the adopters to learn from experiences and success stories of other adopters.

**Step III**

**Train users:** It involves training users in BPDA techniques proposed to be used. Training involves a set of activities aimed at imparting knowledge or skill into individuals to improve their performance or attain a given level of understanding required to perform a given activity. It overcomes the challenge of lack of knowledge and awareness and about BPDA techniques before their adoption. Training creates awareness about the proposed techniques by emphasising their usefulness and benefits [Davis, 1986], and provides documentation and study manuals that were used as training documents.
**Step IV**

**Collective adoption or rejection:** All previous guidelines should take place for this step to succeed, otherwise rejection would prevail. Collective adoption or rejection is a situation where all stakeholders in an organisation decide as a team to either adopt or reject BPDA technique [s].

**Step V**

**Integrate BPR software tools:** After successful adoption of the techniques, there may be need to enhance their capability, for instance, a need to increase the rate at which information is generated and stored. Such a need may call for integration of software tool[s] with the use of a given technique to improve its capacity and capability of the user as far as generation and storage of information is concerned. This step overcomes the limitation of lack of documentation presented by some of the techniques. Use of BPR software tools would enhance a technique’s documentation capacity to support users during BPDA and provide a platform upon which performance measurement can be based. Examples of such tools include but are not limited to; Yawl, UML, protos, etc.

**Step VI**

**Measure performance:** This step provides checks and balances based on the requirements specified for use of the techniques [section 4.1] against the expected outcomes from the use of such techniques. Performance measurement is a means to setting a standard that forms a basis for comparison and evaluation. It therefore provides a reference point against which the outcomes from the use of BPDA techniques are compared against requirements for their use.

**Fig.1 BPDA adoption framework [BPDAAF]**
For successful adoption to take place attention should be paid to the following critical success factors [Miers, 2006];

- Top management support; a situation where organisation leaders support all activities geared towards adoption of BPDA techniques. This success factor is a major requirement at all stages of BPDAAAF because management support helps to prevent the resistance that would otherwise come from junior stakeholders. It also ensures that resources needed to support adoption activities like finances are availed since decision makers are part of the project.

- Education and training; this involves equipping individuals with knowledge and information necessary to execute certain tasks. Education and training as a success factor facilitates the adopters to gain knowledge and skills in area of BPDA which are a major requirement for success of each adoption step. Education and training should be continuous to increase the capability of the stakeholders to perform their roles.

- Building IT infrastructure; putting in place hardware, software, networks and IT personnel with relevant skills to support adoption. Making use of IT infrastructures at each step of BPDAAAF eases the creation and processing of information required to be used during adoption.

The guidelines presented in BPDAAAF if followed in a logical and hierarchical manner would lead to successful adoption of BPDA techniques. However, if objectives of a particular step are not achieved, adopters can revert to the previous step[s] to correct mistakes that might be responsible for failure to achieve the objectives. Once the mistakes are corrected, the adopter can proceed to the next step. We also emphasise that successful execution of each step requires adherence to the critical success factors.

**Conclusion and Future Work**

The quality of business processes determines an organisation’s success measured in terms of customer satisfaction, retention and profitability. This quality is achieved through the use of methods, models, tools and techniques that simplify the design and analysis of such processes [Aalst, 2006]. Failure to use BPDA techniques compromises the quality of business processes which in turn affects organisational reputation, image and profitability. In this study, we observed that Ugandan organisations were not using BPDA techniques due to lack of knowledge about their existence, lack of institutional support, lack of skills necessary to use the techniques, among others. As such, the study established requirements that could be used to address the challenges, and later used to design the BPDAAAF. Among these included; the need to sensitize and manage change, need for planning and benchmarking, need for training, and performance measurement. The BPDAAAF framework has been developed but is yet to be empirically validated to prove if indeed it enables Ugandan organisations to adopt BPDA techniques in improving their business processes.
References


AALST, W. M. P. 2006. Trends in Business process analysis: from verification to process mining


MIERS, D. 2006. The Keys to BPM Project Success.


UMARJI M. AND SEAMAN C. 2005. Predicting Acceptance of Software Process Improvement, St. Louis, Missouri, USA.


Building a Case for a Dynamic Requirements Process Improvement Model

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**Abstract**

Software requirements management is a volatile and dynamic process that requires continuous requirements process improvement in order to arrive at adequate requirements. However, there is interdependence amongst the processes themselves that leads to requirements managers’ inability to achieve satisfied requirements for the intended software system. As a result, several software projects have either a cost, schedule and quality creep or a mixture of them due to poor requirements process improvement (RPI) management. Currently, no attempt has been made to model the impact of the relationships amongst requirements processes to help gain problem understanding while using highly visualized tools. This has been cited by several authors as the reason why the attainment of a satisfied state for the requirement engineering processes cannot be achieved. This research is an attempt to develop a generic model for RPI by triangulating System Dynamics (SD) and Statistical Process Control (SPC) that exploits SD’s ability to analyze dynamic complex systems and SPC’s highly visualizable time series analyses to achieve satisfied system.

**Keywords**: Interdependence, Requirements process improvement, system dynamics, satisfaction

**Introduction**

In businesses across the world, the need for RPI has never been more critical to ensuring project success. To bring this into perspective, Conetta [2010] argued that the cost of
replacing marine one helicopters rising from 6.1 to 11.2 billion dollars was a result of poor communication of the aircraft requirements. Interestingly, a surprising number of companies suffer from ineffective requirements process improvement. Requirements process improvement (RPI) is the process through which changes are made to improve a requirements specification in terms of having a balance amongst cost, quality and schedule variables. Without effective requirements process improvement, business users lack access to timely and accurate information, hindering communication and contributing to delays, errors and excessive rework.

In order to ensure that adequate requirements are arrived at, software requirements managers are always carrying out RPI. However, there is interdependence amongst the processes themselves that leads to requirements managers’ inability to achieve satisficed requirements for the intended software system. A satisficed system is one that meets the criteria for an adequate system but does not identify an optimal solution. For such a system, a few alternatives are compared and the best course of action is chosen from this limited range of options [Simon, 1956]. As a result, several software projects have a cost, schedule and quality (quality triangle) creep or a mixture of them due to inefficient RPI management [Ferreira et al., 2009; Wiegers, 1999].

Previous research attributes this to the fact that the interdependence amongst the requirements processes causes complexity of analysis of these processes. Even with this problem, there is lack of tools that model impact of the relationships amongst requirements processes to help gain problem understanding while using highly visualized tools to prioritize key processes for system development [Williams, 2003; Ferreira et al., 2009]. Despite the attempt by [Ferreira et al., 2009] to capture complex dynamics for requirements resulting from their volatility in a software development project, they did not look into analysis of the impact of interacting dynamic requirements processes and the need to understand the impact of these processes on the software project management. Understanding of these interactions is important because it helps generate policies to achieve satisficed systems.

This research is an attempt to use a triangulation of SD that is known for its ability to handle complex dynamic problems [Forrester, 1991; Williams, 2003] and SPC that uses time series analysis to monitor process performance and identify the process that require improvement and verify the effectiveness of the improvement made [Baldassare et al., 2004]. The triangulation of the two methodologies will help RPI achieve the required satisficed system. The rest of the paper is structured as follows. Section 2 describes the problem area and motivation of this research, while Sections 3 and 4 are a discussion about the state of art and practice of process improvement models and methodologies, Section 5 discusses the proposed solution to the identified problem, and Section 6 gives a summary of the paper and proposes the future work.
Problem Description and Motivation

Ruhe et al. [2002] argue that the hardest part of building a software system is deciding precisely what to build since requirements keep on changing throughout the development process. This creates difficulty in selecting and visualizing the appropriate requirements that fulfill the critical stakeholders’ preferences as well as maximization of the quality of the end product [Pfhal and Ruhe, 2003; Ruhe et al., 2002].

Sommerville and Ransom [2005] support this position by arguing that the interaction among requirements engineering processes is dynamic and reveals a non-linear relationship. To analyze this interrelationship amongst requirements engineering (RE) processes in order to achieve process improvements, current RPI tools use work breakdown structure methodologies which are unable to capture and visualize the feedback between or amongst processes [Ruhe et al., 2002; Duggan, 2006]. In reality processes are interlinked and dynamic, and thus should be analyzed in a holistic manner to enable one capture the interdependence and feedback amongst the processes with an aim of visualizing and achieving satisfaction for the quality triangle [Beecham et al., 2005; Williams, 2003]. Current methods used do not capture the feedback relationships amongst requirements processes when trying to achieve a satisficing level of the quality triangle. This often results into some processes dominating requirement determination while impacting on other processes [Clempner, 2010; Ferreira et al., 2009; Beecham et al., 2005; Williams, 2003]. In the long run this may yield amplification or decay of the intended system performance hence software project failure or escalated post implementation costs. This is supported by Bendor and Kumar [2009] who advocate for a holistic approach to RPI analysis models.

The use of a standard approach to deal with real-world complexity where models of reality are built and analyzed through visualization has been recommended [Clempner, 2010; Duggan, 2006; Williams, 2003; Pfhal and Ruhe, 2003]. The two candidate methodologies are hierarchical decision process petri-nets [Clempner, 2010] and system dynamics [Forrester, 1991]. Although Petri nets have been used in dynamic modeling of complex systems, such models can best be built using a System Dynamics based methodology, which is a very comprehensive and powerful modeling paradigm for its ability to capture both static and dynamic aspects of reality. Furthermore the methodology should also have the ability to visualize the effect of the changes made in the requirements process to enable the requirements process improvement team have a common understanding of the process. This will result in the team making informed decisions about the appropriate process improvement that should be done. It is on these premises that in this paper we attempt to propose the use of a system dynamics based approach as a process improvement methodology for complex requirements process analysis.
State of Practice: Current Software Development process improvement models

Several software development process improvement models exist namely Requirements Capability Maturity Model (R-CMM) [Beecham et al., 2005], Software Capability Maturity Model (CMM) [Paulk, 1996], Requirements Engineering Process Improvement Model (REPSIM) [Williams, 2003], Bootstrap [Kuvaaja, 1999], Trillium [April and Coallier, 1995], and Software Process Improvement and Capability Determination (SPICE) [Dorling, 1993]. However apart from R-CMM and REPSIM, all the models that have been mentioned above are software process improvement models. Review of literature has revealed that the SPI models have both workable and economic potential for software process improvement but they do not adequately address requirements process improvement [Sawyer et al., 1997]. We will therefore discuss in this literature review only R-CMM and REPSIM which are relevant for RPI.

With the approach that R-CMM follows one is unable to exploit the advantage of developing generic processes that can work across all levels of maturity to achieve an optimal system. This is given the fact that in practice, real systems are complex and their RE processes are also complex and dynamic, therefore they interact amongst each other depicting feedback relationships that cut across all levels of organizational maturity with respect to process improvement [Williams, 2003]. In addition R-CMM is heavily dependent on organizational learning and therefore organizations that are at a primary stage of learning may not be able to attain a satisfied state of the requirements processes and thus calls for a methodology that is able to improve its analytical strength as users familiarize themselves with it, irrespective of the organizational level of maturity. Coupled with the above drawback, Ojala [2004] asserts that capability based improvement only, is not enough to start process improvement work. To be effective, software process improvement (SPI) and development methods also need to take into account costs created in processes and thus the need to measure capability and value of processes.

REPSIM is a more promising model for enhancing into a generic tool for RPI for satisfied systems than R-CMM because of its ability to model the RE process in a holistic manner and cutting across all levels of the organizational maturity, but unfortunately it has not been applied in industry. Holistic refers to modeling the process as a whole but not in parts. Williams [2003] holistically modeled the RE process and was able to capture the inter relationships between processes using a tool he developed called REPSIM. REPSIM was used to predict cost, understand the cause and effect between processes and explain the impact of the resulting inter relationship, however, [Williams, 2003] like [Beecham et al., 2005] did not look into a dynamic prescriptive model. A dynamic prescriptive model brings to visibility all the processes interrelating with each other resulting into capture of the best fit which then is able to ensure system satisfaction i.e. cost, schedule and quality are satisfied.
Given the strengths and weaknesses of the current RPI models, to successfully achieve a satisfied system, an appropriate RPI model should have the ability to capture feedback and time delay resulting from interaction amongst the RE processes. This will prevent a separation of the model structure from system behavior with an aim of achieving a satisfied state of the system under development.

<table>
<thead>
<tr>
<th>RPI Models</th>
<th>Development Support</th>
<th>Actors with RE Interaction</th>
<th>Relationship</th>
<th>Synthesize and Evaluation attributes</th>
<th>Synthesise Evaluation and Understanding ability</th>
<th>Holism Explanation</th>
<th>R-P Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generic Tool</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Holmes</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td></td>
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<tr>
<td>Bootstrap</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Trillium</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>SPICE</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
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<tr>
<td>REPSIM</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-CMM</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Comparison of existing RPI tools with a proposed tool depicting a summary of key essential attributes. This table summarizes the characteristics of current tools in use and highlights their deficiencies to meet the requirements of a good tool for a satisfied system.
To address the highlighted gaps of the current models in Table 1, the authors have carried out further literature synthesis in addition to [Williams, 2003; Duggan, 2006; Clempner, 2010]. The literature reveals that only methods that can carry out dynamic modeling for complex systems are appropriate to bridge the gap in RPI modeling for attainment of satisfied systems. Two candidates methodologies have been identified to meet this criteria; System Dynamics as used in REPSIM [Williams, 2003] and Hierarchical Decision Process Petri-nets (HDPPN) [Clempner, 2010]. In the next section we discuss the strengths and weaknesses of both methods and recommend the most appropriate methodology proposed for use in capturing the dynamic complexity of RPI as discussed in the next section.

State of the Art: Process Modeling Methodologies

System dynamics (SD) and Hierarchical Decision Process Petri-nets (HDPPN) have been commonly used for modeling processes of dynamic complex systems. Although some analysts opt for methods that they are more familiar with, there are authors who have come up with guidance on which approach should be used in a given circumstance [Buchholz, 1994; Duggan, 2006]. The main advantage of both SD and HDPPN is that they are used in analysis of real world systems and can generate insights which are essential in theory building [Duggan, 2006].

Petri-nets and system dynamics are used to model work flows and state transitions but the divergence in their approach and effectiveness lies in the difference in their epistemological underpinnings. While Petri-nets are best utilized when simulating workflow systems are based on discrete event simulation and state- transition, System dynamics are best utilized when modeling workflows that are aggregated and the state transitions are modeled continuously through sets of integral equations for natural systems [Duggan, 2006; Forrester, 1991]. However, to adapt Petri-nets to simulation of complex dynamic continuous systems, hierarchical petri-nets have been developed but still suffer from the drawback of time delay due to transitions occurring at discrete and uneven time intervals [Duggan, 2006]. Petri-nets have also been viewed to be inadequate in analysis of complex systems since they give a single view description on a complex system [Buchholz, 1994] as compared to system dynamics that has the ability to give a three dimensional view of the same system. The improved versions of petri-nets including colored and high level petri-nets that have tried to model complexity become more complicated to analyze as the model gets bigger [Clempner, 201]. Table 2 gives a comprehensive comparison between SD and Petri-nets and highlights the importance of each attribute. From the analysis in Table 2, it is clear that SD is the most appropriate method to address the gap for RPI in the development of satisfied systems.
Proposed Solution

From the comparison of the existing RPI methods and Process modeling methodologies, SD qualifies as the most appropriate method for enhancement for attaining a satisfied state for software systems under development. SD helps to explain how the feedback-loop relationships amongst the process improvement variables determine the behaviour of the model [Georgantzaz et al., 1995]. This will be done using stock and flow diagrams to depict the feedback loop relationships amongst the process improvement variables and how they influence the model behaviour.

Table 2: Comparison of commonly used process modelling methods for complex dynamic systems

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Petri nets</th>
<th>System Dynamics</th>
<th>Importance of Attribute</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Level of analysis</td>
<td>Only Hierarchical petri nets analyze complex systems.</td>
<td>SD was designed for complex systems</td>
<td>Natural systems are large and complex</td>
<td>Clempner, 2010 Forrester, 1961</td>
</tr>
<tr>
<td>2. Ease of Model creation</td>
<td>Extra coding after model creation may have to be done to superimpose some model heuristics.</td>
<td>Easy to create all decision rules as equations in a straightforward manner</td>
<td>Use by non experts</td>
<td>Duggan, 2006</td>
</tr>
<tr>
<td>3. Analysis of large models</td>
<td>Analysis becomes complex with large models</td>
<td>Techniques exist to handle large models holistically</td>
<td>Natural systems are large and complex</td>
<td>Taylor et al., 2010</td>
</tr>
<tr>
<td>4. Model scalability</td>
<td>Difficult to add extra structures to an existing model</td>
<td>Flexibility to add and remove variables and links</td>
<td>Identify variables responsible for system behaviour</td>
<td>Clempner, 2010 Duggan, 2006</td>
</tr>
<tr>
<td>5. Update of tables after simulation interval</td>
<td>Special purpose transition is written to record the state of places after each simulation</td>
<td>Automatically recorded by the tool</td>
<td>Ease of use by non experts</td>
<td>Duggan, 2006</td>
</tr>
<tr>
<td>6. Simulation runs</td>
<td>Takes long to run; time lags becomes more significant for optimization or satisfaction</td>
<td>Runs instantly</td>
<td>Analysis for optimization or satisfaction</td>
<td>Duggan, 2006</td>
</tr>
</tbody>
</table>
In order to augment SD’s ability to identify the most influential processes for requirements engineering during system development, SD will be triangulated with statistical process control (SPC) [Georgantzas et al., 1995]. SPC is a statistical based approach that is well known for its ability to determine the stability of a process by discriminating between the presence of common cause and assignable cause variations [Baldassare et al., 2004]. Triangulation of SD and SPC has been done for manufacturing processes but not yet in the requirements and software process context. Due to the primary differences between manufacturing and software or requirements processes as highlighted in [Baldassare et al., 2004], the combination of SD and SPC cannot be used as is but must be tailored to fit the requirements process.

Combining SD and SPC will not only help the RE stakeholders to gain insights about the RPI feedback structure but also carry out assessment of the potential effects of the high leverage points on the stability of the interacting requirements processes directly from the control charts leading to attainment of a satisfied state for a software system under development. Furthermore, the RE stakeholders will have ownership of the RPI model together with its results, and the urge to implement the changes recommended by the model [Georgantzas et al., 1995].
This is a result of understanding the causes of the process variations and being able to deal with these variations most appropriately [Georgantzas et al., 1995]. SPC will help in enhancing visualization while identifying the most influential processes for its ability to determine satisfaction limits dynamically, hence ease of use.

This will be done by examining the system dynamic’s model outputs and describing the evolution of exogenous impacts on model behavior over the course of a simulation. To be able to quantify this, control limits will be set using SPC and process performance will be tracked over a time period on a control chart. If there are any processes that fall outside the control limits, then these will be the points to be considered for RPI. “Control charts either suggest that corrective action is needed to improve quality or give assurance that a process is producing satisfactory quality” [Georgantzas et al., 1995]. The results will be used to link the high-leverage parameters to specific model structures that can then be used to improve the understanding of how the model structure impacts on system behavior. Furthermore, the model will be used as a training tool and a requirements process improvement guide for the concerned RPI stakeholders. The model will also foster improved understanding of the requirements process improvement field.

A review of the RE process variables has been done and variables suited for RPI have been identified. Table 3 highlights the key variables for achieving a satisfied state.

Table 3: Process Improvement variables for the research dynamic hypothesis

<table>
<thead>
<tr>
<th>PI Model Sectors</th>
<th>Process Improvement Variables</th>
<th>Process Improvement Model Outputs</th>
<th>Reference Mode</th>
<th>Process Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Project scope</td>
<td>Process Improvement Capability</td>
<td>Change in process improvement</td>
<td>Paulk, 1996</td>
<td>{scale 0-1}</td>
</tr>
<tr>
<td>2. Project Finance</td>
<td>Process Costs</td>
<td>Change in process costs</td>
<td>Loncosole, 2001</td>
<td>{currency}</td>
</tr>
<tr>
<td>3. Process technology</td>
<td>Process effectiveness</td>
<td>Change in process effectiveness</td>
<td>Williams, 2003</td>
<td>{scale 0-1}</td>
</tr>
<tr>
<td>4. Development process</td>
<td>Process Capability Level</td>
<td>Change in maturity level</td>
<td>Winton, 1999</td>
<td>{scale 0-1}</td>
</tr>
</tbody>
</table>

| Process productivity of requirements engineers | Change in productivity of requirements engineers | Berenbach, 2004 | Number of requirements per person per month |
To depict the interrelationship between the process attributes mentioned above, a dynamic hypothesis has been developed as shown in Figure 1. The research dynamic hypothesis that shows the interrelationships amongst the requirements process improvement variables and their impact on the quality triangle in trying to attain a satisfied state for the system under development has been formulated from reviewed literature. The dynamic hypothesis is the qualitative representation of the proposed system dynamics based requirements process improvement model and it will be tested using field studies that are the next steps to the work done so far.

**Fig. 1: Dynamic Hypothesis for the Requirements Process Improvement Model.**

The results of the field studies will confirm or reject the hypothesis and will help modify the dynamic hypothesis into a detailed causal loop diagram. The dynamic hypothesis in Figure 1 above has 4 balancing loops and 8 reinforcing loops. A reinforcing loop (R) represents growth or declining actions while a balancing loop (B) is a goal seeking...
loop that seeks stability or return to control [Williams, 2003]. An example of one of these loops is described as follows. B1 (going through B-I-H- G-D-A-B) is a balancing loop where increasing the process capability level will cause a reduction in process improvement capability with an immediate increase in process rigor and thus almost immediate gain in perceived effectiveness that will increase customer satisfaction and process effectiveness. This feeds back into increasing process productivity of requirements engineers.

For continuous process improvement in the reinforcing loops, they have to be balanced by the balancing loops to avoid causing a system burnout or chaos. The dynamic hypothesis is expected to evolve overtime as more relationships are explored and understood. This research will study the various loop structures using system dynamics modelling to identify the combination of loop sets that help achieve a satisfaction state to ensure continuous process improvement.

Conclusion and Future Work
The contribution of this paper has been a literature survey that helped to identify the gap that exists with current requirements process improvement tools in capturing the feedback interaction amongst software engineering requirement processes. In addition this paper also proposes how this gap can be closed by proposing a unique solution of reaching a satisfied state to attain a balanced system as opposed to optimization that may not address certain requirements. This is work in progress and as immediate future work, the dynamic hypothesis will be tested in the field to confirm and or improve it based on what is in practice. Simulation models will then be built to explicitly quantify the relationships amongst the variables of the dynamic hypothesis. Quantification of the simulation models is done using mathematical equations to help capture the behaviour of the variables of requirements process improvement.

References
Modeling the Fuel Supply Chain in a Free Market Economy

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Abstract
Businesses in the world are becoming complicated. Many businesses tend to grow into big multinational companies which operate on a low profit margin but with enormous sales. It can be assumed that most businesses aspire to reach that level. Quite often, small/local companies, in the presence of the giant multinationals, have very little chance of surviving in the market unless they make mergers with the multinational giants. We identify a case where the reverse is true. Unfortunately, it is not something the consumer needs to celebrate about over a long time – it’s a time bomb. In this paper, we study and analyze the supply chain of fuel (diesel) in Uganda. We study the profitability of the different business models in the market. We find out that the current ‘hands off’ approach by the government of Uganda to the Fuel Industry, disguised as free market, is detrimental to the general economy in the long run. Multinationals, which have the capacity to distribute fuel throughout the country, are highly vulnerable and likely to be outcompeted out of the market by smaller dealers. However, smaller dealers have no capacity and incentive to cover the whole country with fuel which may leave remote areas with persistent transportation problems, poverty and underdevelopment.

Keywords: Supply chain, margins, profitability, robustness.

Introduction
Businesses world over are changing. So are the consumers. In fact, businesses change so as to address the dynamic needs of consumers. Businesses that fail to adjust to the
needs of the customers end up closing shop irrespective of their earlier reputation and profits. Businesses are also affected by the political environment in which they operate. In some cases, the political environment favors them while in others it doesn’t. In case the political environment does not favor the growth of business, then businesses find it hard to survive. Naturally, there are a lot of uncertainties in businesses and they have been studied extensively [4][6] using various methodologies [7][9][12]. It is up to the proprietors of the business to make it survive within the uncertainties.

Fuel in Uganda is a very sensitive commodity[2][3]. It amounted to about 15% of the imports in 2007 [1] and is one of the direct drivers of the economy. It is therefore logical to allow maximum competition in the fuel sector so as to keep the prices as low as possible.

In Uganda, like in other developing countries, there has been a trend towards liberalization of business sectors. Business players are therefore allowed into the market with minimal restrictions. Such restrictions include minimum capital, number of outlets, types/classes of customers to be served and others. Unlike in the developed countries, there is very little enforcement of environmental and safety standards as far as setting up fuel pumping stations is concerned. It is therefore very common to find many fuel pumping stations in the same locality, pumping stations or fuel reservoirs near residential places, pumping stations along very busy streets as well as pumping stations with excessively large fuel storage.

In the Ugandan fuel market, two wholesale dealer types exist; the local and multinational dealers. Much as they all sell the same commodities and serve the same customers, they operate in different environments. Multinational dealers are tied to the rules of operation in their parent countries – mostly developed countries. This does not apply to local dealers. Local dealers work in a relatively more relaxed regulatory framework. However, the local dealers have a lower amount of capital and therefore cannot cover the entire country. At a national level therefore, we are faced with multinationals who have a lot of money and a big network but are restricted in terms of operations by stringent safety and environmental rules. We also have local dealers with little money but with a lot of operational flexibility.

In this paper, we use system dynamics approach to model the fuel industry in Uganda. We focus on stock, profit margins and sensitivity to competitors prices. We analyze our results in the view points of the local and multinational wholesaler. We use our results to predict the long term effect on the economy if the same business environment is maintained.

We find out that the fuel future of Uganda (and indeed other countries with the same policies) is not good. The multinationals are likely to be outcompeted by the locals who, unfortunately, do not have the network to distribute fuel throught the country. Fuel will therefore be available in urban areas but scarce and expensive in rural areas. Transportation of goods from upcountry will become very expensive leading to higher costs of living in the cities and poorer standards of living in the villages.
The rest of the paper is organized as follows. In Section 2, we discuss the fuel distribution chain. In Section 3, we discuss the set up of the simulation, the parameters used and the assumptions made. We present and analyse the findings of the simulation study in Section 4 and make a deeper holistic discussion of the simulation results in Section 5. We then make conclusions and suggestions for future research in Section 6.

The Fuel Supply Chain

The supply chain of fuel is a long one. It can be traced from levels of exploration and drilling to levels of consumption and homestead use. Its supply chain is like any typical supply chain save for a few constraints. Earlier studies [8][10][11][13] have been carried out on related supply chains and are known to be quite complex. Modeling risks and uncertainties in such supply chains [5] are known to unearth interesting scenarios.

The fuel supply chain is made up of several players. The main players, also considered in this study are the wholesaler, the retailer, the transporter and the (corporate) customer. The common customer consumes from a retailer and takes a few liters of fuel at a go while a corporate customer takes big volumes of fuel. The common customer is therefore modeled as a ‘leakage’ at the retailers site. How the different stakeholders interact determines the cost of the overall supply chain. It should be noted that a change at one stakeholder can lead to changes that affect the other stakeholders and sometimes the stakeholder him/herself. For example, if a transporter increases the rate at which he hires the vans, it eventually increases the cost of fuel which he uses to fuel the van. This implies that he, eventually, increases his operational costs.

The Wholesaler

Wholesalers import and redistribute fuel through their own retail outlets, through privately owned stations or through direct sales to the corporate customers. Wholesalers may have a depot where they store the fuel before it is distributed. The depot acts as a reservoir in case of stock outs in some of the outlets. Some wholesalers do not have depots. Instead, they have very large storage at the outlets. All imports are stored at the outlets. In case of some stock outs, fuel can be moved from the storage of an outlet to another. We need to note that this practice is potentially dangerous and is not acceptable in most developed countries. Wholesale companies from developed countries therefore cannot employ this practice.

The Retailer

These are service stations that sale fuel to small scale customers like individual car owners. In cases of special arrangements with the wholesalers, retailers can also serve corporate customers. Retailers are classified depending on who owns the retail station, and whether or not it is affiliated to a specific wholesaler. A retail outlet owned by the wholesaler but operated by an individual is referred to as ‘Company Owned Retailer Operated (CORO)’. However, if the individual owns the outlet and is affiliated to the wholesaler (only selling the wholesaler’s products), such a retail outlet is referred to as ‘Retailer Owned Retailer Operated (RORO)’. ROROs are branded by the wholesaler.
to which they are affiliated. Some ROROs however are not affiliated to any wholesaler. Such ROROs are referred to as freelance ROROs. The owner individually brands the outlets.

**The Transporter**

Transportation business is sometimes manned by the wholesaler and sometimes manned by the retailer. In other cases, the transportation business is outsourced to another party. In cases where transportation is not manned by the wholesaler, the transporting company must satisfy the health and safety standards imposed by the wholesaler. Quite often, transportation impediments determine the viability of the location of a retail outlet. In cases where the demand is too low, and therefore the volume of fuel is relatively low, it may not make business sense for the transporter to move a small volume of fuel to the retailer. Such localities, therefore, cannot have a fuel retail outlet.

**The Corporate Customer**

These are organizations such as power generating plants, sugar factories and cement factories that consume large volumes of fuel. They tend to make direct purchases from wholesalers so as to get cheaper fuel. Sometimes, corporate customers may make arrangements with wholesalers and lift fuel from a specific retailer (say a CORO) depending on their convenience.

**The Simulation**

**Parameters used**

In the simulation, we considered the following parameters as determinants for the total cost of the fuel supply chain

(a) Investment costs incurred by the wholesaler on storage facilities
(b) The fuel kept at the storage facilities at a certain instance of time (Depot Stock)
(c) The tank capacity at the retailers outlet (Retailer stock)
(d) The storage capacity at the corporate customers site (corporate stock)
(e) The total cost of fuel at the retailers site (pump price)
(f) The price of fuel to the corporate customer (corporate price)
(g) The cost of fuel at the depot (depot price)
(h) The total revenues of the company
(i) The (gross) profit/margin a company makes by selling fuel
(j) The fuel orders from corporate clients/customers
(k) The discounts made to corporate clients
(l) Orders made by retailers
(m) Discounts made to retailers
(n) Sales of retailers
(o) Transportation charges
(p) Retailers’ cash at hand
(q) Delivery charges to the corporate customer
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(r) Competitor’s price
(s) Equipment maintenance costs
(t) The costs of installing the corporate customer’s site
(u) The cost of investing in a new retail site
(v) The cost of revamping an old retail site

Interaction among parameters
The interaction among the parameters are represented in the Causal Loop Diagram in Figure 1 below.

Figure 1. Causal Loop Diagram

From the Causal Loop Diagram, the pump prices are directly affected by the competitor’s price. A decrease in competitor’s price triggers off a decrease in the retailer’s sales since the customers shift to the cheaper offer. This prompts the retailer to reduce the price to recapture the clients. A reduction in pump price reduces the company margins. An increase in retailer sales reduces the retailers stocks which increase the retailer orders that subsequently reduce the depot stock. A decrease in depot stock causes the wholesaler to place more orders thus increasing the fuel imports. The same trend is encountered in the corporate loop. A decrease in corporate competitor’s price causes corporate customers to push wholesalers for more discounts. This reduces company margins. A reduction in prices increases sales (to corporate customers in this case). An increase in corporate orders decreases depot stocks causing the wholesaler to import more fuel.
Simulation Parameters
We use Stella 8.1.1 to convert the Causal Loop diagram into the Stock and Flow Diagram (Fig. 2). There are three sectors in the diagram: The wholesaler/oil company, the retailer and the corporate customer.

Figure 2. Stock and Flow Diagram

The transporter, much as he is influential, was incorporated into the different sectors. The transporter effects like transport costs and delays are incorporated into the different sectors.

The wholesaler has Depot Stock as the main variable and other variables include the fuel accumulation rate, company revenues, depot price, corporate and retail orders, etc.

The retailer sector constitutes of key variables like retailer stock which is controlled by the retailer order rate and retailer sales. Other variables include cash at hand, pump price, etc.

The corporate customer sector includes variables like corporate stock, corporate orders and corporate consumption rates.

Results
We simulated the system on different foci of the wholesaler and evaluated the viability and profitability. A wholesaler can concentrate on corporate customers, retail customers, have a balanced emphasis on both, or have a bigger emphasis on one with little emphasis on another. Price decisions made by the wholesaler are partially dictated by the competitor whose prices are random (within a range) and cannot be predicted by
the wholesaler. Price decisions made by a wholesaler are partially indirectly dictated by the competitor’s price.

**Wholesaler with no corporate customers but with substantial presence in Retail Sector**

We investigated the variation of company stock, company margins and pump prices for a wholesaler who only deals with retailers but no corporate customers. Figure 3 shows the variation of the margins and pump price with time. We observe that the margins and prices can steadily grow and the stock maintains a certain stable value.

**Fig 3:** Variation of stock and margin for a wholesaler with no corporate customers

This implies that in principal, such a business set up is stable, robust and profitable. Customers can be assured of availability of fuel since there are no stock outs on the side of the retailer. We also investigated the variations of parameters on the side of the retailer and summarized the results in Fig 4. Fig 4 shows the variation, with time, of retailer’s stock, order and sales when supplied by a wholesaler with no corporate customers. We observe that the retailer can maintain consistent stock, sales and orders and good margins. This also implies that the model is viable for the retailer.
The stability of this set up can be attributed to the nature of sales by the retail customer. Since the customer sells small volumes of fuel, sales are maintained by selling to many customers who contribute small values to the company margins. Daily variations in consumption by customers have a small effect on the global margins unless it has been done en mass.

It can therefore be concluded that the business model is viable both for the wholesaler and the retailer. However, it is not necessarily the best as the set up is obviously characterized by big labor requirements since it serves many people at the end and they need a lot of efforts to maintain. At the same time, there is a need for a bigger operational cost (globally) on the side of the retailer. The retailer has to set up many pumping stations so that the final consumer is conveniently reached. The set up costs of such outlets obviously translates into higher operational costs which lower the margins.

**Fig 4: Variation of retailers parameters for a wholesaler with no corporate customers**

We therefore need to investigate the trends on the opposite type of model where the wholesaler deals with only corporate customers but not retailers and compare profitability.
**Wholesaler with No Retail customers but with corporate customers**

We investigated the variation of stock, margins and price for a wholesaler who only deals with corporate customers. We summarize the results in Fig 5. We observe a steady increase in the wholesaler margins which give an indication that the business model is profitable.

**Fig 5: Variation of parameters for a wholesaler with only corporate customers**

We also observe that the stock levels vary and the corporate price is not stable. The corporate price essentially has to be well below the average price. This can be explained by the fact that corporate customers have the ability to negotiate downwards the price more than the retail customers. Comparatively, a wholesaler selling to the corporate customer makes more profit. This can be attributed to the bulk nature of sales and lower expenditures due to reduced required manpower.

We further observe that prices fluctuate more in a corporate only business. This is due to the fact that since corporate customers tend to buy in bulk, they have a higher bargaining power and hence can influence the unit price downwards. Likewise, since they buy in bulk, they can easily change to a competitor if the prices of the competitor are lower.

Practically, it should be noted that much as the corporate customer-only model can generate more profit, its reliance on a few heavy customers make it more fragile.
and therefore, may not be easy to sustain over a longer period of time since an away movement of customers can quickly make the business collapse.

We can therefore deduce that dealing with corporate customers only leads to higher profit margins but is less stable. The business is less in robustness and can therefore easily be put out of operation since loss of one or two corporate customers can highly impact on the operations. We therefore need to consider a case where the wholesaler serves both retail and corporate customers.

**Wholesaler with Retail & Corporate Customers**

In this section, we consider a ‘dual’ model where the wholesaler deals with both retail and corporate customers. This is because it is really more sustainable in practice.

Fig. 6 shows the parameter variations for a wholesaler with both retail and corporate customers. We observe that much as the company margins are increasing, the corporate and retail stock are in principle, low. This can be attributed to the dual operations of the wholesaler. The big volumes often needed by the corporate customers and the high dependence on fuel may drive them away. However, since retail customers need smaller amounts of fuel, they can be sustained by the business model. In this model, despite frequent possible stock outs, the business can easily be sustained.

We can therefore observe that this business model has a higher profit margin compared to the retail only and lower than corporate only. However, it is equally as sustainable as the retail only and more sustainable than the corporate only.
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This business model can be adjusted by varying the extent to which the wholesaler is inclined to the corporate customers and retailers. Intuitively, tending more to the retailer lowers the profit margin but makes the business more robust to price changes while tending more to corporate customers makes the profit higher but makes the business less robust to price changes.

Discussion And Implication To Uganda

Like observed earlier, the survival of the wholesaler depends on how he/she balances profit margins and robustness. In a free market economy, as many wholesalers (and retailers) as the market can accommodate can be allowed into the market. In Uganda, it’s a fairly different set up. While there are many wholesalers, they work on different rules. The difference in rules is largely due to operational restrictions from the home country of the wholesaler.

In Uganda, there are local and international wholesalers. Local wholesalers (like Gapco, CitiOil, Mogas, etc) have less safety, environmental and operational restrictions while international wholesalers (like Shell, Total, etc) have stringent restrictions. The local wholesalers have relatively low capital and therefore cannot have a comprehensive distribution network in the country. They therefore concentrate in cities where the sales are high. Multinationals, due to their age and resources, have a more comprehensive distribution network in the country.

Their operational constraints however makes their operations more unprofitable comparatively. In terms of safety, they have to enforce a limited storage on a retail outlet so that the danger, in case of fire, is minimized. Due to their big network, they have to have depots where huge amounts of fuel are kept and it is from there that the distribution to outlets can be made. Inevitably, these multinational wholesalers incur more costs in maintenance of depots which lowers the global margin of the company.

Local wholesalers have no such safety restrictions from any parent company. Some have, therefore, constructed very large storage facilities at their outlets. These facilities act as local storage but also as depots. This saves them costs of maintaining depots and therefore, they operate at a higher profit margin. Such a local wholesaler therefore, due to less emphasis on safety, can afford to reduce the price especially that offered to the corporate customer. He has the capacity to outcompete the multinational wholesaler from corporate customers. Since corporate customers lead to higher profit margins, the local wholesaler is bound to enjoy higher profits compared to the multinational wholesaler. The multinational dealer, therefore, has to rely on retail business which has lower margins. In case there was uniform environmental and safety restriction, the ground would be more level for competition. In such a set up, the multinational wholesaler may be better off shifting the business to a country with more safety standards.

Shifting the business of multinational wholesaler comes with more longer term on the fuel distribution chain. This is because the remaining players in the market do not have the capacity and network to distribute fuel in the entire country. Since it comes
with low margins, it is not something that makes business sense. Therefore, the local wholesalers are not likely to be attracted to it. The distribution of fuel in up country locations is likely to be affected by the lack of fuel supplies. This will lead to high fuel costs there and hence hampering their economic growth.

**Conclusion and Future Work**

**Conclusion**

In this paper, we modeled the supply chain of fuel in a free market economy taking Uganda as a case. First, we look at the variation of business parameters and the viability of the possible business models. We then analyze the results for the Ugandan scenario. Much as the Ugandan government considers a free market environment, the ground is not leveled because of restrictions imposed on multinational dealers by the parent organizations. This makes multinational dealers uncompetitive to corporate customers and they run an expensive, less profitable but safe and environmentally friendly business model. This makes them more vulnerable as the local wholesalers can easily outcompete them. Indeed, this has can be evidenced on the ground as some multi-national wholesalers like Agip and Caltex already chose to quit the market.

**Future Work**

This work creates an opening for further research especially on the long term effect of the current fuel market in Uganda which is seemingly free but actually not free. This is mostly on the effect on economy of Uganda since it is clear that the multinational wholesalers actually may not be sustained in the current situation. The local wholesalers may extend their network to the upcountry locations as the multinationals vacate. However, since they operate on a different model, its effect on the employment status, overall fire/fuel safety in the country as well as the overall cost of fuel in the country is not yet known. There is also a need to study a case where the international safety standards are enforced in Uganda and if it is possible for the local wholesalers to realign themselves in the new rules while still in business.

**References**


On the Mobile Technology Enabled Peer-Evaluation: A User Centric Approach

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Abstract

In collaborative learning, students at various performance levels work together towards a common goal through both formal and non-formal learning. There is a risk of underperformance for learners unless they can monitor their progress.

One solution to cope with underperformance is to allow students to take part in their regular evaluation and feedback by peer-evaluation. Peer-evaluation encourages active participation, and gives the students an opportunity to compare their work to those of others, which leads to positive competition. On the other hand, peer-evaluation gives the teacher an overview of the students’ perspectives and expectations from each other which can translate their own understanding of the subject matter. However, peer-evaluation presents many challenges in terms of organization, management, usability and technology support.

This paper discusses how to use the mobile communication technology to support peer-evaluation and proposes a user-centered design approach for system design. Given our interest in mathematics education at university level, we have adopted an exploratory interview study with a target user group consisting of engineering students who have completed at least one mathematics course. Based on the information gathered from the intended users, we propose a mobile peer-evaluation system functional baseline, comprising processes that are presented in this paper.

Keywords: Peer-assessment, peer-evaluation, mobile learning, user-centered design.
Introduction

Learning in the 21st century comprises both formal and non-formal learning, the latter being embraced at almost all levels of university education thanks to Information and Communication Technologies (ICT). Learners are struggling to cope with the new ways of learning where the information reaches them in different formats and from different sources. It is difficult to keep track of individual progress in such a learning environment. Furthermore, the concept of collaborative active learning makes it imperative for learners to cooperate in their learning. Given the differences in students’ abilities, there is a need for regular formative assessments to ensure that everyone is on the right track. Topping [1998, p.249] argued that “Formative assessment aims to improve learning while it is happening in order to maximize success rather than merely determine success or failure only after the event”.

In a collaborative learning environment, students have the possibility to achieve shared meanings of concepts through discussion and argumentation. They have a shared responsibility and ownership of learning; hence they should also play an active role in their progress control. Maclellan [2001] stated the need for students to monitor their own performance so that they could effectively use feedback for improvement in learning. Progress control (evaluation) provides performance indicators which can motivate learners to achieve their learning goals in time.

Peer-evaluation, a process by which learners evaluate each other, provides feedback to each learner and the process gives them - learners- an exposure to their peers’ work. This exposure can create a sense of competition among learners and also help them to experience their peers’ approach to problem solving. We also believe that reviewing the work of colleagues through criterion-based reference evaluation does not only promote the generation of a constructive feedback but this also improves the students’ reflective learning skills.

Previous studies in the area of technology enabled feedback systems. [Venkataramanujam et al., 2010; Chen 2010; McLuckie et al., 2004; Denton et al., 2008] have shown a number of issues such as the difficulty to provide constructive feedback, inconsistency between teacher’s feedback and students’ feedback, time consumption, complex facilitation and moderation of peer-evaluation, technical issues in terms of connectivity, usability and others.

The motivation behind this work is the possibility of solving the above mentioned issues, through the use of appropriate information and communication technology tools. This would provide an opportunity to achieve the pedagogical objectives while technological complexities are seamlessly addressed. The question is to know whether the students would be interested in a modern technology based peer-evaluation solution or not, and what their needs and requirements for such a system would be. This paper proposes a user-centered design approach for a mobile communication technology supported peer-evaluation system. The aim of this paper is to present the methods and results of interacting with the intended users, in order to find their needs, and establish...
their requirements for defining the system processes. The mobile communication technology supported peer-evaluation system, which is hereafter referred to as “Mobile peer-evaluation system (MOBIPEV)”, entails the use of mobile devices for end-users in the context of “mobile learning” as discussed in section 2.

The next section presents a brief introduction to mobile learning and an overview of existing mobile peer-assessment systems. In the third section, a description of the interview study is given followed by the results findings in section 4. Section 5 discusses the novel mobile peer-evaluation system processes based on the collected users’ needs. Concluding remarks and future directions are presented in the final section.

Related work

In addition to personal computers, handheld mobile devices are being used for educational purposes, in what is known as “mobile learning”. Mobile learning or m-learning offers mobility, portability and availability of learning anytime, anywhere thus making “ubiquitous learning” a reality. It is believed [Dias et al., 2008] that m-learning will enhance learners’ engagement to create, access, revise and share course content. Despite their known limitation in terms of processing power, memory capacity, display screen size and resolution, as well as input facilities, mobiles devices’ mobility, availability, affordability and various access network technologies support make them candidates for future educational applications. Several studies have been reported in the literature, mostly focusing on learning content delivery and collaboration using mobile devices [Liu et al., 2010; Botzer et al., 2007; Cobcroft, 2006].

On the other hand, there is a growing interest of taking mobile learning beyond content delivery and collaboration to include new concepts such as context aware-mobile learning and mobile self/peer-assessment. While the former is out of scope of this work, the latter is closely related to our area of interest. In the following paragraph, this paper summarizes mobile self-assessment and mobile peer-assessment studies of interest.

Liu [2004] proposed a peer- and self-assessment model for mobile learning comprising a step by step list of activities. The model describes the procedures involved to ensure that learning is achieved through multiple assessments. The author raised open questions from the suitability of mobile devices for peer-assessment to procedural arrangements and target user group. Later on, de-Marcos et al. [2010] discussed the improvement of student performance in secondary and tertiary education using m-learning auto assessment. The authors presented a mobile web-based tool to support self-assessment in such a way that the students complete questionnaires and the system shows them their results. This solution is limited to multiple choice questions and does not provide elaborate feedback to the student. Another recent study on mobile self- and peer-assessment [Chen, 2010] has developed a “Mobile Assessment Participation System (MAPS)” on PDA (Personal Digital Assistant) platform. Using this system, students provide feedback on their peers’ presentations; and subsequently each student can assess
his or her own presentation as well as the peers’ presentations anonymously via PDA. This approach shows potential benefits to the students, as they receive detailed feedback based on predefined assessment criteria. The author stressed the need to prevent potential negative effects of unfair or harsh peer-assessment from those students with low scores; it was suggested that all results be given once the entire process is finished. It is noted that this system was designed only for assessment of presentations, which means that there is no record for student's work; therefore students may challenge their given scores and it may also be difficult for students to recall how they performed in order to improve their performance in the future. Furthermore, the system does not provide for asynchronous assessments and from a system design perspective, there is lack of user involvement even though it is vital to consider user requirements from intended system users.

Methodological Approach: User-centered design

Methodology consideration and selection of tools
This research work has adopted an interview study because of two main reasons: a pedagogical perspective and best practice in user centered design (with reference to ISO 13407 [ISO 1999]). The first reason, the pedagogical perspective, stems from the fact that interviews enable the interviewer to collect the learners’ opinions about peer-evaluation as a process, especially on those aspects relating to how this can affect either positively or negatively the teaching and learning. By conducting interviews, an understanding of what learners would expect from the peer-evaluation process is depicted, including the learners’ views on how and when this should be undertaken. Furthermore, any misunderstanding or misconceptions would be cleared early enough, for both the interviewee and the interviewer throughout the interview process, which also serves as a learning opportunity for both.

The second reason is that, an interview study can be used as part of an iterative development cycle for the development of human-centered interactive systems. The interviews foster active involvement of users in understanding and specification of the context of use, user requirements as well as organizational requirements. Further on, usability issues have to be considered in software product development process, in order to develop easy to use applications which can meet the intended users’ needs.

This research has considered one-to-one interviews with students, whereby the same researcher conducted interview sessions with digital audio and video recording. Although digital audio and video recording presents many benefits in terms of storage, sharing, processing and analysis; one of the interviewees was not comfortable with video recording, thus opting for audio recording only. With reference to the works of Hall [2000] and Roschelle [2000], Carlsen [2008, p.58] reiterated the effects of video camera presence in data collection, saying that “the key question is whether the participants change their behavior, because of the video camera, to a degree that makes answering of the research questions difficult”. Besides dealing with video recording
issues, this research has also considered other ethical issues including but not limited to participants’ privacy, anonymity, the consent to participate, the right to withdraw from the research, data usage and honesty on behalf of the researcher among other things.

In order to obtain a representative sample of users, this study identified and selected a target group of engineering students who have completed at least one mathematics course at undergraduate level and a graduate (master) student who has taken an advanced mathematics course. With reference to the study by Kujala and Kauppinen [2004] regarding the number of representative users, we consider that ten users can provide useful information given the scope of our study. Students meeting the above mentioned criteria were randomly contacted both in person and by e-mail. The areas of study of the student participants comprise Computer Engineering (7 students), Civil Engineering (1 student) and Renewable Energy (2 students). There were 9 undergraduate students and 1 master student. The age group was 20-25 years old (7 participants) and 25-30 years old (3 participants). Two female participants and 8 male participants were interviewed on a one-to-one basis, each interview taking roughly 25 minutes, and all interviews were conducted during a 2 week period.

**Interview questions**

The interview questions used in this study are framed under three main themes as shown below:

**Students’ opinions regarding “peer-evaluation” process:**

1.1 What do you think about peer-evaluation?
   1.1.1 On a scale of 1-5, how would you rate peer-evaluation with 5 being “Strongly like it” and 1 being “Strongly dislike it”?
   1.1.2 What would be your preferred type of feedback? Please choose from the list below and give details:
   1.1.2.1 Peer-feedback
   1.1.2.2 Teacher feedback (formal feedback)
   1.1.2.3 Automated (computer generated) feedback

1.2 Learners participation in peer-evaluation:
   1.2.1 Would you take part in peer-evaluation as a feedback provider? Please give details.
   1.2.2 If you answered yes on the previous question:
   1.2.2.1 How many peers’ work would you feel comfortable to evaluate?
   1.2.2.2 How many evaluation cycles (iterations) are you willing to make?
   1.2.2.3 How frequently are you willing to take part in peer-evaluation?

1.2.3 How long should a peer-evaluation session take?

1.2.4 How much of your own free time are you willing to spend on peer-evaluation?

1.2.5 Would you like to receive feedback from your peers? Please provide details.
1.2.6 What is your opinion regarding anonymity for feedback provision?

II. The expected impact of “peer-evaluation” on teaching and learning:
1.3 How do you think peer-evaluation could influence your learning performance?
1.4 Would you like peer-evaluation to contribute to the final grade?
1.5 Learners’ Grouping:
   1.5.1 Do you prefer group work or individual work?
   1.5.2 What do you think should the ideal group size be?
   1.5.3 What do you think should be the grouping criteria?
1.6 Feedback on feedback:
   1.6.1 Do you think there should be an evaluation (by a learner) on the feedback provided by another learner? Please provide reasons.
   1.6.2 Should the feedback on feedback contribute to the final grade?

III. Opinion on mobile peer-evaluation system (MOBIPEV)
1.7 Would you prefer MOBIPEV over a personal computer web based peer-evaluation? Why?
1.8 What would you prefer between synchronous peer-evaluation and asynchronous peer-evaluation? Please give details.
1.9 Considering a MOBIPEV intended for a mathematics course, please give your opinions about the following:
   1.9.1 Minimum acceptable screen size
   1.9.2 Graphics / Visualizations: minimum screen resolution, colors
   1.9.3 Input type: QUERTY keyboard, numeric keypad, touch screen with/without radio buttons, drop-down menus
   1.9.4 Access technology: Wi-Fi, 3/4G, Bluetooth
   1.9.5 Multimedia support: Audio, video, still pictures

Interview study results and analysis
In this study, we adopt a thematic and comparative analysis in order to present the outcomes of the interview study.

Where possible a graphical representation of data is given together with interpretations, otherwise a summative discussion of the respondents’ points of view is provided.
Students’ opinions regarding “peer-evaluation” process

Figure 1. Rating of MOBIPEV

The interview’ results indicate that the students are interested in getting feedback from peers, the reasons being that students can easily remember things if they do it many times through peer-evaluation and can improve their performance if regular feedback is given. Student number five said that “it can be easier to improve if you get feedback more often”. Additionally, students could learn while marking others’ works. However, one of the respondents was concerned with the ability of students to evaluate their peers’ works. On the other hand, there are clear indications that students would prefer the teacher’s feedback because they believe that the teacher knows better even though the peer-feedback would be more time saving. Therefore, the peer-evaluation process should be well explained to students and the grading criteria must be clearly and objectively presented. Figure 1 shows the students’ attitude regarding MOBIPEV. “Std#” represents a student number hereafter.
Furthermore, it is shown in Figure 2 that, according to the students, the number of feedbacks/assessments should be around 3-4. The respondents were concerned about the amount of time spent on peer-evaluation but they also stressed the importance of having multiple feedbacks. It was mentioned that students could learn various approaches to problem solving and get better understanding of the course subject by reading feedbacks from different individuals. Figure 3 and Figure 4 respectively show
that, the amount of effort for peer-feedback should be within limits of 1 hour and peer-evaluation should be included in a course not more than every 2-3 weeks.

**Figure 4. Frequency of evaluation**

Another finding was that the iterations in peer-evaluation are useful but should not be more than two. Iterations could be used to increase learners’ mastery of the subject through repeated tests on a given topic. However, if a particular group of students does not perform well despite the iterations, the group members should be swapped with members of other groups.

On the issue of anonymity in peer-evaluation, 50% of the respondents said that it should be compulsory, 40% of them thought that it is not necessary; with student number 7 explaining that “it should be open so that you can have the possibility to ask the one that marked you why, may be he can explain why and may be help you”. One student was indifferent on this.

**The expected impact of “peer-evaluation” on teaching and learning**

This research has found that the students expect the peer-evaluation to have a positive impact on their learning performance. It was said that peer-feedback could give more opinions in a short time and by seeing the peers’ work, students would push themselves to work harder in order to get better results. In addition to this positive competition
effect, the respondents revealed that peer-evaluation would improve their analytical skills as they try to provide constructive feedback.

As for the contribution of peer-evaluation results to the final grade, 60% of the respondents thought that this would not be helpful because they don’t trust that their peers’ evaluation would be correct and fair. Student number 3 said that “it would have to be marked by at least 4-5 people, I think, for that to really work and to be fair, so that not just one get graded and you are stuck with that grade”. Another raised concern was that the final grade could be affected by underperformance at the early peer-evaluations when the students have not yet settled into the course. On the other hand, 40% of the respondents said that peer-evaluation results should contribute a percentage of the final grades, with one of them suggesting up to 70%.

**Figure 5. Student group size**

![Figure 5](image)

Figure 5 indicates that when students study in a group, there should be not more than 3 students per group. The respondents suggested a manageable size of 3 for all group members to be able to discuss without much interference or the tendency to move away from their task. This size also allows easy communication and it is expected that at least one group member is likely to know how to approach the given assignment. It became apparent that the group members’ selection criteria were not straightforward, but it was suggested that groups be made of a mixture of different skills/performance levels perhaps based on earlier grades. Even though there were also suggestions of putting together the students of the same caliber, ideally each group should consist of at least one very good student, one good student and one average or below average student.

When asked whether “feedback on feedback” should be provided, respondents indicated the need for it, saying that it would help on quality feedback provision. But, this being time consuming, they also suggested that it should not be carried out all
the time. An indication of 1 out of 4 feedbacks was given. 60% of the respondents recommended the contribution of the feedback on feedback towards the final grade to ensure commitment and objectivity in feedback provision. One participant noted that this contribution should not exceed 5% of the final grade, whereas two other participants commented on its drawbacks such as time consumption and penalizing students on first rounds of peer-evaluation when they are not yet confident about the process itself and the course of study.

**Opinion on mobile peer-evaluation system (MOBIPEV)**

The participants were also asked questions designed to evaluate their attitude about a potential mobile communication technology supported peer-evaluation system, which could be used in mathematics courses. The respondents indicated a great interest in the system but 60% of them mentioned their preference for a Laptop PC over smaller mobile devices. This is also reflected in Figure 6 which shows the minimum acceptable screen size for the mobile devices. For instance, student number 1 indicated that the minimum screen size should be 3 inches because “it is the same screen I’ve been using to read text and I can read documents on this”. In addition to that, 90% of the respondents chose QWERTY keyboard as their preferred input device for text input in feedback provision. On the visualizations and screen resolutions, the respondents appeared not to be aware of available options but they noted the need for color graphics.

Furthermore, all respondents indicated their concern about data traffic costs, thus opting for Wi-Fi access technology because it is free to use on university campus and cheaper than cellular network if not on campus. Only 10% of the respondents expressed a willingness to pay data traffic charges to carry out peer-evaluation, but not to exceed 30 minutes of cellular network connection time. It is noted that, 60% of the respondents preferred “asynchronous” peer-evaluation because of flexibility. The advantages of synchronous peer-evaluation such as easier organization and efficiency were noted by 20% of the participants. The participants also indicated that written text feedback is more suitable because the reader can have direct control and easily grasp the feedback. Audio feedback would be optional.
A novel mobile peer-evaluation system processes

The previous two sections describe user studies and analysis that are used for studying the user requirements and context of use. Subsequently, we proceed with a conceptual presentation of the MOBIPEV system processes as follows:

1. The students enroll for a course
2. The students learn the course contents
3. The system prepares exercises
4. The system creates student groups (criteria based grouping)
5. The system distributes group exercises
6. Groups meet physically to work on exercises
7. Group members separately submit individual exercise solutions
8. The system assigns answer-sheets for review/evaluation to students
   a. Students are selected for evaluation and feedback provision:
      i. random selection
      ii. criterion based selection
   b. Each student is assigned 3 answer-sheets
9. The system distributes answer-sheets and correct solutions to students
10. Students evaluate answers and submit their feedback and grades according to:
    a. The review/feedback criteria set by the teacher
    b. Grading criteria set by the teacher
11. The system has now three reviews per answer sheet:
    i. The quality of review is ensured by: Feedback on feedback with reference to the correct answer
    ii. Comparing the reviews from 3 students
12. System generates and distributes new exercises based on last exercises’ topic
13. Students meet physically and work on updated exercises
14. Go to step number 7 one more time
15. Post processing:
   a. Performance statistics are collected
   b. Individual progress monitoring and reporting

Conclusions and future work
A user-centered design approach was adopted to develop mobile peer-evaluation system processes. The results of one to one interviews of the potential system’s users, have given early indications that the students are interested in getting feedback from peers. The regular peer-feedbacks should be carried out every 2 to 3 weeks; with each session not taking more than 1 hour, during which every student participant would provide 3-4 feedbacks.

The respondents commented on the positive impact of peer-feedback on learning performance and they indicated the necessity to implement the system on mobile platforms with screen sizes of 7” to 10” as well as QWERTY keyboard text input facility.

Future work will follow the steps of an iterative user-centered design cycle to develop the MOBIPEV system. The next step is the visualization of the design ideas and evaluation of designs against user requirements through user studies. This research has encountered user involvement challenges; however student participants took part thanks to using multiple communications channels. The authors will in the future engage with the intended users at a very early stage.

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References


Towards a Model for Implementing Local E-government in Uganda

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Abstract

The need to implement local e-government for improved service delivery is well documented and various models have been proposed for this important task. However, existing models are known to be suited for implementing e-government in the developed countries at the national level. In the developing countries, the technical and non-technical infrastructures are not as mature as those of developed countries. Requirements for local e-government also differ from those at the national level due to differences in technical, social and political factors, necessitating customized local e-government implementation models. In developing countries, local e-government implementation is also constrained by lack of information about its requirements, with the possible risk of duplication of national experiences and knowledge. The need therefore remains, to determine requirements and customize existing e-government implementation models to suit local governments in developing countries. This paper reports on a study that developed a model for implementing local e-government in Uganda, as an example of a developing country. The model which builds on an existing one defines dimensions of financial constraints, ICT infrastructure, sensitization, training and social political factors as pre-requisites for successfully implementing local e-government projects in Uganda.
Introduction

E-government brings benefits to citizens of both developed and the developing countries. It enables them to collaboratively participate in decision and policy making, and to bridge the interaction gap between ordinary citizens and government. This leads to savings on costs for both governments and citizens and facilitates increased transparency and reduced corruption in public service delivery [Bwalya, 2009]. E-government practices are therefore a means for public administrations to improve their performance by increasing the efficiency of management processes and reducing costs in the provision of public services. It is applied across a wide range of services including city planning, social services administration, physical or information infrastructure management, emergency management, public records and archives, community or economic development, health care, education and property assessment.

Local e-government is part of e-government. It enables administrations to extend services to local communities by providing space and online means for people to get together and communicate in a non-commercial environment in ways that are more relevant to government. It also provides government agencies with the opportunity to offer new and enhanced services to the public, to increase the involvement of communities in policy making and improved service provision [Carbo et al., 2005]. Although e-Government is a reality at all public organization levels, it has the biggest impact at a local level where between 50% and 80% of the citizen’s interactions with public bodies occur [Heeks, 2006]. Thus Local e-Government is vital as it empowers managers with the software to integrate changes in the internal workflow that makes municipal administrations run smoothly [Cortés et al., 2006].

Despite its importance, the implementation of local e-Government has remained problematic and constrained in developing countries. This is because Local governments often lack independent decision making powers in the area of e-Government, and often rely on funding from central governments to implement new initiatives [Shackleton and Dawson, 2007]. There is also lack of information regarding e-Government implementation at the local level since most of the current e-Government research and designed models have focused on national and state-level e-Government practices with few investigations focused on the local government [Capgemini, 2007]. The need
for local government agencies to interact with other government agencies to deliver their services is yet another impediment to local e-Government implementation for a developing country [Benamou, 2005].

For the successful implementation of local e-government in developing countries, the gap therefore remains between current e-government implementation models design and the real conditions on the ground. This according to Heeks [2003] ‘Archetypes of failure’ is referred to as the Design-reality gap. The existing International e-government implementation models are focused at national and state level and are more suited to the developed countries with up-to-date technology, and more non-technical issues such as concentration on public awareness and e-readiness than developing countries [Zarei et al., 2008].

This study aimed at developing a model for local e-government implementation in Uganda, as an example of a developing country. Questionnaires in a descriptive field study were used to collect requirements for local e-government implementation. A model defining dimensions of financial constraints, ICT infrastructure, sensitizations, training and social political factors as pre-requisites for implementing local e-government in Uganda was developed. The model describes requirements that are critical to successful implementation of local e-government in Uganda. It therefore has potential to guide successful local e-government project implementation in Uganda and other developing countries with similar contexts. The model is generic and can therefore be applied to other developing countries. Furthermore, understanding of requirements for local e-government projects contributes to extending existing e-government implementation models.

The rest of this paper is organized as follows. Section two discusses e-government and its implementation models and their shortcomings. Section three explores local e-government in Uganda and its shortcomings. Section four presents the research questions for this study. Section five explains the methodology used to answer the research questions and derive a new model for local e-government implementation as an extension of existing ones. The new model is then presented. Conclusions are made in section six.

E-Government Implementation

E-government uses Information and Communications Technologies to build information systems for improved efficiency and effectiveness in service delivery. It ensures accountability of government to citizens using applications like the internet, websites, mobile phones, telegrams, telex and fax messages [Eilu, 2009]. Using E-government, employees are provided with an effective means of sharing information and exchanging knowledge. It enables government agencies to talk, listen, relate and continuously communicate with citizens. This helps to support accountability, democracy and bring improvements in public services. E-government systems help to deter corruption and
tribalism in the public sector since every action taken involves a machine which is difficult to corrupt [Al-Shehry et al., 2006].

The State of E-government Implementation in Sub Saharan Africa
The state of e-government development in Africa varies from country to country. In Zambia e-government is still at the infancy stage of implementation without a dedicated strategy in place [Bwalya and Heally, 2010]. Zambia has a deficiency of e-government capacity with the index of 0.76, below many African countries like Zimbabwe, Congo and South Africa [UN Report, 2008]. The challenges to e-government development in Zambia are; resistance from both employees and citizens, lack of ICT infrastructure for accessibility to e-government projects, lack of IT skills among human resources especially in rural areas, and overreliance on donor support to fund e-government development [Bwalya, 2009].

Based on the e-government indices, Botswana is currently considered one of the ICT usage power houses in sub Saharan Africa [Bwalya, 2009]. Despite such gains, it still lags behind other countries like Tanzania, South Africa and Lesotho, due to lack of a formal e-government strategy. It also has a problem of lack of trust by both the citizens and employees in the e-government technology employed. Thus, citizens are still reluctant to fully utilize the e-government services. There is also a problem of limited levels of education. This makes it hard for people to access e-government information and exchange views with government officials when it comes to decision making. There is also the problem of ignorance of the importance of e-government to citizens due to limited sensitization, promotions and awareness campaigns.

In Kenya the e-government development effort is constrained by the lack of government ICT policy, poor information infrastructure, entrenched graft, the digital divide, and inadequate human skills. The reluctance to share information has resulted in policies that deny access to information and the creation of government ministry websites with content of little value to the public. Low IT literacy in the country has slowed down the process of e-government in Kenya. There are inadequate qualified ICT staff and training schemes to serve the country. The existing training opportunities are limited and costly for the ordinary citizen [Jaeger and Thompson, 2003]. There is a problem of a mismatch between the current and the future systems resulting from the large gap between physical, social, cultural, economic and other contexts between the software designers and the place in which the system is being implemented [Kamar and Ongo’ndo, 2007]. Financial constraints and mixed government priorities have also slowed down the rate at which e-government is introduced in Kenya.

In Uganda, the e-government strategy aims at delivering high-quality customer-centric and performance-driven services to its customers. The expectation is that e-Government will contribute to Uganda’s economic and social development, as well as the transformation into a competitive, innovative knowledge society [Rwangoga and Baryayetunga, 2007]. The challenges to implementing e-government in Uganda are, the lack of adequate resources to dedicate to ICT programs, a limited effort at reviewing
business processes and rearrangement of staffs to promote efficient application of electronic Government processes and applications, lack of coordination and training across the government, lack of staff training, poor connectivity of networks and low appreciation of integrated information systems [ibid].

Generally, implementing e-government in developing countries faces problems of: 1) limited ICT infrastructure especially in the remote rural areas, 2) poor non-user friendly design of websites for e-government due to limited computer literacy levels, 3) low education levels have also increased the rate of unwillingness to use e-government because the content is mainly presented in English other than common local languages, 4) inadequate human resource base trained to handle e-government projects to produce efficient public service delivery, 5) donor funding strongly affects the sustainability of the developed projects in the aftermath of project sponsorship from the donors, 6) lack of a formal e-government strategy, 7) Ignorance on the importance of e-government to citizens due to limited sensitization, promotions and awareness campaigns [Bwalya, 2009]. However, on the other side government agencies have the political will and intentions to implement e-government because they understand its benefits to their country.

E-government Implementation Models
Many countries using different models have attempted to implement e-government as the most fundamental infrastructure for programs that leverage Information Technology in facilitating organizational change [Zarei et al., 2008]. Based on the complexity and level of integration, Siau and Long [2004] provide a taxonomy of the different stage models of e-government implementation. The taxonomy is based on the e-Government implementation models of: i) Hiller and Be’langer [2001]; ii) Layne and Lee [2001]; iii) Moon [2002]; iv) the United Nations [UN] web Presence Measurement Model [2001]; v) Gartner Group [Baum, and Maio 2000]; and vi) Deloitte and Touché [2001]. Some of the stages for the different models are similar while others are different as described in the following subsections.

The UN web Presence Measurement Model [2001] provides an efficient web-based public service whose implementation has five stages of i) emerging, ii) enhanced, iii) interactive, iv) transactional, and v) seamless web presence. The emerging web presence has a dormant website for posting information on different activities. The enhanced web presence stage creates and links together websites to enable citizens access information across ministries. The web sites provide dynamic, specialized, and regularly updated information. The interactive web presence is a two way communication stage where citizens’ and government can exchange information easily. At this stage, government web sites act as a portal to connect users and service providers. At the transactional stage buying and selling of products take place online. At the integrated presence stage, governments utilize a single and universal website to provide a one-stop portal in which users can immediately and conveniently access all kinds of available services.
Gartner’s Four-stage Model [Baum, and Maio 2000] has four stages of e-government implementation namely: i) web presence, ii) interactive stage, iii) transaction stage, and iv) transformation stages. The presence stage is where a website enables government to offer static information to citizens. The interactive stage is where the website has search ability to enable citizens interact with the government. The transaction stage enables exchange of services like making payments and receiving services online. The transformation stage is the online execution of public services requiring integration of different ministries to provide all kinds of information to citizens in one place.

Layne and Lee’s Four-stage model [2001] has four model stages of catalogue, transaction, vertical and horizontal integration. At the catalogue stage, static information is posted on the government website for public viewing, but citizens can neither reply nor make any comments. The major task of the administration is the management of the content published on the web. The transaction stage enables citizens to have two way communication, and they can read, down load forms, fill and submit. The vertical integration stage is where different government ministries and departments are linked or connected together to offer seamless information to citizens, employees and government agencies. It focuses on integrating government functions at different levels, such as those of local governments and state governments. The target is to integrate central agencies with regional and local offices within similar functionalities. Horizontal integration involves different departments and sections of different ministries to enable easy exchange and communication of information. The outcome of horizontal integration is an automated process oriented back-office organization able to interact within different offices in different regions and countries and to share resources.

Deloitte and Touché [2001] proposed a six-stage model consists of: i) information publishing, ii) official two-way communication, iii) multi-purpose portals, iv) portal personalization, v) clustering of common services and vi) full integration and enterprise transaction. Information publishing is where governments provide users with increased access to information on a website. Official two-way communication stage is where interaction between government agencies and citizens are made possible through use of government websites using information and communication technologies such as digital signatures and security keys. A multi-purpose portal provides information concerning different departments to citizens using a single portal. Portal personalization is where citizens can customize the portals to their needs. Clustering of common services is where governments encourage collaboration and reduce on the mediators purposely to provide a unified service. Full integration and enterprise transaction offers sophisticated and personalized services to customers basing on their tastes and preferences.

Hiller and Be´langer [2001] identify five stages for e-government implementation as information stage, two-way communication, transaction, integration and participation stage. The information stage is where basic information is put on the government website for public viewing. Two-way communication is where citizens are able to interact with government agencies through viewing, downloading, filling and resubmitting forms.
Transaction stage enables citizens to carry out online transactions and applications. Integration stage is where all government websites are integrated horizontally and vertically to enable citizens access information from different ministries and departments at the same time and in one place. Participation stage is where one can vote online or file comments online. This stage requires a very high level of security and privacy and is in its infancy stage throughout the world.

Davison et al. [2005] argue for e-government implementation in five stages of web presence, interaction, transaction, transformation and e-democracy. The first three stages aim at automating and digitizing the current processes while the last two aim at transforming government services. The five stages are interrelated and one leads to another though it’s not a must that one has to follow the order. The stages present a development rather than a must-go-path. System complexity and integration increase with advancing stages.

Zarei et al. [2008] describe a nine stage model for e-government implementation in a developing country has been described by Zarei et al. [2008]. The nine stages are strategy development, building infrastructure, building trust, making a physical and electronic portal, initial interactions and stimulation, prototyping, enrichment and multidimensional development, integration, and development of the ICT industry. These nine stages are based on the Iranian experience.

Siau and Long [2005] conducted an analysis of the existing e-government implementation models in order to find commonality for the various phases. From their meta synthesis, they summarize e-government implementation into five phases of: i) Web presence for posting static information for public viewing ii) Interaction for two way communication iii) Transaction iv) Transformation for business process reengineering and horizontal and vertical integrations and v) E-democracy for online voting, polling and surveys. The models as presented above are here summarized and compared as shown in table 1 on the basis of the synthesized e-government stage models of Siau and Long [2005] and Zarei et al. [2008].

Table 1: A Summary Comparison of the e-Government Implementation Models

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Table 2.1 above reveals that none of the models caters for implementation of e-government across all national contexts and perspectives. It also reveals that based on the complexity and level of integration, the models of Hiller and Be’langer [2001], Layne and Lee [2001], the UN web Presence [2001], Gartner [Baum, and Maio 2000], and Deloitte and Touché [2001] have similar stages with few variations. This conforms to the taxonomy for e-Government implementation as described by Siau and Long [2004]. A major variation is provided by the nine stage model of Zarei et al. [2008] developed based on the Iranian experience as a developing country.

A Critique of the E-Government Development Models
Existing models for e-government implementation (EGIM) have been developed and used in the developed countries. These models are however oversimplified and are not easily applicable for e-government implementation in developing countries where the technical and non-technical infrastructures are not as mature as those of developed countries [Zarei et al, 2008]. The authors argue for the customization of the international EGIMs to suit the different contexts of the developing countries. Similarly, e-government experiences vary dramatically from one government to another, both between and within countries and there is need for country specific assessment indicators to enable cross-country comparisons by relative scores [Flak et al., 2005].

Existing EGIMs and research have been used in efforts to develop and assess e-government projects with central or national government as the unit of analysis with little regard for the local governments [Lofstedt, 2005]. They are little used in projects to assess e-government services at the local government level that has the most direct contact with the citizens and businesses and is responsible for providing a collection of basic services [Flak et al, 2005]. These models have largely been used in developed countries, and are not equally used in developing countries like Uganda. This is because, developed countries have more up to date technology than developing countries. Therefore there is need for different countries to consider requirement for e-government implementation and incorporate them in the model [Zarei et al., 2008]. In response to these shortcomings of international EGIMs Zarei et al. [2008] proposed a nine stage model of e-government development respect to the experience of Iran, a
developing country as an example of a model that may be applicable for other developing countries with some customization [ibid].

**Local E-Government**

Local Government is an administrative body for a small geographic area, such as a city, town or state controlling a specific region, that cannot pass or enforce laws affecting a wider area. It is a governing institution with authority over a sub national territorially defined area [Hopkins, 1997]. Local government is where the majority of interaction between government and civil society occurs [Flak et al., 2005]. It only acts within powers delegated to it by directives of the higher level of government and each country has a kind of local government which differs from those of other countries.

Local e-Government is the management of all local government processes, in and outside administrative premises by deploying Intranet and Extranet applications to empower managers with proper software to achieve integration and develop changes in the internal workflow to make the city council’s administration run smoothly [Cortés et al., 2006]. It is an online presence to enhance the quality, speed of delivery and reliability of services to citizens and businesses by adopting ICTs to modernize and change the way their administrations work [ODPM, 2003]. The development of local e-government projects can involve individuals from different departments within the local authority, other local authorities, regional partnerships, national projects, other public organisations and the private sector.

Local e-government provides benefits to both government and citizens like electronic voting [WITSA, 2003]. This is because e-voting is still at a local rather than central government level. Local e-government once implemented allows voters to cast their ballots in the local assembly elections from electronic voting machines. Local e-government can also help to renew local democracy by making councils more open, more accountable, more inclusive and better able to lead their communities. It enhances the opportunities for citizens to debate with each other and to engage with their local services and councils [ODPM, 2003]. It also enables employees to provide call centres to citizens in local governments. Call centres process big numbers of inquiries that were previously handled separately by respective departments in organizations. Local e-government enables municipal authorities to exercise electronic documentation management, electronic applications and electronic procurement.

Local e-government promotes change by offering citizens’ access to the data held by local government. Citizens can carry out transactions with a 24-hour online service all year round. It also offers citizens the ability to access and check their personal details in the database of the local administration, providing clear, comprehensive and easy-to-access information in areas like legal residence, salary and personal details, new and removed taxable items and many others. Local e-government has the potential to help local authorities improve on their services by making them more accessible, more
convenient, more responsive and more cost effective [ODPM, 2003]. It also makes it easier to join up local services.

**Issues for Successful Local e-government Development**

Although the concept of e-government has been in existence for long, it’s majorly concentrated at the national level and is in short supply at the local level. There is lack of information regarding local e-Government. Most studies about e-Government evolution have been tailored to the national level where it is currently more concentrated, with little information focused on local e-Government [Capgemini, 2007; Gronlund, 2004]. According to Gronlund [2004], the reasons for the concentration of e-government research and projects at the national level are: i) the conflicting goals and priorities of government agencies at different levels which affect the implementation and adoption of local e-government in most developing countries Gronlund [2004], ii) Lack of independent decision making powers by local government in the area of e-Government since they rely on funds from higher levels of government to implement new initiatives, iii) Lack of staff to support Information Systems in the Local Governments since they have to compete for qualified IT professionals with the private sector, iv) fear of change by employees as they feel threatened by new web technologies, creating a resistance, v) lack of sufficient resources to invest in local e-government coupled with budget restrictions, thus making it difficult to spend optimally; vi) Staff turn-over coupled with staff restructuring that lead to loss of skilled and experienced staff in Local Governments [Ndou, 2005], vii) limited ICT infrastructure commonly experienced by developing countries also affects usage and performance of local governments [Uganda e-government, 2005], viii) Inadequate and erratic power supply in rural areas of most developing countries affect performance of local governments [Uganda e-government, 2005], and ix) the Digital Divide which is common in most developing countries.

Furthermore, while indicators of e-government at country level are widely accepted and commonly used, the presence of such standards at regional level are not widely accepted. Therefore, while at the national level, there are many theories and models for e-Government, for local e-government little research is reported [Janssen & Wagenaar, 2004; Kaliontzoglou et al., 2004; Shackleton et al., 2004; Norris, 2005].

Local governments share some of their e-Government requirements with those at the national level, including such needs as interoperability, security, and user friendliness. Besides these, local governments also have specific requirements that are either unique to their context or, because of their characteristics, demand more attention [Kaliontzoglou et al., 2004]. These include cost and resource considerations, enhanced accessibility and greater scalability due to the larger number of citizens and businesses served. The prerequisites for local e-government differ in comparison with the national e-government by way of having fewer and limited resources, which necessitates theories and models dealing with these aspects [Lofstedt, 2005].

Grabow et al. [2002] also mention the factors for the successful implementation of local e-government projects as: i) the need to adapt and fit the guiding principles
and strategy for local e-government to those of the municipality and other central local communities, ii] top leadership and political support for local community e-government from council, iii] e-government is challenged by the financial shortages of towns and cities, and requires that priorities be set for normative, strategic and operational control, iv] integration of e-government requires administrative processes at the local, central or federal level to be seamlessly interlinked without discontinuity of media regardless of where the responsibilities lie., v] motivation and competence of the various groups of stakeholders - for the success of local e-government measures to promote competence and greater qualifications are integrated into the comprehensive strategy of local e-government, vi] staff motivation and training are therefore required for staff to actively participate in the e-government innovations; vii] compliance with the legal provisions is a basic requirement for the successful implementation of local e-government. Legal expertise needs to be integrated into its planning and implementation at an early stage [Eifert et al., 2003].

**Local e-Government in Uganda**

In Uganda, the Ministry of Local Government [MoLG] in Uganda is responsible for supporting and ensuring the efficient and effective operations of Local Governments through proper management and coordination of the Decentralization process [Rwangoga & Baryayetunga, 2007]. After recognizing the urgent need to harness the benefits of e-Government services, the (MoLG) embarked on the harmonization and coordination of e-Government initiatives. Some of those initiatives are the Local Government Information Communication System (LOGICS) and Local Government Financial Information Analysis System (LGFIAS).

LOGICS is an e-Government application chosen for developing national output and outcome indicators along the e-Government domains of e-administration, e-services, e-citizen and e-society. LoGICS has three subsystems of Monitoring and Evaluation, Compliance Inspection and the Computerized Software Sub-system. LoGICS is a multi-sectoral information system covering all sectors in Local Government including: Education, Health, Water, Roads, Prisons, Police, Production, Planning, Finance and Administration, Council and Social Services to mention but a few. It was developed to monitor and evaluate service delivery in Local Governments and also to disseminate the Local Government service delivery and compliance reports to various stakeholders involved in the implementation, via an online [internet-based] One-stop Information Resource Centre facility located at the Ministry of Local Government headquarters. It covers areas like service delivery, area profile, compliance inspection, resource usage, availability, activity planning and completion. However, though LoGICS was put in place to perform the above mentioned tasks, it has not been successful due to a number of weaknesses like i) inadequate capacity of ICT skills at the Local Governments to handle information systems, ii) limited ICT infrastructure, iii) inadequate LoGICS rollout and follow up by the parent Ministry, iv) inadequate and erratic power supply, v) lack of ICT staff to support Information Systems and ICT equipment Local Governments, vi) staff
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turn-over coupled with staff restructuring that led to loss of skilled and experienced staff in Local Governments, vii) attitude, resistance and fear of change, viii) inadequate funding in Local Governments in using LoGICS for planning and carrying out their duties and [ix] inadequate technical capacity at the Ministry of Local Governments [Rwangoga & Baryayetunga, 2007].

LGFIAS is a system for capturing all relevant financial data on revenues and expenditure for all levels of Local Governments. The system has been designed with facilities to analyse and generate in-depth reports on revenue performance, expenditure, donor funds and Central Government transfers to the Local Governments. The reports generated are used by the Local Authorities, Central Government, Development Partners, NGOs and other stakeholders for decentralized fiscal planning, policy formulation and decision making functions.

Challenges to Local e-government Implementation in Uganda

E-government experiences vary between developed and developing countries and these differences are in technical, social and political factors [Flak et al., 2005]. Different countries therefore need to identify major activities required for the development of their local e-government, and incorporate them into the existing e-government implementation models to suit their conditions [ibid]. Thus the need remains, for determining requirements, analyzing and assessing conditions of developing countries in general and Uganda in particular in order to identify weaknesses, strengths, threats, and opportunities before customization of models for implementation of local e-government in Uganda.

There are differences in requirements for national and local e-government implementation. While local e-governments share some requirements like interoperability, security, and user friendliness with national e-governments, they also have specific requirements because of their characteristics including cost and resource considerations, enhanced accessibility and greater scalability due to the larger number of citizens and businesses served. The need therefore remains for empirical studies to investigate and determine requirements for local e-government implementation in Uganda. Such studies should collect, compare, and assess data about actual local e-Government to identify good and bad practices through analysis with a view to improving the development of local e-Government, given its special requirements that focus on cost, resources, and enhanced accessibility [Lofstedt, 2005].

The development and integration of ICT within Uganda’s ministry of local government is uneven, with the lack of adequate resources to dedicate to ICT programs [Rwangoga & Baryayetunga, 2007]. In addition there is very limited effort to review business processes and realignment of staff to promote efficient application of electronic Government processes and applications. Worse still, ICT investment still remains an “ad hoc” affair, with each individual Ministry seeking ICT funding to offset the minimal funding available through the governmental budgetary channels and also most installed systems are not fully being utilized. Part of the reason advanced is lack of
staff training, poor connectivity of networks is poor and low appreciation of integrated information systems [ibid].

**Research Questions**

The literature points to a gap between the existing e-government implementation models design and the real conditions on the ground for the developed and developing countries (the Design-reality gap). The current e-government development models are more appropriate for developed countries that have up-to-date technology, and have resolved the non-technical issues of public awareness and e-readiness. E-government experiences vary dramatically, both between and within countries [Flak et al., 2005].

Motivations toward e-government implementation are essentially different in developing countries. There are fundamental differences in technical, social and political factors of various countries, which demands more customized local models [Flak et al. 2005]. The literature points to the need for different countries to identify major activities required for development of their local e-government, and then incorporate them into a national e-government development model [ibid]. The establishment of an appropriate infrastructure and technical factors are major obstacles for successful implementation of local e-government in developing countries.

The literature also points to differences in requirements for national and local e-government development. While local governments share some needs like interoperability, security, and user friendliness with national e-governments, they also have unique context specific requirements because of their characteristics including cost and resource considerations, enhanced accessibility and greater scalability due to the larger number of citizens and businesses served. The literature also points to two distinct approaches to developing e-government [Flak et al, 2005] One approach is characterized by primarily focusing on cost efficiency whereas the other is driven by a desire to offer added value to citizens. This raises the question of which approach is superior to the other in the development of local e-government. This calls for research towards investigating the different country specific drivers of e-government development. The need thus remains to determine requirements for local e-government implementation models in developing countries [Zarei et al., 2008].

The literature therefore points to the following unresolved questions for successful local e-government implementation in Uganda as a developing country: What are the requirements for a successful local e-government implementation in Uganda? Which model design best supports the implementation of local e-government in a developing country like Uganda? The study presented in this paper sought to provide answers to these questions above and proposed a model for successful local e-government implementation in a developing country. The model is derived and outlined as described in the following section.
Deriving a Model for Local E-Government Implementation

This subsection outlines the steps taken to develop the local e-government implementation model for the Ugandan context as based on the perceptions of managers and administrators. Theoretically, the new model adopts and builds an existing e-government implementation model. The requirements elicited from the field study are used to extend a selected e-government implementation model. The new model of local e-government implementation for Uganda extends the synthesized e-government stage model as proposed by Siau and Long [2005]. Requirements for the model are here revisited and used to extend the adopted model. A summary of the meta-synthesis phases for e-government implementation according to Siau and Long [2005] is also presented as used in deriving the model.

Determining Requirements for the Model

A descriptive survey used to determine requirements for local e-government implementation in Uganda was used. The requirements for the design of local e-government implementation model were derived from the challenges and requirements obtained from the field study. The requirements for implementing local e-government in Uganda are summarized and categorized as technical or non-technical in the following Table 2. The implications of these findings and requirements for local e-government implementation are then mentioned.

Table 2: Summary of the Requirements

<table>
<thead>
<tr>
<th>Technical Requirements</th>
<th>Non Technical Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT skills to use the website.</td>
<td>Low illiteracy rates among citizens.</td>
</tr>
<tr>
<td>Reliable power supply.</td>
<td>Funds to sustain the website.</td>
</tr>
<tr>
<td>ICT Infrastructure</td>
<td>Low costs of internet</td>
</tr>
<tr>
<td>Website connectivity</td>
<td>Staff Training</td>
</tr>
<tr>
<td>Putting in place IT standards</td>
<td>Building trust in citizens</td>
</tr>
<tr>
<td></td>
<td>Adequate financial resources</td>
</tr>
<tr>
<td></td>
<td>Sensitizing citizens on the relevancy of the website</td>
</tr>
</tbody>
</table>

According to the results presented in Table 2 above, in order for local e-government to be successfully implemented, the technical and non-technical requirements need to be put in place. These requirements are: i) adequate financial resource mobilization, ii) Build ICT infrastructure, iii) user training, iv) sensitization of users to benefits & relevancy of e-government and v) favorable Social political factors.


The growing interest in e-government development has led to a number of models with varying or overlapping phases being proposed for its implementation. E-government
research has thus been based on different stage models [Baum, and Maio 2000; UN 2001; Deloitte 2001; Layne and Lee’s 2001; Hiller and Belanger’s 2001] which presents a difficulty in comparing and understanding different research results. Siau and Long [2005] thus have synthesized these five current stage models into a single one that offers a common framework for researchers and practitioners in the area. The new e-government stage model has the following five stages: web presence, interaction, transaction, transformation, and e-democracy.

The Web presence stage has a website to post basic and static information for public viewing. Here interaction between government agencies and customers/citizens is not possible. The Interaction stage is where simple communication between government, government agencies and customers/citizens happens. The transaction stage allows customers/citizens to carry out complete online transactions using the designed government websites. At the transformation stage, governments transform the processes of offering services to customers through horizontal and vertical integrations. E-democracy stage allows citizens to carry out online voting, polling, and survey. This stage therefore promotes online political participation.

The synthesized e-government stage model presents a road map for practitioners to follow in their e-government projects. Its strength is in unifying a number of existing e-government implementation models into one framework for researchers and practitioners to use. These steps though synthesized from existing models, do not suit all contexts as they unify models based on developed countries’ requirements and not those of transitioning countries. The steps can best be used to implement e-government in developed countries where ICT infrastructure, power supply and IT skills are already in place but not in developing countries like Uganda. This is because, in Uganda, ICT infrastructure is not well developed, power supply according to results obtained from the field is not reliable and in some cases does not even exist. The ICT skills among employees are still missing; there is a lot of illiteracy among citizens who cannot use websites on their own. Therefore, the need remains to extend existing model by incorporating requirements generated from the field in order to build one for the Ugandan context.

**An Outline of the Model**

The model outlined in Figure 1 below is an extension of that of Siau and Long’s [2005] synthesized e-government stage model using requirements obtained from the field study. Besides the five established steps of web presence, interaction, transaction, transformation, and e-democracy used for existing e-government implementation, the new model therefore describes new dimensions of: i) financial resources mobilization; ii) Building an ICT infrastructure, iii) training, iv) sensitization and v) Social political factors.
Figure 1: A model for Local e-government Implementation in Uganda

- **Build ICT infrastructure**
  - Provide Networks
  - Network connectivity, Computers hardware, and a Reliable power supply

- **Financial Resource Mobilization**
  - Increased ICT budget allocation
  - Financial control by local government
  - High cost of internet connectivity

- **Web presence**
  - Simple Website with: Static or dynamic information. One way communication with Regular updates and No Interaction

- **Interaction stage**
  - Advanced website, Dynamic information, Simple Two way communication, Can download information

- **Transaction stage**
  - Online transactions. Self services and online applications, online orders and auctions

- **Transformation**
  - Horizontal and vertical integration of Govt. - services. Portals used for seamless services. Remove intermediaries

- **E-democracy**
  - Improve political participation and transparency by - Online voting -surveying -polling

- **Training**
  - Provide ICT skills
  - Computer literacy
  - Sensitize to benefits & relevancy of eGov. Easy communication, reduce costs, faster decision, increase transparency, decrease in corruption

- **Social political factors**
  - Establish IT standards, legal framework, political will, Trust

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**Contributions of the Model to Local e-government Implementation**

While the outlined model in Figure 1 extends an existing one as described by Siau & Long [2005] it also makes a contribution by presenting new features useful for implementing local e-government for a developing country environment like Uganda. The model provides for new dimensions required for the e-government implementation process mentioned and discussed here under the themes of financial resource mobilization, ICT infrastructure development, training, sensitization and Social political factors.

**Financial Resource Mobilization**

The primary challenge to e-government implementation in Uganda is limited financial resources to build sustainable ICT infrastructures. The need therefore remains to mobilize resources to acquire the necessary infrastructure and equipments to support implementation and sustenance of the local e-government projects. Funds are needed to expand capacity, support essential infrastructure and human resource training. Local governments need to lobby for funds from the national government to enable successful implementation of e-government projects. Local governments also need support from development partners (donors) and other private companies and Non Government Organizations.
Build ICT Infrastructure
An ICT infrastructure is recognized as one of the main challenges for e-government implementation in developing countries like Uganda. Following successful resource mobilization, local governments need to put in place an ICT infrastructure supported by reliable power supply and network connectivity. In Uganda, most of the available infrastructure dates back to the 1960s and is outdated. Most public offices in the ministry of local government have few computers that are largely outdated, yet this is a vital part of the ICT infrastructure if e-government is to be successfully implemented. Thus local governments need to put in place basic ICT infrastructure to enable the government capture the advantages of new technologies and communication tools which are very significant for undertaking an e-government initiatives.

Irregular and non-existent electricity supplies are also a barrier to implementation of e-government projects in the ministry of local government especially outside the major towns. This equally affects implementation and usage of e-government projects in Uganda.

Training
Employee training should be done at all the five implementation stages, that’s after putting up a web presence, at interaction stage, transaction stage, transformation and e-democracy stage. This is because different activities take place at different stages and also different services are offered at different stages therefore management need to equip staff members, citizens and well wishers with different skills at different stages. Following the web presence phase, management needs to train staff on how to use and post basic information on the website. At the interaction stage, they need to train staff on how to update information on the website, respond to clients’ requests, complaints and comments. At the transaction stage, staff need to be trained on how to make and obtain orders online and how to offer services to clients. At the transformation stage, management needs to train staff on how to use the new processes. At the e-democracy stage, there is need to train them on how to prepare for online voting, polling and surveys.

Sensitization
Sensitization is important for successful implementation of an e-government project in a developing country like Uganda where literacy is very low, people have negative attitude towards use of the website and are ignorant of the relevancy and benefits of using the website. It is therefore important for the government to ensure that citizens are sensitized at each and every stage of implementation to enable them easily adopt and enjoy services offered at each and every stage. Sensitization can be done through use of public places like libraries, schools, and any other points of computer contact by putting up instruction manuals in both English and local languages to enable them learn, develop interest and then use the system. Citizens should therefore be sensitized
at all the five stages that’s to say at web presence, interaction stage, transaction stage, transformation stage and e-democracy stage.

**Social political Factors**

Local government needs to put in place IT standards, legal framework, have political will and build trust in the use of ICTs. This can be achieved through putting in place clear policies and procedures, treating website users equally and lawfully at all stages, being transparent, giving accountability and holding those in charge responsible for their actions, establishing formal privacy policies and proactively monitoring actual practices to help avoid privacy breaches, setting the legal framework for electronic transactions and integrating IT Security in the system. For the e-democracy stage, the government needs to build trust by introducing use of e-signatures, data security, copyrights and many others.

**Conclusion**

The existing E-government development models have been of little use in implementing local e-government in developing countries. This is largely because the models were developed based on requirements from developed country environments. Developing countries are still in transition and lack up-to-date technology, still face non-technical issues such as lack of public awareness about the benefits of e-government, coupled with a low e-readiness index. Therefore, the requirements and motivation toward e-government implementation is essentially different in developing countries due to these fundamental differences in technical, social and political factors. For a developing country like Uganda the need remains for customized local e-government models. This requires identifying the major activities required for development of local e-government, and incorporating them into the existing models that were designed based on the conditions in developed countries.

This study therefore identified requirements critical to successful implementation of local e-government projects in Uganda as a developing country. The model that was developed incorporates activities required for successful implementation of local e-government. These requirements include i) financial resources, ii) building ICT infrastructure, iii) training, iv) sensitization of relevancy and benefits of e-government and v) social political factors. This model outlined is therefore a step towards supporting local government agencies to successfully implement e-government projects in Uganda. The model generic and can be applied in other developing countries with similar contexts. Furthermore, the understanding of requirements and design of a model for local e-government project contributed to the extension of existing knowledge on e-government implementation models.
References


ARSLA, N. 2007. E-government, contrary to common belief, is not solely a new hype of the [King 2006 p18]. Taking a broad view of this reinvigoration, e-democracy.


BENAMOU, N. 2005. Bringing e-government interoperability to local governments in Europe, European review of political technologies


ZAREI, B., GHAPANCHI, A., AND SATTARY, B. 2008. Toward national e-government development models for developing countries: A nine stage model, the international information and library review, 40,199-207.
A Framework for Managing Intranet Usage in HEIs: A Case of selected Kenyan Universities

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Abstract

These days Intranets are becoming more and more popular throughout the business world and other types of organizations including learning institutions. This paper develops and validates a credible body of evidence supporting the value of corporate intranets in relation to learning institutions’ productivity. The specific goal of this study is to assess both the character and the degree of the impact of the extent to which an intranet is used within institutions of higher learning on both individual organizational functions (such as intra-organizational communications, decision making, group collaboration and employee productivity) and overall, organizational business activities. As this paper purposely sought to assess the impact of intranet in institutions of higher learning, three public universities-Masinde Muliro University of Science & technology, Moi University and Nairobi University - with a functioning intranet in place - were included in the research sample for the study. We therefore develop a framework of measuring intranet usage in higher education institutions for effective return on investment.

Key Words: intranet framework; Higher education institutions; knowledge society; ROI; knowledge management;
Introduction

Organizational intranets in university play a critical role in the emerging dynamic environments of higher education.

Emerging Issues of Corporate intranets

Because intranet infrastructure has an important democratizing effect—data can be made available to everyone, not only to professional scientists but also at the same time to students and teachers [Ed et al. 2008] and this can be measured by looking at its effectiveness in support of business requirements [Grant et al. 2005] in which institutions of higher learning are part. Beyond new scientific discoveries, we are at the dawn of a new revolution in learning due to information and communication technologies.

According to Lytras et al. [2007], in our emerging knowledge society, a firm understanding of the interplay between the management of knowledge and learning is of strategic importance to create and maintain effective learning processes in a large variety of non-traditional learning situations. Intranets allow people to work in a manner that best corresponds to their personality, style and work habits [Chuo 1998]. Wachter and Gupta [1997] note that the increasing use of intranets makes the need to actively manage the development process even more urgent, and although they acknowledge the many tradeoffs involved in intranet management, they advocate a centralized management system that can exercise control and ensure that consistency is maintained [Stenmark 2005]. Through collaboration, intranet IS can function efficiently within the system to drive sustainability [Molly et al. 2008].

The findings of Jonassen et al. [1999] are in line with other researchers, claiming that the empowerment of intranet users enables the employees in an organization to learn about the organization—its goals, ongoing projects, organization and other colleagues [Stenmark 2002, 2003, Duane and Finnegan 2003, Bank and Nystrom 2004]. Learning about the organization through the use of an intranet increases the quality of the human capital in the organization. Furthermore, collaboration and vertical communication are to a high degree supported by functions in an intranet and are examples of technology supporting learning.

In making one-time stimulus expenditures, care must be taken to make investments that lead to substantial short and long-term gains [Ed et al. 2008]. Providing network-enabled opportunities for more students and faculty to work with large-scale data-intensive computing and other cyber infrastructure will yield high returns over many years. A fundamental shortcoming today in trying to increase value from corporate intranets is due to a lack of comprehensive and credible means in which to measure how effective the portals meet the demands of their employees (knowledge workers) and other intended audiences in pursuit of carrying out business objectives [Grant & Luqi 2005].

According to Maria et al [2008], given this challenging context, implementing an effective technology with enhanced learning solutions requires a well-defined strategy.
concerning both the pedagogical model and the integration of emerging technologies to the learning context. According to Miltiadis et al. [2008], to complement the learning process and promote continuous learning, there is need for an environment that uses knowledge management techniques to improve the learning process for building personal knowledge through the exchange of knowledge chains in learning communities.

On the other hand educational productivity is a concept most happily found in economics textbooks where the productivity of a worker or economic unit is defined by dividing the output (revenue) by the input (costs). This is more difficult to define for the education industry since the output is not easily measured, particularly not in monetary terms to compare with the costs. The output is largely the quantity and quality of learning demonstrated by students, or learning outcomes which can be expressed as:

\[
\text{Productivity} = \frac{\text{Output}}{\text{Input}} = \frac{\text{Educational outcomes}}{\text{Costs}}
\]

Outcomes is quality and quantity of student learning
And Costs is Teacher and student time, lecture

From the formula above it is clear that to increase productivity either the outputs must increase, the inputs decrease or both. There has been research conducted to attempt to estimate a numerical value for educational productivity. The best known work goes back to that by Niemiec, Sikorski and Walberg [1989] who calculated cost-effectiveness ratios. They found about a 30% average productivity improvement for examples involving computers compared with about 10% for peer tutoring. Unfortunately, educational productivity is difficult to calculate because it is difficult to estimate the value of educational outcomes. Even so it is useful to consider the concept of educational productivity, particularly the effect that educational technology may have. Educational technologies such as intranets should hence influence educational outcomes and costs.

Turning information into knowledge capital that corporations (such as institutions of higher learning) can leverage quickly for competitive advantage requires a model and supporting metrics [Grant and Luqi 2005]. Nevertheless, in order to measure efficacy of a corporate intranet’s portals, one requires a coherent and balanced combination of metrics taken from all segments. When these metrics are collectively and uniformly applied in periodic measurements, they can indicate tractable improvements over time. Leveraging the intranet from the knowledge management perspective means that the individual employees, and therefore the institutions as a whole, are better to use of their knowledge.

**Intranet Architecture**

There are a number of different definitions of an intranet. Some of them focus on technology while others focus on purpose and use [Bark, 1997; Stenmark, 2002; Telleen, 1998]. Technically, an intranet is an application based on Internet technology, hyperlinked, richly networked, flexible and organizationally bounded [Bansler et al.,
2000; Stenmark, 2003]. Intranets differ from traditional IT systems although they don't exclude the presence of other IT systems and work as a unifier in terms of integrating IT systems [Damsgaard and Scheepers, 2001]. Initially the technology is used for simple publication of more or less static information. When the organization becomes more familiar with the technology it is used for more advanced purposes. Intranet can be said to go from simple use modes towards more advanced ones [Damsgaard and Scheepers, 1999]. The chart below shows the basic architecture of the intranet building blocks.

Figure 1: Intranet building Blocks (Source: Hummingbird Communication Inc. 1996)

| Advanced Intranet Desktop Application Suite (User Interface) |
| Web Interface |
| HTML & Portable Electronic Document Servers | SQL RDBMS & Legacy Database Servers | Multimedia Database Servers |
| Search & Indexing Tools | Collaborative Computing Technologies | Portable Electronic Document Technologies |
| Authoring Tools & Applications | Intelligent Agents |
| HTTP | Email | Internet Relay Chat | Other Application Protocols | White Boards | Object Technologies & Languages (OLE, Java, Python, etc.) | Scripting Languages (CGL, etc.) |

Rationale for the study
Research universities are the central engine of the innovation economy [Ed et al. 2008]. But this role depends critically on having state-of-the-art cyber infrastructure as a foundation for e-management research and education activities [Maria & Miltiades 2008]. In this era; a progressive enterprise should strive to adapt itself successfully to new management skills, principles, abilities and higher levels of competency [Ansari et al. 2009]. Liu states that a firm that is contemplating investing by adopting the existing new technology will face unexpected coming of some further new technologies that will displace the existing new technology in the future [Liu 2009].
The absence of adequate infrastructure services is one of the main problems that hinder efforts to develop learning institutions in developing countries. The complexity of new teaching and learning environments and also cross-communication among staff members is apparent when students and staff are required to work in synchronous and asynchronous environments. There is a clear need to identify a framework of how corporate intranets can be a critical tool for effective service delivery in learning institutions success, based on knowledge network analysis, and determine their main ‘external’ barriers impeding networks across the field of sustainability.

The possibility to be able to connect every employee and students via a unifying and single client promised to make the intranets ideal arenas for corporate members to meet and share knowledge quickly and efficiently [Stenmark 2002]. To achieve a better match, managers must shift from an emphasis on traditional systems, such as transaction processing, integrated logistics, and work flows, to a new emphasis on systems that facilitate communications, people networks, and on-the-job learning and training [Wang et al. 2006]. According to Rikard and Stenmark [2004], a typical competence system is designed to support organizations in their competence management processes by providing information about competence status and competence development needs of organizational members.

Intranets allow people to work in a manner that best corresponds to their personality, style and work habits [Chuo 1998]. Wachter and Gupta [1997] note that the increasing use of intranets makes the need to actively manage the development process even more urgent, and although they acknowledge the many tradeoffs involved in intranet management, they advocate a centralized management system that can exercise control and ensure that consistency is maintained. Through collaboration, networks can function efficiently within the HEI’s system to drive sustainability [Molly et al. 2008].

Research hypothesis
In order to study the underlining problems stated above, seven assumptions were postulated, which are in agreement with those suggested by Mohamad et al. [2007]:

H1: Effective usage of intranets is positively associated with individual impact.

H2a: Proper management of intranets is positively related with effective intranet usage.

H2b. Proper management of intranets is positively related with intranet service quality.

H3a: Computer efficacy by the intranet users is positively related with effective intranet usage.

H3b: Computer efficacy by the intranet users is positively related with intranet service quality.

H4a. IT infrastructure flexibility is positively related with effective intranet usage.

H4b. IT infrastructure flexibility is positively related with intranet service quality.
H5a: User involvement is positively related with intranet usage
H5b: User involvement is positively related with intranet service quality
H6a: Intranet service quality is positively associated with effective intranet usage.
H6b: Intranet service quality is positively associated with individual impact.

Conceptual Framework
There has been a lot of research work on intranet use [Stenmark 2005, Molly et al. 2008; Miltiadis & Roberto 2008; Peter, Tony and Chris 2000; Mohamad et al. 2007; Rodger 2003 and Grant & Lugi 2005]. Based on the explanatory studies carried out via the literature survey, the following conceptual framework was formulated in which three antecedent variables namely organizational, technological and individual are explored to determine their possible contribution to effective intranet usage and service quality in institutions of higher learning. The other three variables namely: intranet effective usage, intranet service quality and individual impact contribute towards measuring the effectiveness of the intranets. Undeniably, there are other potential and possible antecedents that could be included into this conceptual framework, but this model is on McKinsey 7S Framework, where we are interested in investigating seven specific factors which are:

- Intranet adoption and management
- Management support
- IT infrastructure flexibility
- Information systems integration
- Information systems structure
- Individual factors
- User involvement

Figure 2: Conceptual framework
Intranet Usage
The mode of intranet utilization depends upon the complexities and maturity of the intranet. The literature suggests that intranet maturity can be identified as low, medium or high [Gartner Group 1996; Caselberry et al. 1996]. Low maturity signifies that information is published on the intranet for one-way communication. Medium maturity indicates that the intranet is used for groupware and collaborative application. High maturity denotes that the intranet serves as a common user interface to back-end applications. In a situation where intranet is of high maturity, five different modes of utilization are possible, publishing, transacting, interacting, searching and recording [Damsgaard and Schippers 2000].

Depending on the nature and design of the job, the five different modes of utilization vary across various users (employees and students). In a situation where an employee has to daily engage with organizational information systems such as financial or marketing, then the degree of utilization on transacting mode would be definitely high. Likewise, a head of a department or supervisors with many subordinates would heavily publish memos or notices, thus suggesting that their intranet utilization in terms of publishing mode would be relatively high. However, as a typical intranet user in these institutions, three commonly found utilization modes are transacting, interacting and searching. In a transacting mode of utilization, users inevitably commit to HR systems that are integrated into the intranet.

To interact with other staff in the institution, users engaged in interacting mode via e-mail, forum room, e-sm or e-chatting. To facilitate their jobs in locating organizational documents or tracing the whereabouts of specific individuals, users commit to searching mode via the use of search engines or directory that are built into the intranet. In addition to these common modes of utilization, users exploit the intranet for decision support and knowledge sharing purposes and in the case of learning, the students can be able to acquire all related information from the teachers/lecturers.

Intranet Service Quality
In the intranet and extranet environment, the use of service quality for measuring effectiveness was accomplished by Cody and Hope [1999] and Miller [2004] as cited by [Mohamad et al. 2010]. SERVQUAL instrument developed by Parasuraman et al. [1991] was mainly used for assessing the service quality in the marketing field and was the most adopted model for measuring web-service or e-service quality. SERVQUAL model consists of five dimensions namely reliability, responsiveness, assurance, empathy and tangible. Hope also elaborated how the original SERVQUAL dimensions are applicable in the context of the extranet [Hope 2001]. Since intranet and extranet can be almost equated, the researcher also argues that elaboration by Hope [2001] holds valid in the context of the intranet. Table 1 illustrates the details adapted from Parasuraman et al [1991]. In the context of this study, the researchers also conceive that intranet service quality is significantly related with intranet usage.
Table 1: Service quality dimension of intranet adapted from Parasuraman et al. [1991] and Hope [2001][as cited by Mohamad et al. 2010]

<table>
<thead>
<tr>
<th>Construct</th>
<th>Definition</th>
<th>Description and examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliability</td>
<td>The ability to perform a promised service dependably and accurately</td>
<td>Using backup systems can help ensure availability of the intranet and minimize downtime. Reduced downtime and accurate data reflects reliable and dependable service.</td>
</tr>
<tr>
<td>Responsiveness</td>
<td>A willingness to help users and to provide support services</td>
<td>Responsive intranet would mean quick response to email and on-line queries from users.</td>
</tr>
<tr>
<td>Assurance</td>
<td>Knowledge, courtesy and ability to inspire trust and confidence</td>
<td>The embedded security precaution ensures employee trust and confidence. Judicious and prompt use of email follow ups to user enquiries reflects intranet knowledge and courtesy.</td>
</tr>
<tr>
<td>Empathy</td>
<td>The caring, individualized attention the intranet provides to users</td>
<td>Allowing intranet access to every employee conveys a sense of caring. Intelligent use of user profiles, based on preferences and usage patterns conveys a sense of individualized attention.</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>The extent of user feeling adequately serviced</td>
<td>The extent to which users of the intranet feel their needs are adequately handled.</td>
</tr>
</tbody>
</table>

Methodology

The research design for this study is a descriptive survey. In view of this, the study adopted field survey to collect both qualitative and quantitative data. Three public universities were included in the research namely Masinde Muliro University of Science & Technology, Moi University and University of Nairobi. A target sample size was 50 respondents from each University that included both students and staff. Actual number of respondents was 87 which represented 58%. Both purposive and stratified sampling approaches were adopted for the study.

Strauss and Corbin [1990] claim that qualitative methods can be used to better understand any phenomenon about which little is yet known. Additionally, they can also be used to gain new perspectives on things about which much is already known, or to gain more in-depth information that may be difficult to convey quantitatively. Open-ended interview questions were used to gather in-depth information concerning intranet use among students and staff in institutions of higher learning.

Besides the interviews were questionnaires which were administered to staff and students in the sample institutions. After going through all the collected questionnaires, uniform categories of responses were identified, classified and fed into appropriate
categories in a statistical data analysis using SPSS Version 11.5. Data collected through quantitative research is predominantly objective and this was obtained through structured questionnaires. Objectivity ensured a high degree of reliability of the results.

**Research Results**

Table 2 shows all the factors have correlation which has met the criterion set for this research project. The responses were obtained from staff of the HEIs sampled. Intranet management, user involvement and user self-computer efficacy appear to have strong positive relationships with the level of intranet usage.

**Table 2: Correlation matrix of the variables**

<table>
<thead>
<tr>
<th>Intranet Variable</th>
<th>Intranet Usage (IU) level (Y)</th>
<th>Intranet management (IM)</th>
<th>IT Infrastructure (ITI)</th>
<th>Individual Impact (II)</th>
<th>User Computer Efficacy (UE)</th>
<th>Service Quality (SQ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intranet Usage (IU) level (Y)</td>
<td>Pearson Correlation</td>
<td>.606</td>
<td>.533</td>
<td>.761</td>
<td>.539</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td>87</td>
</tr>
<tr>
<td>Intranet management (IM)</td>
<td>Pearson Correlation</td>
<td>1</td>
<td>.533</td>
<td>.566</td>
<td>.761</td>
<td>.539</td>
</tr>
<tr>
<td>N</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td>87</td>
</tr>
<tr>
<td>IT Infrastructure (ITI)</td>
<td>Pearson Correlation</td>
<td>.606</td>
<td>1</td>
<td>.095</td>
<td>.415</td>
<td>.891</td>
</tr>
<tr>
<td>N</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td>87</td>
</tr>
<tr>
<td>Individual Impact (II)</td>
<td>Pearson Correlation</td>
<td>.566</td>
<td>.415</td>
<td>.268</td>
<td>.453</td>
<td>.496</td>
</tr>
<tr>
<td>N</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td>87</td>
</tr>
<tr>
<td>User Computer Efficacy (UE)</td>
<td>Pearson Correlation</td>
<td>.761</td>
<td>.192</td>
<td>.260</td>
<td>.453</td>
<td>1</td>
</tr>
<tr>
<td>N</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td>87</td>
</tr>
<tr>
<td>Service Quality (SQ)</td>
<td>Pearson Correlation</td>
<td>.539</td>
<td>.891</td>
<td>.993</td>
<td>.496</td>
<td>1</td>
</tr>
<tr>
<td>N</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td>87</td>
</tr>
</tbody>
</table>

Table 3 exhibits the descriptive profile of the intranet systems quality variable. All the items recorded mean values greater than 3.00. The highest mean which stood at 3.75 was for the item that states “finding the items I want from the menus and tool bars”,
hence suggesting that the HEIs users are expecting that the intranet they use in their workplace should have good user interaction mechanisms through menus and tool bars. However, the mean score for all items is 3.52 based on the scale 1-Excellent and 4-Poor, denoting that users were generally inclined to agree that the systems qualities of the intranet did not fulfill their expectations. The intranets system in all the three participating universities has integrated their intranet with numerous organizational applications. Hence, users whose works have to constantly engage with various functional business applications that are integrated with the intranet would surely expect the intranet to fulfill their systems qualities requirements. These systems requirements characteristics include aspects such as accessibility, prompt response, secured transactions, easy navigation, personalization, user-friendly, etc.

These aspects have been fully addressed as evidence by the findings of the study. The availability of strong maintenance team coupled with management support as indicated in earlier findings of this study could perhaps explain the reasons why the systems quality of the intranets are favorable to the users’ expectations.

Table 3 Descriptive profile of systems service quality variable

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>The software is easy to use</td>
<td>3.60</td>
<td>0.982</td>
</tr>
<tr>
<td>Control of the contents of the menus and tool bars</td>
<td>3.41</td>
<td>1.394</td>
</tr>
<tr>
<td>Able to learn how to use all that is offered in the intranet</td>
<td>3.77</td>
<td>0.845</td>
</tr>
<tr>
<td>Navigation through the applications on the intranet is easy to do</td>
<td>3.64</td>
<td>0.835</td>
</tr>
<tr>
<td>The intranet is engaging</td>
<td>3.56</td>
<td>1.031</td>
</tr>
<tr>
<td>Contents of the intranet match my needs</td>
<td>3.46</td>
<td>0.950</td>
</tr>
<tr>
<td>Getting started with software is easy</td>
<td>3.47</td>
<td>0.887</td>
</tr>
<tr>
<td>The software is flexible</td>
<td>3.64</td>
<td>1.000</td>
</tr>
<tr>
<td>Finding the options I want in the menus and tool bars is easy</td>
<td>3.75</td>
<td>0.824</td>
</tr>
<tr>
<td>Easy to make the information system do exactly what I want</td>
<td>3.45</td>
<td>0.937</td>
</tr>
<tr>
<td>Discovering new features is easy</td>
<td>3.32</td>
<td>0.785</td>
</tr>
<tr>
<td>Get my office work done using the intranet</td>
<td>3.38</td>
<td>0.967</td>
</tr>
<tr>
<td>This information system is satisfying to use</td>
<td>3.24</td>
<td>1.089</td>
</tr>
<tr>
<td>Average</td>
<td>3.515</td>
<td></td>
</tr>
</tbody>
</table>

H1: Effective intranet usage is positively associated with individual impact.

Studying the impact of IT on individual performance has become an important factor in determining the value of information systems. Previous studies on IT adoption have
recognized the contribution of IT in enhancing individual performance especially in terms of productivity, efficiency and effectiveness [e.g. Jiang & Klein, 1999; and Iivari, 2005]. In light of this study, individual impact of intranet utilization is assessed in terms of task productivity, task innovation and individual sense of accomplishment. Task productivity refers to the extent that an intranet improves the user's output per unit of time. Past researches have shown the contribution of intranet in improving employee productivity and effectiveness [Lai & Mahapatra, 1998; Knight et al. 2005]. According to Torkzadeh & Doll [1999] when studying the impact of IS, we cannot just study what workers do, but rather how innovative they are in what they have to do. This can also be observed from the results obtained [Table 2] which shows that the impact of intranet usage on individual performance particularly in supporting work task and individual sense of accomplishment would also be a valid aspect for measuring intranet effectiveness since it has a correlation coefficient of .566. As such, corporate intranet effective usage is proportional to individual impact.

**H2a:** Proper management of intranet is positively related with effective intranet usage.

**H2b:** Proper management of intranet is positively related with intranet service quality.

Top management support of information systems refers to the degree to which top management understands the importance of the IS function and the extent to which it is involved in IS activities. In the context of intranet, researchers consistently found that top management support is a strong determinant of intranet implementation success [Al-Garbi & Al-Turki 2001; Eder & Igbaria, 2001; Tang, 2000; Bajwa & Ross, 2002]. High degree of managerial support for the intranet implementation will not only demonstrate commitment and continuous support for the project but also develop conducive implementation environment by providing necessary resources such as time, space, equipment and people. Thus, in light of the above discussion it is hypothesized that top management support is significantly related with intranet utilization.

Management support appears to be essential in the use of the intranet in universities. Table 1 shows that management support has a strong positive correlation coefficient of .606 with the level of the intranet usage. Intranet management consists of highly heterogeneous activities including content generation and updates, user support, user account management, hardware and software maintenance, and many more. We realized that intranet management is critical to the success of the intranet. Critical factors looked at include:

- Management processes that may involve fault, configuration, performance, security and accounting management
- Management tools that will be utilized for supporting management processes and are usually assigned to human resources, and
- Human resources of the management team that would embrace their skills and network management experiences.

From the above discussions it’s thus evident that, intranet management is positively related with effective intranet usage and that intranet management is positively related to effective service quality.

**H3a:** Computer efficacy by the intranet users is positively related with effective intranet usage.

**H3b:** Computer efficacy by the intranet users is positively related with intranet service quality

Computer efficacy is an individual’s belief in their ability to use technology in order to solve problems, make decisions, and to gather and disseminate information. Table 2 shows correlation coefficient of .761. Top management, employees and many students have proved that a high level of computer self-efficacy contributes towards high degree of IT acceptance and usage.

When senior management were interviewed about the challenges faced by the institutions of higher learning in developing their intranet system, all the top-management interviewed like the other staff cited a number of challenges. According to their perceptions, user skills level on use of intranets was felt as one of the challenge that HEIs need to address when developing intranet strategy. Their responses also indicated that most students come from varied backgrounds with reference to IT skills which were a common phenomenon with staff. It can thus be concluded that user computer efficacy is positively related with effective intranet usage and that user computer efficacy is positively related to effective service quality.

**H4a:** IT infrastructure flexibility is positively related with effective intranet usage.

**H4b:** IT infrastructure flexibility is positively related with intranet service quality

IT infrastructure flexibility is the organizational capability to support a variety of information technologies and information services. IT infrastructure that is flexible should provide a foundation that is less complex, making it easier for departments to implement intranet applications. Further, they pointed out that it should also hold valid that a more flexible IT infrastructure will result in greater service offerings of the intranet, that is, higher levels of infusion among the intranet applications deployed. Thus, from Table 2 the study discovered positive association between more flexible IT infrastructures and intranet infusion with correlation coefficient of .533. Thus, there is positive association between more flexible IT infrastructures and intranet infusion. These findings are comparable to the intranet usage findings in the respective institutions of higher learning as depicted from Table 3.
It can then be concluded that Flexible IT infrastructure is positively related with effective intranet usage and Flexible IT infrastructure is positively related with intranet service quality.

**H5a:** User involvement is positively related with intranet usage

**H5b:** User involvement is positively related with intranet service quality

User participation in the development of the Intranet applications appears to have significant impact on the use of the Intranet with correlation coefficient of .566 [Table 2]. It is assumed that strong involvement of future users in the design of IS will lead to successful outcomes in terms of more IS usage, greater user acceptance, and increased user satisfaction. As for the intranet computing environment, managers perceived user involvement as one of the important criteria for ensuring successful intranet adoption as it minimizes resistance and motivates employees and students to use intranet.

As for the intranet computing environment, managers perceived user involvement as one of the important criteria for ensuring successful intranet adoption as it minimizes resistance and motivates employees and students to use intranet. These results are comparable to intranet usage indicators as depicted from Table 2. It can thus be concluded that user involvement in the development of corporate intranets in higher education institutions is positively related to intranet usage and intranet service quality.

**H6a:** Intranet service quality is positively associated with effective intranet usage.

**H6b:** Intranet service quality is positively associated with individual impact.

Table 2 shows coefficient correlation of .539 for service quality being depicted as one of the strong measures in the composite measures of the IS (intranet success). The model consists of nine constructs namely accessibility/availability/convenience, accuracy, adequacy/relevance, comprehensiveness, cost, information currency, delivery method, technical accuracy, and timeliness. The most common responses to the question about “intranet services, intranet usage and individual impact” were as follows based on a number of intranet service qualities.

Discussion

Traditionally, management consulting and professional services firms have been considered knowledge-intensive firms and therefore interested in knowledge management [Alavi and Leidner 1999] where corporate intranets are essential tool. However, corporate intranets usage is also highly felt in higher education not just for consulting and professional services only, given that knowledge has currently been recognized by other industries as the organizations’ main asset. In cases of Masinde Muliro University of Science and Technology, Moi University and Nairobi University, the advancement of information technology gives new ways to create an appealing environment for exchange of knowledge and opportunities to improve the ability to manage and utilize knowledge. However, these advantages may cause some challenges
to the university as it may become overwhelmed by the volume of information and may not know how to use it for the university’s advantage [Alavi and Leidner 1999].

Table 4 provides a summary of various kinds of intranet metrics which when adapted can foster quality, usability and more so cost-effective IT investment in HEIs:

**Table 4: Framework of Intranet Efficiency and Effective Usage (IEEU)**

<table>
<thead>
<tr>
<th>Intranet Domains/ Areas of Concern</th>
<th>Metrics description</th>
<th>Intranet Characteristics</th>
<th>Metrics Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IT Infrastructure</strong></td>
<td>Intranet Architecture Information Architecture Application platform</td>
<td>Information grouping Navigation Personalization Search User data Taxonomy Configurations IT infrastructure flexibility Information system Integration</td>
<td>Derived Metrics</td>
</tr>
<tr>
<td><strong>Intranet management</strong></td>
<td>Managerial support Planning Mission and Objectives management Intellectual Capital management</td>
<td>Intranet and IT investment policy Intranet management personnel Better Decisions Intranet adaption More creativity Reach New Opportunity ROI</td>
<td>Derived Metrics</td>
</tr>
<tr>
<td><strong>User Involvement</strong></td>
<td>Ideas management Usability issues Design decisions</td>
<td>Self development initiatives Visual analysis Ease of Navigation Usability of intranet Mouse movements Communication facilities Authority Ease of understanding intranet services</td>
<td>Soft Metrics</td>
</tr>
</tbody>
</table>
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| Usage | Domain Integration  
|-------|-------------------|
|       | Global search     
|       | Across critical content  
|       | Develop shared taxonomy  
|       | Content  
|       | Traffic Volume  
|       | User documentation  
|       | Call handling  
|       | No. of Hits per link  
|       | Explicit content  
|       | Access time  
|       | Information and Knowledge on Intranet  
|       | Hard Metrics  

| Individual factors | User experience  
|--------------------|-----------------|
|                    | User computer efficacy  
|                    | Innovation  
|                    | Self development  
|                    | Statistical packages  
|                    | Internet/ web search techniques  
|                    | Graphics  
|                    | Programming  
|                    | Application packages  
|                    | Knowledge of chart/ e-mail/intranet tools  
|                    | Soft Metrics  

| Quality Metrics | Accessibility  
|-----------------|-----------------|
|                 | Navigation  
|                 | Reliability  
|                 | Customization/ Personalization  
|                 | User assistance/ Responsiveness  
|                 | Satisfaction  
|                 | Empathy  
|                 | User data  
|                 | Time to locate  
|                 | Abandons  
|                 | Time to build  
|                 | No. of Errors  
|                 | No. of Clicks to find  
|                 | Hard Metrics  

| Versioning | Intranet Versioning/ improvement  
|------------|---------------------------------|
|            | Business Strategy  
|            | Versioning, Business Process  
|            | Versioning, Operational changes  
|            | Soft Metrics  

Grant and Luqi [2005] states that in order to measure efficacy of a corporate intranet’s portals, one requires a coherent and balanced combination of metrics taken from all segments. When these metrics are collectively and uniformly applied in periodic measurements, they can indicate tractable improvements over time. In order to do this, these metrics should be grouped into metric categories that support business requirements. He thus essentially provides three types of metrics: hard, soft and derived.
Hard metrics can be objectively measured, i.e., by directly interpreting server log-file data, server requests, number of visitors over a given period of time, etc.

Soft metrics involve many subjective and qualitative aspects that provide a frame of reference to interpret the results, i.e., survey results, visual analysis and usability.

Derived metrics consist of hard and soft metrics from a variety of business and knowledge data involved and an educated assumption to draw conclusions, i.e., estimates of speed to market, loyalty and reach.

The last domain which is versioning relies on the fact that, technology changes now and then and hence, to keep pace with the changes, the intranet information system needs to be updated, versioned and managed in relation to content, business strategy changes, and business process versioning where all the factors have a direct effect on the intranet service quality in institutions of higher learning, hence effective usage. The proposed Intranet Efficiency and Effective Usage (IEEU) Framework can be mapped on corporate portal framework by Atul, Chia & Brain [2000] as shown in the chart below.

Figure 3 Corporate Intranet portal framework [Atul et al. 2000]

Conclusions and Way Forward

We believe that recognizing the potential of corporate intranets in institutions of higher learning will encourage other companies/organizations to develop this system. However, the difference in implementing effective intranets depends on institutional IT policies and the structure and culture of the university. The key is making sure that
people, particularly in top management, understand the advantages of these information technologies (i.e. intranets) what makes them useful. Future research should determine the ways to overcome problems and failures with corporate intranets in higher education as well as other tertiary institutions such as middle-level colleges to understand the whole picture of the education service industry. Although the study has recommended a uniform framework that should be adapted by all institutions of higher learning on intranet effective usage, information is needed on what components should constitute a university policy to make it effective.

In addition research is needed to ascertain the relationship between university policy and intranet usage in higher education. There is a substantial need for well-evaluated trials of the proposed intranet framework in this study to address intranet usage in institutions of higher learning. There is also need for accompanying training for intranet personnel and users on the intranet effective usage metrics proposed by the current study. This would make it easy to plan and implement them.

References


DICK STENMARK (copyright 1999). Asynchronous Brainstorm: An Intranet Application for Creativity. Association for the Advancement of Computing in Education (AACE)
DICK STENMARK (copyright 1999). To search is great, to find is greater: as study of visualization tools for the Web. Sweden


MOHAMAD N., NORIZAN A., & FARRAH D. 2010. Enterprise intranet effectiveness: a case study at selected Malaysian companies. Proceed. of Regional Conference on Knowledge Integration in ICT, Malaysia


The Application of Structural Equation Modeling Technique to Analyze Students Priorities in Using Course Management Systems

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Abstract

The objective of this paper is to report on the application of Structural Equation Model (SEM) to analyze factors that influence students’ priorities when selecting a Course Management System (CMS). A Conformation Factor Analysis (CFA) was performed to test the reliability and validity of the measurement model. The study is motivated by the inconsistencies, duplication and loss of integrity of data caused by simultaneous usage of two CMS-WebCT and Electronic Campus (EC) e-learning tools in the faculty of Information and Communication Technology (ICT) at Tshwane University of Technology. A composite model of Diffusion of Innovations (DOI) theory and Technology Acceptance Model (TAM) was used to predict actual selection of CMS when mediated by prioritization. Results indicated
that the complexity of WebCT negatively influences students’ prioritization, whereas perceived ease of use and less complexity of EC drives them towards its selection. This paper provides an insight for antecedent factors essential for planning and implementing CMSs. The developed framework is expected to act as a guide for university administrators in making informed decision about investing in e-learning tools.

**Keywords:** E-learning tools, Course Management Systems, Structural Equation Modeling, Technology Acceptance, Diffusion of Innovations

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**Introduction**

The increasing use of the internet and the evolution of Information and Communication Technology (ICT) have enabled teachers to extend the classroom beyond its traditional boundaries of time and space. Facilitation of online teaching and learning has been made possible through ICT. Course Management Systems (CMS) have been extensively used to supplement or organize a conventional course experience. This has led to very many e-learning tools being developed and many implemented in institutions of learning. Learners and their instructors have been made to cope with these changing trends in their general socio-cultural, educational, economical and technological environments for a better future. In spite of the multitude abundance of e-learning tools especially those meant for effective and real time delivery means to support teaching and learning, institution administrators should focus on the most important ones that are relevant to the learners’ context.

A careful consideration of e-learning granularity [Horton and Horton 2003] indicates that relevancy is a key factor for the success of any e-learning tool. If students perceive a CMS as not appropriate or relevant to their needs, such perception may render the CMS’s expected benefits to be partially, if at all, attained. Researcher [Nanayakkara 2007] noted that institutions of higher learning spend huge sums of money on IT. However, as also noted by researchers [Abrahamson and Rosenkopf 1993; Saadé and Galloway 2005] many organizations adopt an innovation because of bandwagon pressures “rather than their updated assessment of the innovation efficiency or returns”. Such a poorly evaluated acquisition may in most cases lead to poor utilization of the system and, to an extent, resistance from the users.

This paper proposes a structural equation modeling method to explain factors that influence students’ priorities when selecting a CMS in learning and communication. This study is expected to contribute conceptually and operationally. It is expected to provide university administrators with a basis to make informed decisions amidst strict IT budgets. It will also help them to make better choices and selections of relevant CMS in the market flooded with e-learning tools.
Theoretical Framework

Researchers [Allen and Seman 2003] agree that e-learning is among those educational methods that allows flexible learner-centered education. Increasing use of e-learning has helped to bridge the gap between the rural disadvantaged and the urban rich by providing improved access to education. Universities world-wide have expanded by establishing different campuses beyond their geographical locations. Therefore, apart from electronic the ‘e’ in e-learning may also represent; extended, everywhere, experience, eccentric, every time, engagement and enhanced delivery of learning through Internet and wireless enabled mobile electronic devices [Wexler et al. 2008]. E-learning tools on the other hand may be classified into three categories [Horton and Horton 2003]; namely course or learning management systems (CMS/LMS), synchronous collaboration applications, and all other computer tools/applications including asynchronous collaboration applications. Recent research studies [Karaali, et al. 2010; Lee et al. 2009] have added game simulation software as an emerging accepted e-learning tool.

In their review of information systems success research, Delone and Mclean [2003]; established that different researchers emphasize the importance of system usage based on empirical findings. In the same perspective they found that many theories have been postulated and developed to explain the multidimensional nature of IS/IT success. These theories have been acknowledged in information system (IS) research for the role they play in giving useful insight into the perception of users towards IT and factors enabling their perception. These theories include; Theory of Planned Behavior (TBP) [Ajzen 1991]; Technology Acceptance Model (TAM) [Davis 1989]; Diffusion of Innovation Theory (IDT) [Rogers 1962 2003]; Model Combining the Technology Acceptance Model and Theory of Planned Behavior (C-TAM-TPB) [Taylor and Todd 1995]; Model of PC Utilization (MPCU) [Thompson et al. 1991]; Task Technology Fit model [Dishaw and Strong 1997]; General System Theory [Raisinghani and Schkade 1997]; Diffusion Theory [Raisinghani and Schkade 1997; Mao 2002]; and later the Unified Theory of Acceptance and Use of Technology (UTAUT) [Venkatesh et al. 2003].

Several researchers [Ma et al. 2005; Lee et al. 2009; Karaali et al. 2010]; have studied the factors influencing adoption and acceptance of e-learning. However, this study found little literature explaining students’ preferences when they are faced with a situation of simultaneously using more than one e-learning tool. In their research, Nanayakkara and Whiddett [2004]; noted that one’s choice to use a system may heavily depend on his perception to see that system as relevant and reliable. Researchers [Rogers 2003; Lee et al. 2009; Park 2009]; agree that a combination of factors influences choice of using an IT system and Rogers [2003]; adds that users will be less attracted to complex systems. Basing on this argument this study decided to use a composite model figure 1 combining TAM [Davis 1989; Davis et al.1992]; and the DOI [Rogers 1962 2003]. Both TAM and DOI express the need to investigate the various factors influencing the user’s choice to accept and adopt technology which two are major antecedents for
actual selection to use a CMS. These two models signify that such factors should not be considered in isolation from technical aspects. TAM’s constructs perceived ease of use and perceived usefulness when mediated by behavioural intention, has been found to highly influence actual usage. Studies of Park [2009]; and Lee et al. [2009]; empirically tested TAM in regard to e-learning and found it very predictive. Landry et al. [2006] and Saade and Galloway [2005]; used TAM in their studies to measure students’ acceptance of web-based e-learning tools. In both studies TAM was found to perform well. Landry et al. [2006]; found usage to be determined by the two TAM’s constructs perceived ease of use and perceived usefulness though actual usage varied at different levels. This study therefore, intends to find whether relative advantage and complexity when used perceived ease can explain this variation.

**Perceived Ease of Use**: relates to the degree a student believes that he/she will find a CMS easy to use [Davis 1989; Davis et al. 1992]. This study assumed that since students have limited time to learn how to use a new IT innovation, a system assumed to be less complicated would attract many to use. This study derived its first hypothesis from this concept.

**H1**: Perceived ease of use will positively influence students’ priority to select a CMS

Rogers [1962, 1995, and 2003] developed the diffusion of innovations [DOI] model to explain the rate of adoption of a new innovation and the factors influencing its usage. DOI has been applied in many studies [Rogers, 2003, Miner, 2007] to explain the adoption [or non-adoption] of IT systems. Two constructs of DOI relative advantage and complexity are used in this study.

**Relative advantage**: is the degree to which an innovation is perceived as better than the idea it supersedes [Rogers 1995; Miner 2007]. In this study, relative advantage refers to the degree students find convenience and satisfaction from a CMS hence the higher the priority they give to the system. Rogers [1995 2003]; adds that, the greater the perceived relative advantage of an innovation, the more rapid its rate of adoption will be. From this perception this study derived its second hypothesis.

**H2**: Relative advantage will positively influence students’ priority to select a CMS

**Complexity**: is the degree to which an innovation is perceived as difficult to understand and use [Rogers 1995]. In this study complexity relates to students’ perception of a CMS as difficult to use. The more complex a CMS is perceived the less priority it will be given. From this notion this study derived its third hypothesis.

**H3**: Complexity of a CMS will negatively influence students’ priority to select it.

The three constructs, perceived ease of use, relative advantage and complexity are mediated by prioritization to inform choice of selection of a CMS. This lead to the fourth hypothesis.
H4: The higher the priority given to a CMS the higher the chances for it to be preferred for usage by students.

Figure 1: below represents the theoretical framework of the study.

**Figure 1: Theoretical Model**

Researchers [e.g. Ma et al. 2005; Park 2009; Lee et al. 2009]; argue that there are several antecedents for users to perceive a system as easy to use. Nanayakkara and Whiddett [2004]; noted that these antecedents may include organisational, social, and individual factors. Several latent factors may create an impact on an individual's perception of a system. Such factors may also account for the inconsistencies in similar research studies like in the case of [Grandon et al. 2005; Ndubisi 2006]. In these two studies, one study found a factor as significant whereas the other found it insignificant. To avoid these contradictions, this study used structural equation modelling (SEM) for testing and estimating causal relations.

**Methodology**

**Data Collection**
Data was collected from Soshanguve and Pretoria campuses of Tshwane University of Technology using close-ended questionnaires. The questionnaire was designed based on a five point Likert scale for which (1) and (5) represented strongly agree and disagree respectively, (3) represented neutral and (2) and (4) median answers. A total of 200 questionnaires were distributed and 150 were returned registering a response rate of 75%. Out of the returned questionnaires 131 (87.3%) were usable while 19 (12.7%) had missing data which led them to be discarded. Distribution of questionnaire depended on lecturer and class representatives of the sampled classes who administered them to students before or after the lecture. Cases of non-returned questionnaires rose because some lecturers were forgetting to take them to class. A pre-test was conducted to validate the instrument with one class which the researcher was lecturing. From the feedback, it was agreed to change the layout of the questionnaire since most students
had preferred to start with strongly agree rather than starting with strongly disagree. Therefore, some changes were made as deemed appropriate. Collected data was analyzed using SPSS 17.0 and AMOS 18.0 was used for SEM. The following steps of SEM analysis were followed; confirmatory factor analysis (CFA), discriminant analysis, composite reliability, and average variance extracted and finally the testing the fit for the hypothesized structural model and revised model as suggested by Hair et al. [2006].

Table 1 demonstrates the demographics of the respondents. Results shows that a big number of students (64.3%) use WebCt less or once a week whereas 57.3% of the students indicated that they use Electronic campus more than four times a week. This implies that there is a good usage of Electronic Campus as compared to WebCt. Results further indicate that students relatively have good experience of internet usage. This implies lack of experience of using web-based tools is not a hindering factor.

### Table 1: Demographic Data of the Respondents (N=131)

<table>
<thead>
<tr>
<th>Character</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>64</td>
<td>48.9</td>
<td>48.9</td>
<td>48.9</td>
</tr>
<tr>
<td>Female</td>
<td>67</td>
<td>51.1</td>
<td>51.1</td>
<td>100.0</td>
</tr>
<tr>
<td><strong>Year of study</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First year</td>
<td>1</td>
<td>.8</td>
<td>.8</td>
<td>.8</td>
</tr>
<tr>
<td>Second year</td>
<td>34</td>
<td>26.0</td>
<td>26.0</td>
<td>26.7</td>
</tr>
<tr>
<td>Third year</td>
<td>90</td>
<td>68.7</td>
<td>68.7</td>
<td>95.4</td>
</tr>
<tr>
<td>Fourth year and above</td>
<td>6</td>
<td>4.6</td>
<td>4.6</td>
<td>100.0</td>
</tr>
<tr>
<td><strong>Experience with Internet</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>less than a year</td>
<td>2</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>1-3 years</td>
<td>68</td>
<td>51.9</td>
<td>51.9</td>
<td>53.4</td>
</tr>
<tr>
<td>4-6 years</td>
<td>46</td>
<td>35.1</td>
<td>35.1</td>
<td>88.5</td>
</tr>
<tr>
<td>more than 6 years</td>
<td>15</td>
<td>11.5</td>
<td>11.5</td>
<td>100.0</td>
</tr>
<tr>
<td><strong>Frequency of usage of Webct</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Once week</td>
<td>81</td>
<td>61.8</td>
<td>64.3</td>
<td>64.3</td>
</tr>
<tr>
<td>2-3 times a week</td>
<td>27</td>
<td>20.6</td>
<td>21.4</td>
<td>85.7</td>
</tr>
<tr>
<td>3-4 times a week</td>
<td>10</td>
<td>7.6</td>
<td>7.9</td>
<td>93.7</td>
</tr>
<tr>
<td>more than four times a week</td>
<td>8</td>
<td>6.1</td>
<td>6.3</td>
<td>100.0</td>
</tr>
<tr>
<td><strong>Frequency with electronic campus</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Once week</td>
<td>10</td>
<td>7.6</td>
<td>7.6</td>
<td>7.6</td>
</tr>
<tr>
<td>2-3 times a week</td>
<td>21</td>
<td>16.0</td>
<td>16.0</td>
<td>23.7</td>
</tr>
<tr>
<td>3-4 times a week</td>
<td>25</td>
<td>19.1</td>
<td>19.1</td>
<td>42.7</td>
</tr>
<tr>
<td>more than four times a week</td>
<td>75</td>
<td>57.3</td>
<td>57.3</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Reliability Analysis

Internal consistency reliabilities of the constructs of the proposed model were tested with Cronbach’s Alpha coefficient, which is recommended to be at least 0.7 being acceptable [Pallant 2005]. The testing instrument of the model reported a reliability of 0.855 and the reliability of each construct is as shown in table 2. All α coefficients show good reliability of the constructs apart from perceived ease of use in electronic campus whose reliability is 0.558 below the recommended 0.700. However, since the same construct fared well in webet with a coefficient of 0.773 it was considered to be used for further analysis.

Table 2: Cronbach’s Alpha for WebCT

<table>
<thead>
<tr>
<th>Construct</th>
<th>Cronbach’s α (WebCT)</th>
<th>Cronbach’s α of Standardized Items (WebCT)</th>
<th>α (Electronic Campus)</th>
<th>α of Standardized Items (Electronic Campus)</th>
<th>No. of Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived Ease of Use (EU)</td>
<td>.773</td>
<td>.772</td>
<td>.558</td>
<td>.609</td>
<td>4</td>
</tr>
<tr>
<td>Relative Advantage (RA)</td>
<td>.872</td>
<td>.873</td>
<td>.759</td>
<td>.759</td>
<td>4</td>
</tr>
<tr>
<td>Complexity (C)</td>
<td>.870</td>
<td>.871</td>
<td>.871</td>
<td>.872</td>
<td>4</td>
</tr>
<tr>
<td>Prioritization (P)</td>
<td>.860</td>
<td>.862</td>
<td>.727</td>
<td>.744</td>
<td>3</td>
</tr>
</tbody>
</table>

Presentation of Results

WebCt is also known as my MyTuT or Blackboard. For the purpose of this study we shall stick to one name WebCt which we abbreviate as (W) and Electronic Campus as (EC). The constructs are abbreviated as shown in table 2 above. Their corresponding indicators are abbreviated as; EUW 1 and EUEC1 the first indicator for perceived ease of use for WebCt and Electronic Campus respectively and so on. Table 3 gives the descriptive statistics of WebCt and Electronic Campus with their corresponding indicators.
Table 3: Descriptive Statistics for WebCt Selection Indicators

<table>
<thead>
<tr>
<th>Construct Indicators</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Construct Indicators</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUW1</td>
<td>2.42</td>
<td>.896</td>
<td>EUEC1</td>
<td>1.31</td>
<td>.580</td>
</tr>
<tr>
<td>EUW2</td>
<td>2.32</td>
<td>.976</td>
<td>EUEC2</td>
<td>2.29</td>
<td>.988</td>
</tr>
<tr>
<td>EUW3</td>
<td>2.52</td>
<td>.916</td>
<td>EUEC3</td>
<td>1.45</td>
<td>.738</td>
</tr>
<tr>
<td>EUW4</td>
<td>2.37</td>
<td>.936</td>
<td>EUEC4</td>
<td>1.56</td>
<td>.737</td>
</tr>
<tr>
<td>RAW1</td>
<td>2.56</td>
<td>1.061</td>
<td>RAEC1</td>
<td>1.62</td>
<td>.728</td>
</tr>
<tr>
<td>RAW2</td>
<td>2.60</td>
<td>1.019</td>
<td>RAEC2</td>
<td>1.69</td>
<td>.786</td>
</tr>
<tr>
<td>RAW3</td>
<td>2.51</td>
<td>.972</td>
<td>RAEC3</td>
<td>1.68</td>
<td>.747</td>
</tr>
<tr>
<td>RAW4</td>
<td>2.62</td>
<td>1.037</td>
<td>RAEC4</td>
<td>1.72</td>
<td>.797</td>
</tr>
<tr>
<td>CW1</td>
<td>2.69</td>
<td>1.052</td>
<td>CEC1</td>
<td>1.72</td>
<td>.787</td>
</tr>
<tr>
<td>CW2</td>
<td>2.73</td>
<td>.985</td>
<td>CEC2</td>
<td>1.85</td>
<td>.881</td>
</tr>
<tr>
<td>CW3</td>
<td>2.49</td>
<td>.869</td>
<td>CEC3</td>
<td>1.76</td>
<td>.755</td>
</tr>
<tr>
<td>CW4</td>
<td>2.53</td>
<td>.893</td>
<td>CEC4</td>
<td>1.81</td>
<td>.851</td>
</tr>
<tr>
<td>PW1</td>
<td>2.51</td>
<td>1.170</td>
<td>PEC1</td>
<td>1.48</td>
<td>.770</td>
</tr>
<tr>
<td>PW2</td>
<td>2.52</td>
<td>1.094</td>
<td>PEC2</td>
<td>1.72</td>
<td>.934</td>
</tr>
<tr>
<td>PW3</td>
<td>2.66</td>
<td>1.232</td>
<td>PEC3</td>
<td>1.68</td>
<td>.743</td>
</tr>
</tbody>
</table>

The mean of the indicators of the constructs ranges between 2 to 3. This implies that students’ answers to the questions were affirmatively weak. However, a comparison of results in table 3 shows that student’s preference to use electronic campus is higher than that of using WebCt. The mean for Electronic Campus for the students’ answers ranged between 1 and 2 implying that most of the students’ responses were either strongly agree or agree hence giving a lower standard deviation. On the other hand webCt shows a lower positive skewedness registering negatives with some constructs. The descriptive results also indicate a high preference to Electronic campus than WebCt.

Analysis of the Measurement Model

It is important to note that the use of Cronbach’s $\alpha$, alone to test the reliability of such latent factors is limited [Kamata et al. 2003]. They put it that, composite reliability estimates the extent to which a set of latent construct’s indicators share in their measurement of a construct whereas the average variance extracted is the amount of common variance among latent construct indicators. Basing on (Heir et al., 2006; Kamata et al., 2003; and Jöreskog & Sörbom, 1993), composite reliability (CR) and average variance extracted (AVE) can mathematically be derived from equations (i), (ii) and (iii) below.

Error term = $E = 1 - S^2$ ................................................................. (i)

Composite reliability = $CR = \frac{[\sum_{1}^{n} (S)]^2}{([\sum_{1}^{n} (S)]^2 + \sum_{1}^{n} (E))}$ ................................................................. (ii)
Average variance extracted = \( \text{AVE} = \frac{\sum_{1}^{n} (S)^2}{\sum_{1}^{n} (S^2) + \sum_{1}^{n} (E)} \)  

Where \( n \) is the number of indicators for each construct, \( S \) is the standardized loadings for the indicators and \( E \) is the corresponding error term.

The above formula, do not assume a tau-equivalence among the measures; hence it is capable of providing more accurate results of the composite reliability. As suggested by researchers [e.g. Park 2009; Hair et al. 2006]; for a good measure all composite reliabilities (CR) should exceed 0.7, the indicators’ factor loadings [\( \lambda \)] should be significant and exceed 0.5 and the average variance extracted (AVE) of each construct should exceed the variance due to measurement error for the construct (e.g., AVE should exceed 0.5). This is as shown in Table 4 below.

Results in Table 4 shows that, the selected constructs have a good measure with the individual indicators belonging to their specified core values. This is because all the indicators’ loading factors and the construct’s composite reliability and average variance extracted all above the threshold of 0.5, 0.7 and 0.5 respectively. Factor loadings also shows that indicators that give a good representation of the construct are those with higher loadings on the same construct as demonstrated in Table 4. Similarly, the factor loadings the indicators’ significance shows the validity comprehension of the construct.

**Table 4: Factor Loading, Composite Reliability and Average Variance Extracted for WebCt**

<table>
<thead>
<tr>
<th>Construct</th>
<th>Indicator</th>
<th>Factor Loading [( \lambda )]</th>
<th>Composite Reliability (CR)</th>
<th>Average Variance Extracted (AVE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived Ease of Use (EU)</td>
<td>EUW1</td>
<td>.704</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>EUW2</td>
<td>.842</td>
<td>0.8567</td>
<td>0.6004</td>
</tr>
<tr>
<td></td>
<td>EUW3</td>
<td>.814</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>EUW4</td>
<td>.731</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>EUEC1</td>
<td></td>
<td></td>
<td>0.776</td>
</tr>
<tr>
<td></td>
<td>EUEC2</td>
<td></td>
<td></td>
<td>0.662</td>
</tr>
<tr>
<td></td>
<td>EUEC3</td>
<td></td>
<td></td>
<td>0.689</td>
</tr>
<tr>
<td></td>
<td>EUEC4</td>
<td></td>
<td></td>
<td>0.753</td>
</tr>
<tr>
<td></td>
<td>EUEC5</td>
<td></td>
<td></td>
<td>0.505</td>
</tr>
</tbody>
</table>
### Analysis of the Structural Model

As Heir et al. [2006]; noted it is always important to assess how well the structural model matches the observed data. The descriptive analysis carried out, it was established that students prefer Electronic campus to WebCt. Therefore this study decided to establish which factors play major role with the least used WebCT. Therefore this study’s structural equations analysis is based on WebCt’s parameters. The study found it paramount to assess the model fitness to establish whether the relationships are consistent with the theoretical or hypothesized expectations. In the same view, researchers [e.g. Heir et al. 2006; Jöreskog and Sörbom 1993]; recommend that, relevant model fit indices should be compared with their corresponding recommended threshold values in order to establish and recommend a good model fit. Among the most commonly used fit measures in research are; Chi-Squared test ($\chi^2$), absolute, incremental and parsimony fit measures. Others include root mean square error of approximation (RMSEA), goodness-of-fit statistic (GFI) and the adjusted goodness-of-fit statistic (AGFI), root mean square residual (RMR) and standardized root mean square residual (SRMR). However, Jöreskog

<table>
<thead>
<tr>
<th>Construct</th>
<th>Indicator</th>
<th>Factor Loading ($\lambda$)</th>
<th>Composite Reliability (CR)</th>
<th>Average Variance Extracted (AVE)</th>
<th>Indicator</th>
<th>Factor Loading ($\lambda$)</th>
<th>Composite Reliability (CR)</th>
<th>Average Variance Extracted (AVE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Advantage (RA)</td>
<td>RAW1 .733</td>
<td>0.8571</td>
<td>0.6001</td>
<td>RAEC2 0.639</td>
<td>0.751</td>
<td>RAEC3 0.536</td>
<td>0.504</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RAW2 .751</td>
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<td></td>
<td>RAEC4 0.743</td>
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<td></td>
<td>RAW3 .804</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>RAW4 .808</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complexity (C)</td>
<td>CW1 .841</td>
<td>0.8663</td>
<td>0.6193</td>
<td>CEC1 0.705</td>
<td>0.845</td>
<td>CEC2 0.734</td>
<td>0.578</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CW2 .814</td>
<td></td>
<td></td>
<td>CEC3 0.793</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CW3 .704</td>
<td></td>
<td></td>
<td>CEC4 0.804</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CW4 .782</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prioritization (P)</td>
<td>PW1 .805</td>
<td>0.8524</td>
<td>0.6584</td>
<td>PEC1 0.752</td>
<td>0.752</td>
<td>PEC2 0.643</td>
<td>0.504</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PW2 .845</td>
<td></td>
<td></td>
<td>PEC3 0.729</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PW3 .783</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
and Sörbom [1993]; further adds that the performance of Chi-Squared test ($\chi^2$), may be limited as the sample sizes increases or when there are small sample sizes that are not normally distributed. Heir et al. [2006]; recommend the use of the chi-square per degree of freedom ($\chi^2 / \text{d.f.}$) which makes the model less dependent on the sample size. In the category of absolute, incremental and, parsimony fit measures Heir et al. [2006]; observed that due to different software used by researchers to analyze their data, at least one absolute index such as RMSEA and an incremental index like the comparative fit index (CFI) may be used to determine the goodness of fit. They further suggested that, for models that include a comparison of varying complexity, a researcher should add one other fit index from a choice of parsimony normed fit index (PNFI) such as GFI and SRMR. Results of measurement of goodness of fit index shown in Table 5 indicate that, all goodness-of-fit statistics are in the acceptable ranges. Results in Table 5 imply that since the fit indices GFI, CFI > 0.90 both exceeds the threshold value and 0.06 < RMSEA < 0.08 also falls within the range, the structural model fits the data following some modifications as per the Modification Indices (MI).

### Table 5: Structural Model Measurement Basing on Fit Indices

<table>
<thead>
<tr>
<th>Model Goodness-Fit Indexes</th>
<th>Results from this Study</th>
<th>Recommended Value</th>
<th>Recommendation of the Structural Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\chi^2$/d.f</td>
<td>2.862</td>
<td>$\leq 3.000$</td>
<td>Less than the threshold, shows model is good</td>
</tr>
<tr>
<td>RMSEA</td>
<td>0.068</td>
<td>$\leq 0.060 &amp; &gt; 0.08$</td>
<td>Less than the threshold, shows model is good</td>
</tr>
<tr>
<td>CFI</td>
<td>0.984</td>
<td>$\geq 0.950$</td>
<td>Greater than the threshold, shows model is good</td>
</tr>
<tr>
<td>GFI</td>
<td>0.915</td>
<td>$\geq 0.90$</td>
<td>Greater than the threshold, shows model is good</td>
</tr>
</tbody>
</table>

$\chi^2$/d.f = Chi-square per degrees of freedom

RMSEA = root mean square error of approximation.

CFI = comparative fit index

GFI = goodness-of-fit index

Figure 2 below shows the path diagrams with their respective significance levels. Results from figure 2 and Table 6 are used to prove the set hypotheses. From figure 2, it can be deduced that the proposed structural model explained 58% variance for the actual selection of a CMS to use. Of the four set hypotheses, three were found to be significant at $p < 0.05$, with the exception of perceived ease of use. Hypothesis (H4)
that postulated that the higher the priority the higher the chances of actual selection of a CMS was found to be highly positive significant with a regression coefficient (β) is 0.578 with t value of t = 12.52 and p<0.05 indicating acceptance that prioritization significantly has a positive direct influence on actual selection of a CMS. This was followed by hypothesis (H3) with (β) is 0.545, t = 11.402 and p< 0.05. This implies that students will be attracted to use a system that they perceive to be less complex. On the other hand, hypothesis (H2) was found less significant with (β) is 0.149, t = 3.225 and p slightly < 0.05. This implies that students see little difference in terms of the relative advantage between the CMS. Hence relative advantage is not a strong factor for them to prioritize one. Hypothesis (H1) was found to be insignificant with (β) is 0.031, t = 1.272 and p>0.05. This supports the conclusion obtained in table 1 that, the advent of social networking sites has made the use of web-based tools easy to use. Students with such experience see little difference when using CMSs hence such a factor may not be based on for them to prioritize a given CMS. Results are summarized in Table 6 below.

**Figure 2: Path Diagram for the Structure Model of Factors influencing students’ Choice**
Table 6: Implication of the Hypothesis Basing on the Path Diagram Summary

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Relationship</th>
<th>Path Coefficient $\beta$ – value</th>
<th>t-value</th>
<th>Sig. p</th>
<th>Results implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>EU</td>
<td>0.031</td>
<td>1.272</td>
<td>.585</td>
<td>Not Accepted</td>
</tr>
<tr>
<td>H2</td>
<td>RA</td>
<td>0.149</td>
<td>3.225</td>
<td>.041</td>
<td>Accepted</td>
</tr>
<tr>
<td>H3</td>
<td>C</td>
<td>0.545</td>
<td>11.402</td>
<td>.000</td>
<td>Accepted</td>
</tr>
<tr>
<td>H4</td>
<td>P ASU</td>
<td>0.578</td>
<td>12.523</td>
<td>.000</td>
<td>Accepted</td>
</tr>
</tbody>
</table>

Discussion and Conclusion

In this study we used both TAM and DOI constructs to develop a model for factors influencing students’ choice to select between two e-learning tools taking a case of two CMS WebCt and Electronic Campus. The findings indicate that complexity and relative advantage when mediated by prioritization are good antecedents for actual selection of a CMS to use by students. Moreover, perceived ease of use didn’t show significant relationship with prioritization. This may be so because students with good experience of internet usage as shown in this study will assume every web-based tool to be easy to use. Therefore, they couldn’t take perceived ease of use as a major issue. Similar to earlier studies [Lee et al. 2009; Saadé et al. 2007]; this study substantiates further evidence of the appropriateness of DOI and TAM in explaining the role played by students’ latent behavioral when making choices to use e-learning tools. For instance, students may fear to use a CMS they perceive complex for several reasons like; fearing to fail their coursework, feeling socially uncomfortable to be seen falling behind other students who are using it and fearing to be called IT illiterates.

In their studies of TAM [Davis 1989; Davis et al. 1992]; perceived ease of use was found to be a major antecedent in determining users’ intention to use. This study’s descriptive analysis for both Electronic Campus and WebCt are in line with this finding. However, the SEM analysis has varied conclusions with perceived ease of use being very significant with Electronic Campus with 36.5% prediction and insignificant with WebCt having 3.1% at p > 0.05. One explanation of this is that, the advent of social computing tools like Facebook, Skype, Twitter and many others has made the use of internet to generally be perceived as easy. Another reason is that, students’ demographics like level of study, course or program of study where only used in the descriptive analysis and not included in the SEM. Moreover, much as perceived ease of use was not found significant to influence university students’ intention to prioritize a CMS, this constructs highly relates students’ attitudes toward e-learning [Nanayakkara 2007; Lee et al. 2009] overlooking it may negatively impact on the students’ acceptance of information technology.
From the goodness-of-fit test, this study led to the conclusion that the model well represented the collected data. This study therefore recommends that universities should have clear e-learning policies before e-learning implementation can take place. These policies are fundamental because of the role e-learning plays in augmenting classroom teaching and to counter balance the exponential increase of e-learning tools on the market. The implications of these findings are also important for the lecturers who use these e-learning tools to enhance classroom teaching. Students’ preferences should be taken into consideration as the lecturer chooses which CMS to use for communications and teaching. This is because if a lecturer adopts one of the systems like WebCT, which is not the students’ choice, he or she will end up doing double work: posting work on the two systems or doing it manually.

Future research should take into consideration students’ comparison of technology on the basis of their social and cultural backgrounds. This implies research should investigate technology comparison cross-culturally. It is a fact that many students in African universities come from less privileged families, gone to poor schools and start using computers at universities.

References


Learning Context of University Students in Africa: A Propeller or Inhibitor for Mlearning?

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Abstract

Context is an important dimension in context-aware eLearning systems. Of particular importance are the Instructional Management System (IMS) Global Learning Consortium learning contexts, namely: Learner Information Context, Device Context, Digital Context, Physical Context and World Context. Whereas these contextual variables are of great significance to conventional eLearning, little research has been conducted to establish their significance to mLearning. In a survey of undergraduate distance and conventional learners at Makerere University in Uganda, it was established that mLearning was still at its embryonic stage. As a result, it was not significantly associated with any of the IMS Global Learning Consortium learning contexts. It was concluded that a specific learning context provides no specific impediment to mLearning because a learner or context-aware system can easily work around a given would be impeding learning context, which means that mLearning can be partaken of in any learning context. Be it as it was, a further investigation was necessitated into the relationship between the different learning contexts and how they impact on mLearning.

*Corresponding Author
Introduction and Related Work

The increasing proliferation of mobile devices and systems means that their users are freed from transacting different processes in tethered environments. In the education sector, learners and their teachers are increasingly using mobile devices in pedagogic services, a phenomenon called mobile learning (mLearning). Compared with conventional eLearning, hereafter referred to as eLearning, mLearning is a relatively new form of use of ICTs in education. It entails learners learning at anytime in anyplace using mobile devices [Traxler, 2007]. It is a form of eLearning which employs wireless, tiny, handheld and portable devices to extend and deliver learning to students [Luis de Marcos et al. 2006]. We conceptualize mLearning as any act of using any services rendered by a mobile device to extend learning or learning support.

Since learner and teacher mobility is enabled in mLearning, it implies that mLearning takes place in varied learning contexts. Consequently, the design of mLearning systems calls for the embedment of learner context [Krause et al., 2006; Schmidt & Winterhalter, 2004; Syvänen et al. 2005]. In Muyinda [2010], learner context, was found to be an important dimension in the mobile learning object deployment and utilisation framework (MoLODUF). This framework can be used by mobile application developers to develop and evaluate mLearning environments.

Context “is typically the location, identities of nearby people, objects and changes to objects” (Zhang, 2003. p.7). Learning context provides information which describes the situation of a learner in a given location. It encompasses the learning environment and tools the learner uses to learn. Learning context can guide learners, educators and instructional systems in choosing and adapting learning content and appropriate learning devices [Denrtl & Hummel, 2005; Schmidt & Winterhalter, 2004]. It can also be used to isolate a given learner’s learning needs and resources in a given situation.

The emergency of pervasive learning models has increased the need for context-awareness. In Denrtl and Hummel [2005]; Krause et al. [2006] and Syvänen et al. (2006), mLearning systems that explicitly decipher the learning context are reported. In traditional learning systems, Educational Modelling Languages (EML) (Koper & Olivier, 2004) have been used to model relationships between learning processes and learning context. Denrtl and Hummel [2005] have developed a method for embedding context information in course activities by extending the Person-Centered e-Learning (PCEl) model [Derntl, 2004]. All these efforts exhibit the need to situate learning in a given context. Learning context can be well understood within the framework of Lave and Wenger’s [1991] situated learning theory.
In the situated learning theory, learning occurs in specific social contexts and communities of practice [Lave & Wenger, 1991]. The theory considers the learner's learning environment as being pivotal to learning. Situating learning increases learner's learning experience because knowledge can be adapted to that learner’s specific context [Caudill, 2007; Uden 2007]. Situated learning is prominently evident in problem-based learning [Koschmann et al., 1996], case-based learning [Kolodner & Guzdial, 2000] and context-aware learning [Naismith et al., 2006].

The aim of problem-based learning [Koschmann et al., 1996] is to develop the learner's higher order cognitive skills by providing that learner with a half defined problem which is synonymous with a real problem they will find in the field as a practicing professional. Problem-based learning is not geared towards testing the learner's skills but at developing their practical skills [Naismith et al., 2006]. It is a good model for training practical oriented professionals such as doctors and engineers. In problem-based learning, learners ought to situate their solutions within the prevailing conditions of the environment they are located in.

Case-based learning was espoused by Kolodner and Guzdial [2000]. Case-based learning resembles problem-based learning though its aim is to solve mainly wholly defined problems. These well-defined problems may or may not be a replica of what the student will be faced with in the field of work. Usually the learner is presented with multiple problems emanating from different learning contexts. “Case-based learning is more flexible than problem based learning in that it can be used in small or large classes and can be used as either an assessment exercise or as a catalyst for class discussions and lectures” [Naismith et al., 2006, p.14]. Case-based learning tests learners’ skills rather than developing skills.

“Context-awareness means gathering information from the environment to provide a measure of what is currently going on around the user and the device” [Naismith et al., 2006, p.14]. In context-aware learning, the learner learns by comparing what they are learning with issues in their context. It means that devices that can capture the learner’s context can facilitate learning in context. Mobile devices fitted with global positioning system (GPS) can be used to capture a learner’s contextual information [Nie, 2007]. The GPS information is useful because it enables learners to receive learning activities and content that is particularly relevant to them in their given situation. Mobile devices can be found in all contexts hence can be adapted to the various learning contexts [Nie, 2007; Naismith et al., 2006]. Mobile devices have aided tourists and shoppers in museums and super stores respectively by providing specific information about different items within their vicinity.

Several frameworks have been used to categorise learning context, but key of these is the IMS Global Learning Consortium’s [2001] Learner Information Profile. The IMS Learner Information Profile groups learning context in five categories, namely: World Context, Device Context, Physical Context, Learner Information Context, and Digital Context [IMS Global Learning Consortium, 2001]. The World Context considers the
location, date and time of learning while the Device Context looks at the hardware, software and connectivity available to the learner. The Physical Context considers the persons, books, journals and learning equipment in the learner's vicinity while the Learner Information Context looks at the learner's personal and task specific information. The Digital Context considers the availability to the learner of e-papers, e-collaboration and e-learning services (ibid).

The learning contexts identified in the IMS Global Learning Consortium (2001) Learner Information Profile manifest in eLearning environments but their significance to mLearning is yet to be studied. For instance, in the Learner Information Context little is known about the significance of ICT Literacy on mLearning. In the Device Context, no exhaustive study has been carried out to establish the relationship between Mobile Phone Ownership and Device Commonly Used for Accessing Internet on mLearning. In the Digital Context, the influence of Availability of Internet Connectivity and Availability of Mobile Network Connectivity on mLearning is yet to be studied. In the World Context, nothing is known about the influence of Type of Learners Location (urban, semi-urban or rural), the Noise Levels of the Learner’s Locations, Availability of Power Supply and Mode of Study on mLearning. This paper answers these research questions.

The Approach
This paper is derived from part of the data collected by the corresponding author for his PhD research, titled ‘Deploying and Utilising Learning Objects on Mobile Phones’. The PhD work was aimed at developing a framework for instantiating/creating pedagogic applications that could enable learners in developing countries obtain access to and use learning objects, delivered over the Internet/other networking technologies, regardless of their proximity to higher education institutions, through the use of mobile phones. In the PhD dissertation, learning context emerged as one of the major dimensions of the Mobile Learning Object Deployment and Utilisation Framework (MoLODUF) [Muyinda, 2010].

The paper provides a quantitative account of the significance of selected sub-learning contexts (from IMS Learner Information Profile) on mLearning. These include: ICT Literacy Level, Mobile Phone Ownership, Device Commonly Used for Accessing Internet, Availability of Internet Connectivity, Availability of Mobile Network Connectivity, Type of Learners Location, Noise Levels of the Learner’s Locations, Availability of Power Supply and Mode of Study. These variables were selected because, in Brown [2005] and Farrell and Isaacs (2007), they have been pinpointed as having significant influence on the adoption of eLearning in developing countries.

A survey approach was preferred because the target respondents were dispersed across the country. The population of the study consisted of undergraduate distance and internal learners at Makerere University in Uganda. Makerere University is a dual mode University because it offers both internal and distance learning degree and diploma programmes [Aguti, 2009].
Using Calder’s sample size determination formula, a sample size of 246 was arrived at. However considering that surveys have a response rate of 20 percent [Burgess, 2001] the required size was multiplied by five to determine the sample size to receive a self-administered survey questionnaire. The questionnaire was distributed to 1,230 respondents who were selected using multi-stage sampling method involving cluster sampling at stage one and stratified random sampling at stage two. The population was clustered along the mode of study characteristics. Distance learners formed cluster one while internal learners formed cluster two. After the survey 446 responses were returned representing a response rate of 36.3 Percent.

The self administered questionnaire, among other questions, included questions on the context variables under investigation. It also had questions measuring learners’ involvement in mLearning related practices such as placing SMSs or voice calls for the purpose of relaying a learning message. Gaming for education/learning purposes and collaboration on mobile phones using mobile chatting tools were not included in the questionnaire because earlier studies [Brown, 2005] had shown that learners in developing countries mainly own low end mobile phones which are not capable of these functions.

Descriptive statistics on the learning contexts were generated and later associated with mLearning through cross-tabulations. The cross-tabulations generated Pearson Chi-square statistics which were used to determine the level of association between the selected learning contexts and mLearning.

**Results**

**Characteristics of Respondents**

Respondents (N=446) in the survey were distributed as 48.9 Percent (n=218) distance learners and 51.1 Percent (n=228) internal learners. Males constituted 62.3 Percent while 37.7 Percent were female. Their minimum age was 18 while the maximum age was 46 with a mean age of 24.7 and mode of 21. The minimum age of 18 was recorded from amongst internal learners while the maximum age of 46 was recorded from distance learners. Forty three Percent of the learners surveyed were pursuing science related programmes while 57.0 Percent were pursuing humanities related programmes. Learners were drawn from all years of study, including: first year (15.9 Percent), second year (32.3 Percent), third year (35.2 Percent) and fourth year (16.6 Percent). Most of the learners were unemployed (67.5 Percent) and not married (79.8 Percent). They joined university after attaining ‘A’ Level (70.2 Percent), diploma (26.9 Percent), grade III teacher certificate (1.1 Percent), degree (1.1 Percent) or other qualifications (0.7 Percent).

**Description of the Learning Context**

The IMS Global Learning Consortium (2001) learning context framework categorises learning context into five groups. These include: Learner Information Context, Device Context, Digital Context, World Context and Physical Context. Whereas each of
these context areas has several sub-contexts, this paper has selected only those sub-contexts which are indicated in Brown (2005) and Farrell and Isaacs (2007) as having significant challenges to eLearning in developing countries. These learning sub-contexts include: ICT Literacy Levels in the Learner Information Context and Mobile Phone Ownership and Device Usually Used to Access Internet in the Device Context. Others sub-contexts considered are Availability of Internet and Mobile Network Connectivity in the Digital Context. In the World Context the sub-contexts considered are Type of Location Where Learning Activities are usually Conducted, Noise Levels of Learning Locations, Availability of Power Supply and Mode of Study. In Sections 3.2.1 through to 3.2.4 below, descriptive statistics on the status quo of these sub-contexts amongst respondents is presented.

**Learner Information Context**

The Learner Information Context describes the learner’s personal attributes. This may include attributes like expertise or interests in learning. Within this research, we investigated the respondents’ ICT Literacy Levels sub-learning context under the Learner Information Context in Figure 1 below.

![Figure 1: ICT Literacy Levels](image)

Figure 1 above shows that a big proportion of respondents were ICT literate. Only 10.5 Percent of them did not know how to use a computer. The term ‘ICT Literacy’ was used in this paper to mean one’s ability to use a computer in their day to day activities.

**Device Context**

The Device Context provides the situation of the learner in as far as devices for use in the learning process are concerned. This being a mLearning research, we concentrated on learning context related to ownership of mobile phones and devices commonly used to access Internet.
The mobile phone has permeated among all walks of life. Of the respondents surveyed, 96.2 Percent owned a mobile phone and only a minimal 3.8 Percent did not own a mobile phone.

Though the majority (96.2 Percent) of respondents owned a mobile phone, only 7.8 Percent used them to access Internet. They mainly (80.7 Percent) used desktop or laptop computers to access Internet. A good proportion of respondents (11.4 Percent) had never used Internet.

**Digital Context**

The digital context describes the digital learning resources available to the learner. Access to the digital resources is only made possible if a learner has access to conventional Internet or mobile network connectivity. Figures 4 and 5 below present the availability to the respondents, of Internet and mobile network connectivity respectively.

**Table 4: Availability of Internet Connectivity to the Respondents**
Whereas 80.7 Percent of the respondents used a desktop or laptop computer whenever they accessed Internet (Table 2 above), the majority of respondents disagreed (42.4 Percent) or strongly disagreed (34.5 Percent) with the statement that ‘Internet connectivity was available to them at all times’. Thus access to digital resources was still problematic under this context. On the other hand, connectivity to the mobile network was pervasive as is shown in Figure 5 below.

**Figure 5: Availability of Mobile Network Connectivity to the Respondents**

Unlike Internet connectivity, mobile network connectivity was present at all times to the majority (71.1 Percent) of respondents. Intermittency in mobile network connectivity was experienced by 28.9 Percent of the respondents. Even if there was high permeation of mobile phones among the respondents, only 7.8 Percent of them accessed the Internet using their mobile phones. Limited access to Internet via mobile phones only suggests limited access to digital resources via mobile phones.

**World Context**

The World Context describes the location of the learner. Figures 6, 7 and 8 below present the results of the type, noise levels and availability of electric power supply respectively of the location where the learners usually undertook their learning activities.

**Figure 6: Type of Location Where Learning Activities are Usually Conducted**

As is shown in Table 6 above, most learners (78.0 Percent) resided and undertook their learning activities in urban areas. This contradicts the common belief that distance learners, who constituted 48.9 Percent of the sample, hail and undertake their studies
from rural areas. Only 10.5 percent of the learners operated from rural areas. The amount of noise in these locations is presented in Figure 8 below.

**Figure 8: Noise Levels of the Learners Usual Learning Environment**

![Figure 8: Noise Levels of the Learners Usual Learning Environment](image)

Learning concentration often requires quiet learning environments. Moreover, voice communication via mobile phones may sometimes be unacceptable in contexts with high noise levels. Figure 8 above shows that the majority of respondents (59.4 percent) found themselves in sometimes noisy learning environment. This can be explained by the fact that the majority (78.0 percent) of respondents (Table 7) lived in and operated from urban areas which tend to be noisier than rural areas.

**Figure 7: Availability of Electric Power Supply**

![Figure 7: Availability of Electric Power Supply](image)

Whereas the majority of respondents lived and worked in urban areas that are expected to have constant electric power supply, a big proportion of them disagreed (40.0 percent) or strongly disagreed (22.8 percent) to the statement that ‘electric power supply is available to them at all times’. This implies that electric power supply is intermittent, a context that negatively affects eLearning (Brown, 2005).

**Associating Different Learning Contexts With mLearning**

Having described the learning context of respondents in the foregoing section, we then measured the association between those learning contexts and mLearning. For comparison purposes, the association between the selected contexts and eLearning was also measured. The association was measured by cross-tabulating the learning contexts with variables related to mLearning and eLearning. ‘Placing of text messages and voice calls for the purpose of learning’ was used to construe participation in ‘mLearning’. Learners were asked in two logical questions to indicate whether they placed SMS
messages or voice calls for the purpose of learning. Likewise, if a learner had ever used any learning management system (LMS), then such a learner was construed as having participated in eLearning. This was unearthed from a logical question which required respondents to indicate whether they had ever used any LMS such as Blackboard, WebCT, Kewl.Nextgen, Moodle or Sakai. Tables 4.1 through to 4.4 below, presents the associations.

Table 4.1: Associating Learner Information Context With mLearning and eLearning

<table>
<thead>
<tr>
<th>Association</th>
<th>df</th>
<th>Likelihood Ratio</th>
<th>Pearson Chi-square</th>
<th>N</th>
<th>Association</th>
<th>df</th>
<th>Likelihood Ratio</th>
<th>Pearson Chi-square</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICT Literacy vs Calls for Learning</td>
<td>4</td>
<td>0.262</td>
<td>0.272</td>
<td>446</td>
<td>ICT Literacy vs Use of LMS</td>
<td>20</td>
<td>0.079</td>
<td>0.116</td>
<td>428</td>
</tr>
<tr>
<td>ICT Literacy vs SMS for Learning</td>
<td>4</td>
<td>0.565</td>
<td>0.568</td>
<td>446</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The sub-learning context considered in the Learner Information Context was ICT Literacy Level of respondents. Table 4.1 above shows that at a level of significance of \( p \leq 0.05 \) and 4 degrees of freedom, \( p > 0.05 \) for the ICT Literacy Level learning context. This implies that ICT Literacy Level was not significant associated with mLearning \( (p=0.272 \text{ and } p=568) \) and eLearning \( (p=0.116) \).

Table 4.2: Associating Device Context With mLearning and eLearning

<table>
<thead>
<tr>
<th>Association</th>
<th>df</th>
<th>Likelihood Ratio</th>
<th>Pearson Chi-square</th>
<th>N</th>
<th>Association</th>
<th>df</th>
<th>Likelihood Ratio</th>
<th>Pearson Chi-square</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone Ownership vs Calls for Learning</td>
<td>1</td>
<td>0.713</td>
<td>0.714</td>
<td>446</td>
<td>Phone Ownership vs Use of LMS</td>
<td>5</td>
<td>0.494</td>
<td>0.494</td>
<td>428</td>
</tr>
<tr>
<td>Phone Ownership vs SMS for Learning</td>
<td>1</td>
<td>0.404</td>
<td>0.409</td>
<td>446</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The sub-learning contexts considered in the Device Context were Mobile Phone Ownership and Device Commonly Used to Access Internet. As is shown Table 4.2 above, none of these sub-learning contexts were significantly associated with mLearning. Likewise, they were also not significantly associated with use of a LMS (p=0.494 and p=0.072).

Table 4.3: Associating Digital Context With mLearning and eLearning

<table>
<thead>
<tr>
<th>Association</th>
<th>df</th>
<th>Likelihood Ratio</th>
<th>Pearson Chi-square</th>
<th>N</th>
<th>Association</th>
<th>df</th>
<th>Likelihood Ratio</th>
<th>Pearson Chi-square</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internet Access Device Vs Calls for Learning</td>
<td>1</td>
<td>0.889</td>
<td>0.889</td>
<td>395</td>
<td>Internet Access Device Vs Use of LMS</td>
<td>5</td>
<td>0.072</td>
<td>0.072</td>
<td>379</td>
</tr>
<tr>
<td>Internet Access Device Vs SMS for Learning</td>
<td>1</td>
<td>0.781</td>
<td>0.781</td>
<td>395</td>
<td>Mobile Connectivity Vs Calls for Learning</td>
<td>3</td>
<td>0.819</td>
<td>0.820</td>
<td>443</td>
</tr>
<tr>
<td>Mobile Connectivity Vs SMS for Learning</td>
<td>3</td>
<td>0.661</td>
<td>0.664</td>
<td>443</td>
<td>Mobile Connectivity Vs Use of LMS</td>
<td>15</td>
<td>0.811</td>
<td>0.700</td>
<td>426</td>
</tr>
<tr>
<td>Internet Connectivity Vs Calls for Learning</td>
<td>3</td>
<td>0.753</td>
<td>0.753</td>
<td>443</td>
<td>Internet Connectivity Vs Use of LMS</td>
<td>15</td>
<td>0.001</td>
<td>0.001</td>
<td>426</td>
</tr>
<tr>
<td>Internet Connectivity Vs SMS for Learning</td>
<td>3</td>
<td>0.897</td>
<td>0.897</td>
<td>443</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In the Digital Context, the sub-contexts considered were Availability of Mobile Network and Internet Connectivity. Table 4.3 above shows that use of mLearning is not significantly associated with availability of mobile network (p = 0.820 and p = 0.664) and Internet (p = 0.753 and p = 0.897) connectivity. However, Table 4.3 indicates that availability of Internet connectivity is strongly associated (p = 0.001) with use of a LMS. This is a truism because LMS are connected in a client server architecture where Internet provides the interconnectivity between the client and the server. On the other hand, availability of mobile network connectivity was not significantly associated (p = 0.700) with use of a LMS.

Table 4.4: Associating World Context With mLearning and eLearning

<table>
<thead>
<tr>
<th>Association</th>
<th>df</th>
<th>Likelihood Ratio</th>
<th>Pearson Chi-square</th>
<th>N</th>
<th>Association</th>
<th>df</th>
<th>Likelihood Ratio</th>
<th>Pearson Chi-square</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learner’s Location Vs Calls for Learning</td>
<td>2</td>
<td>0.221</td>
<td>0.220</td>
<td>446</td>
<td>Learner’s Location Vs Use of LMS</td>
<td>10</td>
<td>0.018</td>
<td>0.051</td>
<td>428</td>
</tr>
<tr>
<td>Learner’s Location Vs SMS for Learning</td>
<td>2</td>
<td>0.172</td>
<td>0.171</td>
<td>446</td>
<td>Noise Levels Vs Use of LMS</td>
<td>10</td>
<td>0.014</td>
<td>0.021</td>
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</tr>
<tr>
<td>Noise Levels Vs Calls for Learning</td>
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<td>0.740</td>
<td>446</td>
<td>Noise Levels Vs Use of LMS</td>
<td>10</td>
<td>0.014</td>
<td>0.021</td>
<td>428</td>
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<tr>
<td>Noise Levels Vs SMS for Learning</td>
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<td>0.810</td>
<td>0.810</td>
<td>446</td>
<td>Electricity Supply Vs Use of LMS</td>
<td>15</td>
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<td>0.503</td>
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<tr>
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<td>3</td>
<td>0.662</td>
<td>0.663</td>
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<td>Electricity Supply Vs Use of LMS</td>
<td>15</td>
<td>0.538</td>
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<tr>
<td>Electricity Supply Vs SMS for Learning</td>
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<td>0.345</td>
<td>0.346</td>
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<td>Study Mode Vs Use of LMS</td>
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<td>0.091</td>
<td>0.096</td>
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</tbody>
</table>

In the World Context we considered the Type of Learner’s Location (urban, semi-urban, rural), Noise Levels of the Learner’s Usual Location, Availability of Electric Power Supply and Mode of Study sub-learning contexts. At different degrees of freedom and at a level of significance of $p \leq 0.05$, $p > 0.05$ for the different sub-learning contexts under the World Context. This implies that World Context sub-learning contexts in
Table 4.4 above were not significantly associated with mLearning. This was not the case with eLearning because the Type of Learner’s Location and Noise Levels of Learner’s Location and were found to be significantly associated with the use of a LMS at \( p = 0.051 \) and \( p = 0.021 \) respectively.

**Discussion**

The results have shown that mLearning can be partaken of in any learning context. What is important is for the learner or system to adapt to the prevailing learning context. Mobile devices are not tethered in specific locations and are therefore found in all contexts (Nie, 2007; Naismith et al., 2006). They can be adapted to the various learning contexts including those of ICT illiterates.

The so called ICT illiterates can partake of mLearning as ICT literacy had no significant association \( (p = 0.272 \text{ and } p = 0.568) \) with participation in mLearning. The day to day companionship and the routine nature of operating a mobile phone makes it easy for an ICT illiterate person to master the art of operating it. This finding concurs with Traxler (2007) who asserts that mLearning can permeate the boundaries of different social classes. On the other hand, studies (Brown 2005; Farrell & Isaacs, 2007) have strongly associated ICT Literacy Levels with ability to use a LMS (eLearning).

The type of learner's location was found to be insignificantly associated with participation in mLearning because mobile network connectivity was pervasive at 71.1 Percent. Also, learners who sometimes found themselves in areas with no mobile network connectivity (28.9 Percent) could still partake of mLearning in offline modes. A learner can reflect on text messages, watch educative videos and listen to lecture podcasts saved in the memory of their mobile phones while in areas with or without mobile network connectivity. In Trifonova and Ronchetti (2006), a system for hoarding mobile content for use during offline sessions is reported.

The noise levels of the learner's usual learning location was found to be of no significance \( (p = 0.740 \text{ and } p=0.810) \) to participation in mLearning. A learning object can be expressed in different media types, including text, video, audio or a combination of these. If the learning context is noisy, the learner may choose to use text instead of audio based learning objects. Likewise, in a dark quiet learning context, a learner can decide to listen to lecture podcasts instead of reading a text based learning object.

Availability of electricity to the learner was found to have no significance \( (p = 0.663 \text{ and } p= 346) \) to his/her participation in mLearning. These findings concur with our earlier study (Muyinda et al. 2010) in which we found that alternative sources of power were being used to charge mobile phone batteries in areas with no national power supply. Solar energy and car batteries were used to provide alternative sources of power.

Availability of mobile network connectivity was also found to have no significant association \( (p = 0.820 \text{ and } p = 664) \) to mLearning because it is possible to have offline mLearning activities (Trifonova & Ronchetti, 2006). A learner can reflect on text messages, watch educative videos and listen to lecture podcasts saved in the memory...
of their mobile phones while in areas with or without mobile network connectivity. Similarly, availability of Internet connectivity did not present a significant association (p = 0.753 and p = 0.897) with mLearning. The reason for this new thinking arises from the fact that mLearning in many developing countries of Africa still remains a new phenomenon which is not wide spread and is thus still insensitive to many learning contexts. Also, availability of mobile network connectivity was of no significance to the use of a LMS because only a minimal number of learners (7.8 Percent) accessed Internet via their mobile phones. Presence of Internet is significantly associated (p = 0.001) with use of a LMS.

In Traxler (2007), Caudill (2007) and Wang and Liu, (2005), mLearning is strongly associated with distance learning. However, in this paper, no significant association was found between mode of study and mLearning. This shows that neither distance nor internal learners were actively engaged in using mLearning. Compared with eLearning, mLearning is a relatively new learning paradigm (Traxler & Kukulska-Hulme, 2005).

Conclusion and Future Work
Learning context forms an important dimension in mLearning. A specific learning context provides no specific impediment to mLearning because a learner can easily work around the would be impeding learning context. In essence, mLearning can take place in any learning context. This then requires context aware mLearning systems to sense the prevailing condition and be able to adjust accordingly. Be it as it is, a further investigation into the relationship between the different learning contexts and how the relationship impacts on mLearning is required.

Acknowledgement
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References


MUYINDA, B. P., LUBEGA, J., & LYNCH, K. 2010. Unleashing mobile phones for research supervision support at Makerere University, Uganda: the lessons learned. International Journal of Innovation and Learning (IJIL), 7(1), 14-34.


Underwriting Cyber Risks in Uganda

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Abstract
Whereas cyber insurance has become a convenient solution to cyber risks in the developed world, developing countries like Uganda still lag behind. The available insurance covers are still limited to physical electronic equipment which is incapable of providing protection for organizations against threats from the Internet. Such threats include viruses, hackers, phishers, denial of service attacks, intellectual property infringements, loss of customer data among others. This work examines the use of cyber insurance as a risk transference strategy in information technology (IT) security and risk management in Uganda. It reviews the extent to which current practices and insurance information systems provide cover for cyber risks. It then provides guidelines that insurance companies in Uganda that would like to provide cyber insurance cover can follow. These guidelines are verified through a prototype of a cyber insurance information system. It is hoped that the cyber insurance underwriting guidelines provided and the associated prototype can enlighten and ignite the spark among insurance companies in Uganda towards providing insurance cover for cyber risks among their other products. Beyond Uganda, this work is expected to contribute to a deeper understanding of the practice of cyber insurance in developing countries.

Key words: Underwriting, Insurance, Cyber risks, Insurance Management System

Introduction
Underwriting in insurance is the process of assessing risks and issuing insurance policies. Today more and more organizations are fully reliant on the Internet and associated
technologies to support their core business operations. These organizations stand to lose in case of any disruptions to the Internet infrastructure or associated perils that come with transacting business on the Internet. These perils include hacking, viruses, denial of service, spam, theft of confidential data, intellectual property suits, and legal liabilities among others. The scale and scope of these perils is on the increase, and many organizations have responded by deploying security technologies like firewalls, intrusion detection systems, anti viruses, biometric and other authentication systems [Doll 2002]. Although deployment of these technologies may reduce security vulnerabilities and losses from security breaches, complete prevention of security breaches remains technologically impossible [Ogut et al. 2005]. Therefore insurance can be called upon to hedge against the potential losses arising from the residual risks.

Cyber insurance is a class of insurance that is designed to protect businesses from Internet based risks, and more generally from risks relating to IT infrastructure and activities. The concept of cyber insurance is new to many firms in Uganda, though it has been available in more advanced markets since 1998 [Majuca et al. 2006]. What has been common in Uganda is the traditional computer insurance, which focuses on material damage to physical components of an organization’s IT infrastructure. However the demand for cyber insurance is expected to rise in Uganda following the linking of the country to high speed Internet via the coastal fibre optic cables. This is expected to deepen Internet penetration in the region, and as a result expose local companies and organizations to the vagaries of transacting on the Internet. Already more organizations in Uganda are launching Internet based services for example the Uganda Revenue Authority with its online tax system, as well as local commercial banks with their online banking services.

The dominant insurance underwriting systems that are currently in use namely Premia and the Advanced Insurance Management System (AIMS) were developed at the turn of the twenty first century and lack the functionality for underwriting cyber risks. So far they only have modules for underwriting traditional computer insurance. Globally, big brands like Oracle and SAP have developed insurance solutions. But despite their promises of flexibility, these solutions still remain out of reach for Ugandan insurers due to their proprietary nature, opacity of the code, high cost, complexity and one-size-fits-all approach. There is need to explore provision of home grown customized and affordable solutions that insurance providers in small economies like Uganda can use. This paper examines the use of cyber insurance as a risk transference strategy in IT security and risk management in Uganda. It provides guidelines that insurance companies in developing economies like Uganda can use to develop and provide cyber insurance cover. It also presents a prototype cyber insurance underwriting system that was developed based on the provided guidelines. The remaining sections include: methodology, related work, findings, a cyber insurance underwriting information system prototype, conclusion and future work.
Methodology

Sampling
This study used a purposive sampling approach to select insurance companies to participate in the study. Out of the 22 insurance companies registered in Uganda, four were chosen for the study. These four were chosen on the basis that they had implemented the AIMS insurance management information system. The companies that were selected for the study are: United Assurance (UAP), National Insurance Corporation (NIC), Statewide Insurance (SWIPCO) and Insurance Company of East Africa.

Data Collection
Data was collected from the sampled insurance companies to understand the scope of existing insurance policies, and to gain a deeper understanding of the underwriting process. The following specific tools were used for data collection:

**Questionnaires:** These were given underwriting managers drawn from the insurance companies covered in the sample.

**Interviews:** These were conducted with underwriting and information technology managers from the sampled companies.

**Document Analysis:** The purpose of document analysis was to understand the growing cyber risks and risk management strategies. Another significant part of document analysis involved reviewing the electronic equipment insurance policies issued by the insurance companies in Uganda as well as those issued in other parts of the world. This was aimed at comparing the state of cyber insurance in Uganda vis-à-vis the practice in more developed economies.

Development of the Prototype Cyber Insurance Underwriting System

System Design
Systems design involves those tasks that focus on the specification of a detailed computer based solution [Whitten and Bentley 2008]. For this research, the object oriented design approach was used. The object oriented approach is a software engineering approach that models a system as a group of interacting objects. An object is a thing of interest to the system and consists of both data and the logic about itself. In order to model the cyber insurance underwriting process, Unified Modeling Language (UML) notations were used to represent the different stakeholders and their roles in the cyber risks underwriting process.

System Implementation
Basing on the system design, a prototype for a cyber insurance underwriting system was implemented using the following tools:
Page Scripting Tools
Page scripts are small bits of code embedded in HTML pages that automate the behaviour of a web page. Hypertext Preprocessor (PHP) was selected from a variety of options. PHP is a widely used general purpose scripting language that is especially suited for web development and can be embedded into HTML. It can be used on all major operating systems and most major web servers, and also supports many database technologies.

Database and Web Server Selection
For the database implementation, MySQL was selected because in addition to being free to use and modify, it works well with client-server or embedded systems. For the Web server, Apache was selected. Apache is a popular web server that is used to serve static dynamic content on the World Wide Web. It is used in many situations where security and reliability is key for example in sharing personal files over the internet. Apache is also open source and free to use.

Guidelines for Underwriting Cyber Risks
The information obtained from questionnaires and interviews on the scope of existing insurance policies and what is involved in the underwriting process was synthesized with that from document analysis to come up with a possible strategy for addressing existing gaps in providing insurance cover for cyber risks.

Related Work

Insurance Underwriting
Underwriting is a term that is commonly used in the financial services sector, including banking, stock broking and insurance. Underwriting simply means assuming a risk [Australian Securities and Investment Commission 2003]. Originating from the Lloyds of London insurance market the term has its roots in maritime England where financial bankers who would assume some of the risk on a sea voyage in exchange for premium would write their names under the risk information that was written on a Lloyds insurance slip.

Cyber Insurance
In 2008, the Betterley Report estimated annual gross premiums from cyber insurance contracts at approximately USD 450-500 million up from USD 350 million in 2005. Despite this growth, cyber insurance is still in infancy and has not grown at a rate proportionate to the level of exposures especially in the developing world. Writing in the Critical Infrastructure Protection Program (CIP) Report, Hauserman [2007] cites several obstacles to the growth of cyber insurance namely:

- Lack of data - reinsurers do not have adequate data to accurately model and therefore price their policies.
- Low awareness - in most companies, risk managers and business continuity executives who make insurance-purchasing decisions are not aware of data
loss risks and cyber liability issues. On the other hand, IT experts assume they have taken all the necessary security measures, such as firewalls and antivirus programs, and do not like to admit that there are still significant risks to their networks.

- Unclear standards of accountability - standards for corporate accountability for cyber liability are unclear. Therefore, nobody shoulders responsibility for the risks, which remain unaddressed.
- Nonexistent standards and best practices - basic industry-wide standards are virtually nonexistent when it comes to cyber security. This makes it difficult for insurers and reinsurers to accurately analyze risk and price insurance policies.

Other general challenges facing the sector according to Baer [2003] include:

- Lack of agreement on basic policy definitions and language – constant developments in IT environments result in ambiguity about what is insured, what risks are covered, and how losses will be assessed. Law involving IT security is also changing, hence cyber insurers are likely to minimize their risks by narrowly defining coverage on new policies.
- Lack of underwriting experience – insurers have limited experience with IT security claims on which to base premiums because cyber insurance is relatively new and firms have resisted revealing losses resulting from security breaches as they fear adverse publicity if their IT vulnerabilities were revealed.
- Lack of adequate reinsurance – the limited nature of claims experience for IT security is restricting the growth of the related reinsurance industry.

This work will contribute to raising awareness for IT experts, risk managers and business continuity executives about data loss risks and cyber liability issues as well as the fact that despite strong technical measures, there will always be significant risks to their systems which insurance can help to mitigate. It is hoped this will spur interest and initiatives to address the other challenges of lack of data, accountability and lack of standards.

**Insurance Underwriting Systems**

A patent was issued in 1989 for the first computerized insurance premium quote and policy issuance system [Luchs et al. 1989]. The patented system was designed to process and prepare applications for insurance and premium quotations and for preparing and writing insurance contracts. The year 1989 was the same year that Sir Tim Berners Lee, working at the European Organization for Nuclear Research (CERN) in Geneva, produced a proposal for a hypertext project which would give rise to what we know now as the World Wide Web. It is fair to surmise that the developers of the first Insurance Management Information System did not foresee the risks presented by cyber space and the system was not built to cover these unforeseen risks.
Since 1989 there have been very significant developments in computerized systems supporting insurance underwriting operations. Some of the major applications in use globally include Oracle Inbridge Rating and Underwriting System [Oracle 2010] and SAP for insurance (SAP 2010). In Uganda, the insurance systems used such as Advanced Insurance Management System (AIMS) and Premia are all older insurance systems and do not cover cyber insurance. SAP and Oracle insurance solutions still remain out of reach for Ugandan insurers due to their proprietary nature, opacity of the code, high cost, complexity and one-size-fits-all approach.

**Cyber Risk Management**

Gordon et al. [2003] developed a framework for managing cyber risks in information security which includes an insurance component among others. Gordon and colleagues advise organizations to do the following:

- Begin by assessing the threats and vulnerabilities associated with their information systems.
- Reduce information security risk to an acceptable level. In an attempt to reduce risks to an acceptable level, an organization may implement technical controls like firewalls, encryption and access control systems. However, even with the best technical controls, there will still be residual risks, but the organization should conduct a cost benefit analysis so as to determine at what level they want to maintain these risks.

In addition, Gordon et al. [2003] presented a cyber insurance decision plan to help organizations in deciding whether they need insurance and choosing the best policy. Diagrammatically, this is illustrated below.

**Figure 1: The Cyber Insurance Decision Plan from Gordon et al. [2003]**

![Diagram of Cyber Insurance Decision Plan]

Supplementing on Gordon et al’s work, Cylinder [2008], advised that the cyber insurance decision plan should be a team approach, involving the information security specialists who will provide guidelines on risk exposure and security procedures, finance specialists
to shed light on the effect of a computer disruption on the entity’s income, and the amount of loss that can be retained, and others like an insurance broker, insurance consultant or computer consultant.

**Existing Gaps**
The cyber insurance framework and decision plan discussed by Gordon et al. [2003] and Cylinder [2008] only look at the perspective of the organizations seeking insurance which only helps an organization determine whether they need to insure against cyber risks but does not cover what the insurance provider needs to do to provide insurance against cyber risks. To fill this gap, this work provides guidelines to insurance service providers based on the current insurance service situation in Uganda and recommended cyber risks insurance practices in literature. The next section presents findings from the field study.

**Findings From the Field Study**
This section presents the findings that were obtained from the field study exercise on types of covers currently offered for IT in Uganda, current practices in insuring IT as well as the strengths and weaknesses of insurance management information systems used in Uganda.

**Current Practices in Insurance of IT in Uganda**

**Type of Covers Offered**
The survey established that all the four insurance companies were providing cover for computers and related devices under the Electronic Equipment (EE) Policy. This policy extends cover to computers, microprocessors, word processors, telecommunications equipment, machines meant for medical use and other miscellaneous equipment like film and television studio equipment and electronic scoreboards.

The EE policies cover the following specific perils:
- Material damage to computing devices
- Cost of data restoration
- Consequential losses
- External data media
- Increased cost of working

**ICT Risk Assessment Practices by Insurers**
It is significant to note that the sampled insurance companies do not conduct a comprehensive IT risk assessment prior to going on cover. Further, they do not review past audit reports relating to the IT environment, nor do they seek information regarding the IT security policies and practices in the organization. When assessing new risks, the insurers seek the following information:
- Physical location of insured equipment
- Nature and structure of building housing the electronic equipment
The above revelation shows that insurers in Uganda still see the threats largely from a material damage perspective, and are more concerned about the traditional risks of fire, natural hazards and water damage. These do not address the risks faced in the modern computing environment such as hackers, viruses, trojans, denial of service attacks, spambots and other malware. They also do not guard against legal liability suits arising from intellectual property infringements, as well as the wrath of customers and regulators in case confidential customer data is stolen. More paramount is the great risks to e-commerce such as risks from phishers and online transaction thieves. Clearly the existing risk assessment approaches as practiced by insurers in Uganda are inadequate to assess the potential risks to modern computing environments.

**Factors Limiting Cyber Insurance in Uganda**

Of the insurance companies surveyed, none of them were offering cyber insurance policies, i.e. specialized cover against threats arising from transacting on the internet. Further discussions with the respondents also indicated that the demand for cyber insurance was currently low, but there was potential for this type of cover following recent developments in the telecommunications sector that would allow more organizations to do business on the internet. A further push for cyber insurance was considered to be the increasing number of cyber incidents some of which have been reported in Uganda. One respondent commented that “to-date, the internet has potential to expose the small scale car trader in Kiseka in Kampala to the internet criminals in other far flung corners of the world”. Such risks could be partially mitigated through insurance. When asked about the greatest limitation to offering cyber insurance, the respondents gave the following factors:

- Inadequate expertise in cyber insurance underwriting
- Low demand for cyber insurance
- Lack of reinsurance support
- Inadequate information on the associated risks
- Lack of information systems to underwrite the risks

**Review of Insurance Underwriting Systems Used in Uganda**

The Uganda Insurance Commission, in its annual report for 2008, decried the low adoption of information technology by insurance companies in Uganda (Uganda Insurers Commission 2008). A survey of the industry revealed that there are two dominant systems used by insurance companies in Uganda. These are the Premia and AIMS systems. Premia is used by the top two insurance companies, i.e. Jubilee and Chartis. AIMS is used by at least four of the other top insurance companies, i.e. UAP, National Insurance Corporation, Insurance Company of East Africa and Statewide.
Insurance. This research restricted its scope to the companies that use the AIMS information system.

**The AIMS Insurance Underwriting System**

The AIMS system is built on the Cyber Science/CyberQuery (CQCS) programming language. This is a derivative of the C language and is developed by the Cyber Science Corporation in the United Kingdom. It runs on a natively embedded CISAM database which is a flat file non relational database. The system runs on a Linux operating system. Reports are generated using an inbuilt query generator called CyberQuery (CQ).

In terms of functionality, AIMS has three modules; the General Business, General Ledger and Front Office modules. The General Business module is used for underwriting, claims and reinsurance management. The General Ledger is used for financial accounting and financial reporting, while the Front Office is used for receipting and payments processing.

AIMS is quite capable of supporting the underwriting of electronic equipment risks. However, it is not suited for underwriting of cyber risks and may need significant reengineering to support cyber risks insurance. AIMS is designed to capture information related to the physical nature of the assets to be insured. There is great emphasis on the nature of the building, and the risk of fire, earthquake and flood to the building. This suggests that the covers underwritten in AIMS are mostly related to material damage to computing equipment and not loss of intangibles like data and intellectual property. It is clear that the information that is captured by AIMS would be inadequate to underwrite cyber insurance risks.

The assessment of the AIMS insurance system highlighted several weaknesses that makes it inadequate for the underwriting of cyber insurance risks as follows:

- Inability to capture additional supporting documents as attachments
- The system runs on a flat file CISAM database. This non relational database has implications on the integrity of data and limits the potential for integration with other systems
- The system has a section for capturing details regarding the assets. However the fields available solicit information regarding the material structure of the assets and the risk of fire and flood. As discussed earlier, cyber insurance requires not only material information but technical and operational measures put in place by an organization.
- The system is incapable of conducting an ICT risk assessment, and does not request for any information that can facilitate this
- It is based on a two tier client server model. This means that it can only be accessed by those who are physically located within a company’s local area network. In contrast, there was a desire from the respondents to have a web based system that could be accessed securely from any location as long as an internet connection existed.
- The system is incapable of generating a cyber insurance policy document
Guidelines for Underwriting Cyber Risks
Based on the findings from representatives of key staff in the insurance business and review of related literature, there is lack of guidance on what insurance service providers need to do to provide insurance cover for cyber risks. This section provides guidelines to insurers on the critical information about an organization that should be captured and analyzed as well as the required steps for processing insurance cover for cyber threats.

Critical Information to Capture and Analyse
To effectively underwrite cyber risks, insurers need to capture and analyze critical information relating to an organization's information security activities. Such information includes:

- Periodic information risk assessment reports
- Information security policies and procedures
- Information security plans
- Information security awareness programs
- Results of periodic information security tests and evaluations, e.g. penetration tests
- Business continuity plans
- Identification and assessment of assets, not just physical but also intangible assets e.g. data and software
- Identification and assessment of threats and vulnerabilities

This is beyond the limited view of Electronic Equipment Insurance that only sees threats from the material perspective.

Cyber Insurance Underwriting Process
Present work such as that by Gordon et al [2003] and Cylinder [2008] has focused on the perspective of the organizations seeking insurance which only helps an organization determine whether they need to insure against cyber risks but does not cover what the insurance provider needs to do to provide insurance against cyber risks. This section discusses the process an insurance service provider can take to process insurance cover for cyber risks. This incorporates the capture and analysis of critical information relating to a potential customer's information security activities in the process of assessing an application for insurance against cyber risks. These provide information about the technical and operational measures put in place by an organization about cyber risks. Diagrammatically the entire process from the time a request for cyber insurance is received to the time the insurance policy is received is presented below:
Figure 2: The Cyber Insurance Underwriting Process

Receive a request for cyber insurance → Identify the information assets at risk → Identify threats and vulnerabilities → Identify security measures and mitigation strategies → Apply rating and impose policy conditions → Issue a policy

Each of the components of the process is explained below:

- **Receive a request for cyber insurance** – This will be in the form of a proposal or a formal request for insurance. The organization making the request will have reviewed the risks facing its information assets and will have decided to transfer the residual risks to the insurance company.

- **Identify the information assets at risk** – this will include a list of all tangible and intangible information assets. Examples include computers, servers, network devices, software and data. Persons who support the information assets will also have to be profiled.

- **Identify threats and vulnerabilities** – this entails a review of potential threat sources, motivation and threat actions in order to determine the likelihood of threats exercising system vulnerability. This should lead to a risk impact analysis, using either qualitative or quantitative means.

- **Identifying security measures and mitigation strategies** – It could be that some of the risks presented to the underwriters for insurance may not be insurable, or might not enjoy the requisite reinsurance support. As such, the insurance company will attempt to define those risks that can be mitigated by insurance, and also isolate those that can be dealt with using technical or other operational controls.

- **Rating and policy conditions** – For the risks that meet insurance requirements, the underwriters will apply premium rates and impose deductibles, limitations and clauses.

- **Issue policy** – The final step is to issue reports and generate policy documents that provide evidence of cover.

Insurance companies in Uganda could adopt this process and develop more detailed procedures for each of the steps to cover cyber risks in their scope of services.
Cyber Insurance Underwriting System Prototype

This section presents a sample cyber insurance underwriting system based on the guidelines discussed in section 5. This was done in order to demonstrate the practicability of the guidelines in providing insurance cover for cyber risks.

Requirements for Cyber Insurance Underwriting System

Requirements of a software system enable the developer to obtain an understanding of the business need and to break it down into discrete parts. The general requirements that emerged from the existing systems’ investigation, literature review and interaction with key staff from the sample insurance companies in Uganda are summarized below.

It was established that the system should be able to:

- Fully capture the details of insured clients
- Capture all the data that is submitted in insurance requests
- Allow for supplementary information to be captured as attachments such as risk assessment reports, network topologies e.t.c.
- Capture the limits of liability for the policies that have been issued
- Capture the premium rates for cyber insurance
- Compute premiums basing on the limits of liability
- Allow issuance of policies with different limits and different scopes of cover
- Generate a unique policy number
- Produce a policy document
- Allow for searches and policy enquiries to be conducted
- Have an easily navigable menu structure. Consider using tabs for fast and easy maneuvering between different options
- Only authorized and authenticated users should be able to access the system
- Be web based
- Allow different levels of access depending on defined roles

System Modeling

The functional requirements reported in section 6.1 were modeled into a use case using the Unified Modeling Language (UML) for easier understanding by stakeholders including non IT people. The use case model represents the major actors involved in the cyber insurance system, i.e. the Customer and the Underwriter. The Customer completes and submits a proposal for cyber insurance. This is received by the Underwriter who reviews the submitted proposal and conducts a risk assessment, on the basis of which the proposal can be accepted or declined. In case the proposal is accepted, the Underwriter requests for premium from the Customer, and upon premium payment the Underwriter issues the policy to the Customer. The use case model is important as it delineated the system boundary in a human friendly manner. The use case is presented below:
The Entity Relationship Diagram
In order to model the entities involved in the cyber risks insurance underwriting system, an entity relationship diagram (ERD) was used. An ERD is a data model utilising several notations to depict data in terms of the entities and relationships described by that data. The ERD emphasises on the structure and relationship of entities in a database, and as such is not strictly an object oriented model since it lacks the behavioural component. However, it provides a useful way of visualising the entities and attributes and their relationships, making it possible to design and develop a relational database management system. The ERD is presented next.
Figure 4: Entity Relationship Diagram for a Cyber Insurance Underwriting System

Prototype Implementation

The system was designed as a web based application. Users will require a browser and will also need to specify the uniform resource locator (URL) for the system. The system is compatible with all the standard browsers. Once the home page loads, the user is required to enter a username and password. This ensures that only authorized users are able to access the system. The system is designed on a tabbed structure to make it easy to navigate. The system is also devoid of animations and graphics to ensure that it loads quickly even for those with slow internet links. The major functionalities of the system include: capturing general requirements relating to a customer, specifying the type of cover required, capturing the corporate network information, data protection measures, attaching additional supporting information, computing cyber insurance premium, printing policy documents and running queries on already existing customers. Below we briefly explain each of these functions and in some few cases add screen shots.

Capturing General Requirements Relating to a Customer

Where a potential customer has selected to enter policy, the first step is to collect general information about a customer who wants to be insured against cyber risks. This
information includes the name, address and description of the customer’s business. Once data has been input in all the fields where information is required, the user updates and moves to the next step. This is illustrated in the figure below.

**Figure 5 Capturing General Information about a Customer**

![Add User Information](image)

**Specifying the Type of Cover Required**
This step gives the underwriter the option of selecting the different types of covers available, and where the customer needs more than one cover, the underwriter will specify the desired limit of liability. This is a useful feature since it allows cyber insurance underwriters to provide customers with a bouquet of products to choose from. This should make it much easier to satisfy the broad demands for cover. The data captured on this screen are on the basis of the response provided by the client in the insurance proposal form.

**Corporate Network Information**
This page allows the underwriter to capture details regarding the customer’s corporate network. It seeks to assess how the network is managed, whether all services are rendered in-house or critical services are outsourced. This reinforces an understanding of the customers ICT network and assets and makes it easier for the underwriter to rate the risk.

**Risk Assessment**
On this screen the underwriter attempts to assess the customer’s risk assessment history. It seeks to answer several questions, including:
i. Have you got a fully documented and tested business community plan – the implication here is that a company with a business continuity plan would be rated as a better risk as compared to one without such a plan.

ii. Have your systems been subject to a third party security audit – these might include statutory audits, internal audits or external risk assessments.

iii. Have your systems been audited as being compliant with ISO 27001 or equivalent – the implication being that the ISO 27001 standard specifies certain best practice recommendations for information systems security. Organizations that comply with this standard will be seen as better risks.

iv. Do your internal IT systems comply with all the basic minimum security requirements – these basic requirements include:
   - Having an ICT policy in place
   - Having an information security policy and program
   - Having a security training and awareness programme in place
   - Having a password policy
   - Antivirus software being installed on all devices and is kept updated
   - All external network gateways are protected by a firewall
   - All critical data backed up at least on a weekly basis, and backups stored offsite in a secure location and fireproof safe
   - Integrity of all backups verified at least on monthly basis

**Data Protection**

Another critical aspect of a cyber insurance cover is the data protection element. Organizations like banks and hospitals hold sensitive data relating to their customers, and they have a responsibility to secure this data from unauthorized access and disclosure. This step captures the type of sensitive data that an organization holds. This is also used to assess the customers risk profile. As a result banks may be charged a higher insurance premium for data protection since they hold very sensitive data and hackers will have a motive to access the data and make some money.

**Attaching Additional Supporting Information**

One of the weaknesses identified in existing information systems in Uganda is their inability to allow supplementary information to be appended to a policy proposal. The cyber insurance underwriting system allows the underwriter to attach and upload supplementary information on to the database and associate the attachments with specific policies. Examples include past risk assessment reports, past audit reports, critical policy documents, e.g. the corporate IT policy, security policy, records of qualifications of staff manning the IT department, copies of the business continuity and disaster recovery plans. The system allows uploads in all formats including PDF, excel, word and images.
**Computing Cyber Insurance Premium**

The previous steps have enabled the underwriter to capture detailed information regarding the customer and the risk to be covered. The underwriter has also conducted a risk assessment and formed an opinion on whether to accept or decline going on cover. Where the underwriter accepts to go on cover, what remains is for him to agree with the customer on an aggregate limit of liability for the policy, deductibles and then impose a rate. The cyber insurance premium is computed on the basis of the limit of liability and premium rate, i.e.:

\[
\text{Cyber insurance premium} = \text{Aggregate limit of liability} \times \text{Premium rate}
\]

The aggregate limit of liability is the maximum amount of liability that the insurance company is willing to accept in a given year. The premium rate refers to a factor that is used to compute the amount that a client should be charged for a given risk. Premium rates are usually computed by actuaries. In the Ugandan insurance industry, premium rates are provided by the industry regulator, the Uganda Insurance Commission. There still lacks standard premium rates for cyber insurance in Uganda. For an underwriter to make a prudent rating, practice on the ground indicates that he/she will have to consult the reinsurers for an acceptable rate. The premium computation screen is shown below:

**Figure 6: Cyber insurance premium computation**
Printing Policy Documents
Upon agreement with the customer on the premium to be paid, and upon receipt of
the premium, the underwriter will print the policy document and attach other policy
conditions. The policy document serves as the evidence of cover, and is signed by a
senior official of the insurance company (preferably the underwriting manager) before
being sent to the customer. This marks the end of the underwriting process.

The cyber insurance underwriting system allows for the preview and printing of the
policy document. The policy document is based on standard wordings and displays the
following information: details of the insured, inception and expiry date of the policy,
premium charged, statutory stamp duty, policy excesses and deductibles, aggregate limit
of liability and detailed perils covered and the corresponding limits of liability.

Running Queries on Already Existing Customers
Apart from processing an insurance cover for a customer, the system provides for
viewing of already existing customer profiles. This is helpful for reference in case a
customer submits a claim or seeks information to facilitate making a decision about
other customers.

Recommendations, Conclusion & Future Research
Besides the low demand for cyber insurance, several other reasons have been found
to contribute to the low penetration of cyber insurance in Uganda namely: lack of
support from reinsurers, lack of underwriting systems that can help manage this kind of
business, low awareness by insurers on the risks posed by the internet, as well as a poor
understanding of the cyber insurance product. In order to address these challenges, we
recommend the following:

- Cyber insurance alone should not be seen as the solution to all the threats
  faced by organizations that do business on the internet. Organizations must
  start by implementing technical and operational controls in order to reduce
  their risks to a manageable level.
- Insurance companies should start to develop capacity for conducting IT
  risk assessments so as to better understand the potential risks presented by
  clients.
- Insurance companies in Uganda will need to either reengineer their existing
  information systems or adopt new ones if they wish to underwrite and
  administer cyber risks insurance. This research has provided guidelines on the
  critical information that should be captured and analyzed as well as presented
  and discussed in the cyber risks underwriting process and developed a sample
  system based on these guidelines that can provide a starting point
- The insurance industry in Uganda should consider coming up with an
  integrated database on which data relating to claims can be accessed by all
  players to ascertain the claims histories of their potential clients
On the whole, it is hoped that the information collected on the importance of underwriting cyber risks, the guidelines and associated prototype system on how this can be done provides awareness to underwriters and IT managers in Uganda on the scope and relevance of cyber insurance. This work confined itself to the underwriting aspects of cyber insurance. This is indeed a small scope of the insurance process. Further research could be conducted in other related areas such as: (cyber insurance) claims management, reinsurance and risk assessment.

References


Part Five

Information Technology
E-Learning Software Acquisition for Blended Learning: The Case of Higher Institutions in Uganda with Limited Budgets

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Abstract

With the rapid growth of information technology together with the growing demand for educational services in developing countries, the blending of face-to-face learning with e-learning is no longer a luxury. The question that remains is how to support institutions of learning in developing countries like Uganda with limited budgets in blending their face-to-face courses with e-learning using low cost resources. The major concerns in blended learning implementation are the blend ratio determination and the technology used to run the e-learning activities in the blend and specifically the e-learning software. The current methods for e-learning software acquisition present a number of challenges which may not favour higher institutions of learning with limited budgets in blended learning implementation. Therefore, this research proposes a method that higher institutions of learning in developing countries like Uganda can use to acquire e-learning software for their blended learning environments as one of the ways of reducing on the initial costs of blended learning implementation.

Keywords: Blended learning, E-learning software, Software acquisition, Blend ratio, Higher institutions of learning

Introduction

Due to the fast growing demand for education in higher institutions of learning in developing countries like Uganda, the practice of blended learning is taking shape. In a blended learning environment, the institution selects a set of class activities to run in
the traditional face-to-face mode and the rest of the class activities are conducted in the e-learning mode. Some institutions have been successful in this transition while others have failed due to a number of reasons but mainly due to poor planning [Stockley 2006]. The major concerns in building a blended learning environment are the blend ratio determination and the technology used to run the e-learning activities in the blend and specifically the e-learning software used to run the e-learning class activities [FLAG 2002; Muilenburg and Berg 2005]. Blend ratio means the percentage composition of the e-learning activities compared to face-to-face activities in the blend. The fact that there is no agreed standard for what should be the blend ratio [Masalela 2007] makes it very challenging for an institution of learning to determine the right blend [Stephenson 2004].

Most of the higher institutions of learning in developing countries like Uganda implement blended learning with limited budgets [Glenda 2003; Levy 2003] and acquisition of an e-learning software that requires less initial costs would be one of the ways to reduce on the initial blending costs [Obuobi et al. 2006; Duhaney and Duhaney 2006].

Therefore, this research focused on proposing a method for acquiring e-learning software for higher institutions of learning in developing countries (taking Uganda as a case study) that implement blended learning with limited budgets as a means of reducing on the initial costs of blending.

The rest of this paper is organized as follows; section 2 presents the current methods used for acquiring e-learning software for a blended learning environment and the challenges they present to higher institutions of learning in developing countries that blend with limited budgets, section 3 presents an investigation of blended learning practice in higher institutions of learning in Uganda, section 4 presents the proposed method for e-learning software acquisition for blending in higher institutions of learning in developing countries operating on limited budgets, section 5 presents the validation of the proposed method and section 6 presents the conclusion.

Current Methods for Acquiring E-learning Software for Blending
Currently, there are a number of methods for acquiring e-learning software for a blended learning environment, namely; using prepackaged proprietary e-learning software like Blackboard, using webpage builders to upload instructional content, through assembling of Commercial-Off-The-Shelf (COTS) software components and lastly using free open source e-learning software. Below, we present problems with these current methods.

Using Prepackaged Proprietary E-learning Software
The problem with most of the current e-learning software systems is that they are introduced on the market as “tightly integrated monolithic software bundles” [Downes 2003] offering a wide range of services and yet some of these services are “not e-learning-specific, such as user management, calendaring, discussion forums, etc” [Piotrowski et al. 2007]. In most cases, an institution of learning blending face- to-face learning
with e-learning that has more of its learning activities running in face-to-face mode might not explore the numerous components that prepackaged e-learning software has [Piotrowski et al. 2007]. For example, most institutions implementing blended approach aim at availing the instructional content online for learners to easily access [Goldberg 2005]. Much as it is good that these e-learning software systems offer a wide range of services [Obuobi 2006], there are issues of complexity, deployment, administration and the costs of maintaining their platforms that can be high [Piotrowski et al. 2007] and thus raising the cost of blended learning implementation.

Using Webpage Builders to Upload Instructional Materials

Some institutions of learning that find it expensive to buy and/or maintain the e-learning software systems available on the market take the option of their instructors designing instructional content as WebPages using a HyperText Markup Language (HTML) editor [like Macromedia Dreamweaver or Microsoft FrontPage] and then the WebPages are uploaded on the institution’s Intranet. This option has problems like uniformity of the WebPages created for all the courses offered by the institution and the expertise in Webpage design needed which can easily limit the instructional designer from achieving course objectives [Goldberg 2005].

Assembling of COTS

Building e-learning software by purchasing and assembling of COTS software components is always aimed at reducing the time and cost of software development but this might be a reverse if the COTS software components are inappropriately selected [Wanyama et al. 2007]. The process of choosing the best COTS software components that will fit together into the new system requires a thorough evaluation of the potential COTS components available on the market which sometimes proves to be complicated. This is because most COTS software components available on the market come as “black box components” [Gilda 1998] and the software developers find themselves only relying on the interfaces of the software components to get information when selecting which components to use [Gilda 1998].

Using Free Open Source Software

The open source movement in the past years has witnessed the development of free open source software for e-learning environments like KEWL,NextGen or Moodle. Being free and open source, such systems seem good and cheaper for an institution with a limited budget. However, such systems also pose a number of challenges like reliance on the developers for new versions. In addition, some open source solutions may not give the institution enough freedom to customize the e-learning software to their satisfaction. For example, Levesque [2004] says that customizing a free open source solution would require you to be “very experienced in system administration, and know how to manipulate the programming language it is written in, because errors are going to occur that are not mentioned in the documentation and you are going to have to debug them”.

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The State of Blended Learning Practice in Higher Institutions in Uganda

Currently, over 30 higher institutions of learning (both public and private universities, and non university degree awarding institutions) in Uganda are licensed by the Uganda National Council for Higher Education (UNCHE) to offer a wide range of courses and award degrees and diplomas [UNCHE, 2009]. Available literature shows that few of these higher institutions of learning in Uganda are currently blending face-to-face with e-learning.


Out of over 30 higher institutions of learning in Uganda, we managed to collect data from 14 institutions through interviews (10 institutions) and documentation review (4 institutions). The various definitions of the term e-learning by a number of scholars imply that provided there is any application of electronic media or tools in the learning environment aimed at achieving a learning objective, then, that can be considered to be e-learning. Therefore, during this investigation, we focused on identifying the e-learning tools used in learning so as to know which institution practices blended learning. The table below shows the e-learning tools by the 14 higher institutions in Uganda in blending.

<table>
<thead>
<tr>
<th>Higher Institution</th>
<th>E-Learning Tools Used</th>
</tr>
</thead>
</table>
| Makerere University                      | 1. E-learning software available to all learning units includes Blackboard, KEWL, MUELE (Moodle) and the TOSS Knowledgebase e-learning software accessible only in the School of Public Health in the college of Health Sciences.  
2. CD-ROMs loaded with instructional content (especially those under the ELATE project at the School of Education).  
3. E-mail service for communication in learning environments.                                                                                                  |
| Kyambogo University                      | 1. CDtL (Moodle) e-learning software is available to all learning units and other affiliated tertiary institutions.  
2. CD-ROMs loaded with instructional content.  
3. E-mail service for communication in learning environments.                                                                                                   |
| Uganda Management Institute (UMI)        | 1. Multimedia learning environments with connectivity to other worldwide distance learning centers  
2. CD-ROMs loaded with instructional content.  
3. E-mail service for communication in learning environments.                                                                                                   |
| Mbarara University                       | 1. No specialized e-learning software used  
2. CD-ROMs loaded with instructional content.  
3. E-mail service for communication in learning environments.                                                                                                   |
| Uganda Martyrs University Nkori          | 1. E-learning software used and available to all learning units includes Blackboard, KEWL and Moodle  
2. CD-ROMs loaded with instructional content.  
3. E-mail service for communication in learning environments.                                                                                                   |
| Galu University                          | 1. E-learning software used is Moodle.  
2. E-mail service for communication in learning environments.                                                                                                   |
| KIU                                      | 1. Plans are underway to use CD-ROMs loaded with instructional content.  
2. E-mail service for communication in learning environments.                                                                                                   |
| Mbarara University of Science and Technology | 1. No e-learning software used but plans underway to acquire one under the HP-UNESCO Brain Gain Initiative  
2. CD-ROMs loaded with instructional content.  
3. E-mail service for communication in learning environments.                                                                                                   |
| UCU Makena                               | 1. E-mail service for communication in learning environments  
2. CD-ROMs loaded with instructional content.                                                                                                                    |
| Bugema University                        | 1. E-mail service for communication in learning environments  
2. CD-ROMs loaded with instructional content.                                                                                                                   |
| Kabale University                        | Note.                                                                                                                                                                                                                 |
| Bishop Barem Kabale                      | Note.                                                                                                                                                                                                                 |
| Bishop Stuart Mbarara                    | 1. E-mail service for communication in learning environments.                                                                                                    |
| Cavendish University                    | 1. Implementation of an Educational Management System underway  
2. An online results management system already running.                                                                                                          |

Figure 1: Results of survey done in 14 higher institutions in Uganda about e-learning tools used for blending.
The results of the investigation above (figure 1) indicate that most of the higher institutions of learning in Uganda (about 64.29% from the sample of 14 institutions) focus on disseminating instructional content to the students using CDROMs and communication by e-mail rather than using the specialized e-learning software like Blackboard, KEWL, WebCT, Moodle among others that are able to offer a wide range of e-learning services than just instructional content dissemination and communication.

A Survey on E-Learning Software usage for blending in higher institutions in Uganda

In order to study the usage of e-learning software in blended learning environments of the higher institutions of learning in Uganda, the researchers made a survey on e-learning software usage in a selected set of higher institutions from the sample of 14 institutions presented in figure 1 above. The selection criteria for these institutions was based on whether the institution currently uses any specialized e-learning software in its blended learning environment and according to the results in figure 1, only 4 institutions namely; Makerere University, Kyambogo University, Uganda Martyrs University Nkozi and Gulu University were the ones meeting the above criteria. Therefore, a total of 640 questionnaires were distributed to the above 4 institutions where the target population consisted of the course instructors and students from different academic units of these institutions as shown in figure 2 below.

<table>
<thead>
<tr>
<th>Institution</th>
<th>Target Population</th>
<th>Sample Size</th>
<th>Actual Response</th>
<th>Response Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Makerere University</td>
<td>Course Instructors</td>
<td>50</td>
<td>47</td>
<td>94.0%</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>200</td>
<td>185</td>
<td>92.5%</td>
</tr>
<tr>
<td>Kyambogo University</td>
<td>Course Instructors</td>
<td>30</td>
<td>25</td>
<td>83.3%</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>100</td>
<td>79</td>
<td>79.0%</td>
</tr>
<tr>
<td>UMU Nkozi</td>
<td>Course Instructors</td>
<td>30</td>
<td>23</td>
<td>76.7%</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>100</td>
<td>74</td>
<td>74.0%</td>
</tr>
<tr>
<td>Gulu University</td>
<td>Course Instructors</td>
<td>30</td>
<td>19</td>
<td>63.3%</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>100</td>
<td>68</td>
<td>68.0%</td>
</tr>
<tr>
<td>Totals</td>
<td>Course Instructors</td>
<td>140</td>
<td>114</td>
<td>81.4%</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>500</td>
<td>406</td>
<td>81.2%</td>
</tr>
</tbody>
</table>

Figure 2: Questionnaire distribution and response rate in the 4 higher institutions

In this survey, the respondents were asked if they were using any e-learning software in their blended learning environments. The overall response was that 78 out of the 114 course instructors (68.4%) and 287 out of 406 students (70.7%) who had responded to the questionnaires said “yes”. Figure 3 below shows the summary of the responses from the respondents about whether they were using e-learning software in their blended learning environments.
Those respondents who accepted that they were using e-learning software in their learning environments (see figure 3 above) were also asked to identify the e-learning software they were using. The dominant answers to this question were Blackboard, Moodle and KEWL, and figure 4 below shows how many respondents use which e-learning software (expressed as percentage of the respondents who said they use e-learning software in their blended learning environments).

Those respondents who had said that they were not using any e-learning software were also asked to state the e-learning tools used (if any) in their blended learning environments. The results from this question indicated that those who do not use e-learning software just focus on instructional content dissemination using CD-ROMs and E-mail service as well as uploading/downloading the instructional content to/from course instructors’ WebPages on their local intranets. Figure 5 below shows the summary of the responses to the above question (expressed as percentages of respondents who do not use e-learning software in their blended learning environments).
Summary of survey results on blended learning practice

Figure 6 (the graph) below shows the summary of the results of the survey done in the 4 higher institutions of learning about the e-learning tools used in the blended learning environments.

![Summary of E-Learning Tools used in blended learning environments of the 4 higher institutions from the survey](image)

Discussion of Survey Results on Blended Learning Practice in Higher institutions in Uganda.

From the investigation carried out in section 3.1 on the state of blended learning practice in higher institutions of learning in Uganda, the results indicate that there are very few institutions currently using specialized e-learning software in their blended learning environments. This is evident from the results of the survey done in 14 higher institutions where only 4 out of 14 (28.6%) currently use e-learning software. The rest either focus only on instructional content dissemination through CD-ROMs, departmental Websites
and the e-mail service for communication in the learning environment or do not practice any blended learning at all.

The immediate question here can be: what are the reasons behind this low level of blended learning practice in higher institutions in Uganda? To answer such a question, one can easily be tempted to conclude that these higher institutions in Uganda are not willing to tap into the numerous benefits of blended learning [Osborne and Oberski 2004]. However, the reasons for such a kind of low level of blended learning practice are many, ranging from administration to economic reasons.

Administratively, most of these higher institutions that already have ICT infrastructure to at least support basic blended learning have failed to enforce blended learning policies in their academic units. This is evident from the survey results presented in figure 5 above about the major blended learning players (course instructors and students) in the 4 higher institutions that are not using e-learning software in learning yet other academic units in the same institutions are using the e-learning software in learning (see figure 4). According to Kwong-Wing et al. [2003], the success of a higher institution in blending is not necessarily the ICT infrastructure it has but the use to which it is put to support the blending process.

Economically, most of these higher institutions are privately owned [Molony 2006] and even the government owned higher institutions receive less funding to support educational activities like integration of ICT in education, leaving them to operate on such constrained budgets. Even most of those higher institutions of learning in Uganda that are currently blending have been able to do so through donor funding [Molony 2006].

Therefore, with such a situation, the higher institutions of learning must carefully plan for the blending that suits such limited budgets and such planning should include exploring low cost alternatives as much as possible. One of such low cost alternatives is to use e-learning software that requires less initial costs during blending and thus meeting the limited budget. The problems involved in using the current methods of acquiring e-learning software for blended learning environments have already been discussed in section 2 of this research. Moreover the fact that there is no agreed standard for blend ratio [Masalela 2007] makes it very challenging for such higher institutions with limited budgets to identify the learning activities to run in which mode [Ogechukwu 2007].

**The Proposed Method for E-learning Software Acquisition for Blending**

Having discussed the problems with the current methods for acquiring e-learning software and also having presented the state of practice of blended learning in higher institutions of learning in Uganda, this research has proposed a method that such higher institutions of learning in Uganda blending [or intending to blend] with limited budgets can use to acquire the e-learning software to use in blending with less initial costs.
The proposed method divides the process of e-learning software acquisition into four major steps namely: 1. Do needs assessment, 2. Determine blend ratio, 3. Determine e-learning software requirements and 4. Acquire the e-learning software. The figure 7 below shows the logical model of the proposed method for e-learning software acquisition.

**Figure 7: Logical model of the proposed method for e-learning software acquisition**
Step 1: Do Needs Assessment

This step focuses on assessing the factors that determine the blend ratio in a blended learning environment. Available literature shows that the major factors that determine the blend ratio are: the learner characteristics, the experience and teaching styles of the course instructors, the course instructional goals and the state of existing ICT infrastructure [Masalela 2007; Stephenson 2004; Ogechukwu 2007].

Determine learner characteristics

Having knowledge about the kind of learners the institution has will help it in determining which learning activities can be best done in which mode (face-to-face or e-learning) in the blend. Some learners may be having learning disabilities. For example, a learner who is deaf may not benefit from an audio file of instructional content posted on the Web. Other learners may not be able to study alone (during e-learning sessions) and may need supervision and mentorship among others. The personality type, level of maturity and level of computer literacy of the learner among others will help the institution to know what its learners can best do in which mode.

Determine experience and teaching styles of the course instructors

Having knowledge about the kind of course instructors the institution has will help in determining which learning activities can such course instructors best do in which mode. Some course instructors may be computer illiterate while others may be lacking expertise in instructional content design and delivery. Other course instructors may be too committed with other activities like administration among others and depending on the enrollment figures and experience of the course instructor, the institution may consider activities like assessment to be done in e-learning mode.

Identify course instructional goals

Having knowledge about the instructional goals for each of the courses to be blended will help the institution know the kind of instructional content to be delivered and this will help the institution to determine which learning activities can be run in which mode. Some courses may be more theoretical while others are practical. In such a case, practical courses may require more interaction between the instructor and the learners through practical demonstrations in face-to-face sessions and multimedia simulations of the practical.

Analyze the state of existing ICT infrastructure

It is important that the institution analyzes the state of existing ICT infrastructure and its ability to support e-learning. For example, knowing the current computer to learner ratio would help the institution to determine if activities like assessment can be done online.
Step 2: Determine Blend Ratio
The needs assessment report obtained from step 1 above will help the institution to determine which learning activities run in which mode. The learning activities chosen to run in the e-learning mode will help the institution determine the kind of e-learning software the institution needs to use in the blended learning environment.

Step 3: Determine E-learning Software Requirements
Each of the learning activities identified in step 2 above to run in the e-learning environment will require a particular software component to support it and each of the needed software components will have its requirements. Putting together these requirements into a requirements specifications document will help the institution to know the kind of e-learning software they need to start blending as well as the necessary technology needed.

Step 4: Get the E-Learning Software
Basing on the requirements specifications document the institution generates from step 3 above, this proposed method is suggesting three options for acquiring the e-learning software that will require less initial costs of blending, namely; 1. Using free open source e-learning software,
2. Building the e-learning software in-house and 3. Building the e-learning software from COTS software components. This is because the initial cost of most of the integrated proprietary e-learning software packages is high and, there are also annual license fees, yet an institution starting to blend [with a limited budget] may not need all the functions that such a proprietary e-learning software offers.

Option 1: Free Open Source Software
The institution may download and customize free open source e-learning software like Moodle, KEWL.NextGen, Bodington, among others. However, a number of factors should be considered here. For example;

i) The likely costs of customization of the e-learning software and its integration into the institution's blended learning environment compared to the institution’s budget. For example the cost of the kind of technology associated with the e-learning software.

ii) The ability of the free open source e-learning software to support the identified e-learning activities in the blend.

iii) The ability of the free open source e-learning software to allow new other software components to be added at any time by the institution without relying on the original developers of the software for new versions.

iv) The level of customization that the free open source e-learning software allows as well as the terms and conditions of use. For example, some of the free open source software developers will require you to maintain their logos, links and some ads [for their sponsors] which can easily distract the learner during learning.
v) The availability of help support from the developers during customization and integration of the e-learning software in your blended learning environment.

Option 2: Build the e-learning software components in-house using CBSD approach
The institution may develop the e-learning software needed in-house by starting with the only software components needed to start blending. Other software components may be added to the e-learning software as more learning activities are moved to the e-learning mode. To achieve this, CBSD approach should be used in software components development and integration. However, a number of factors should also be considered. For example;

i) The likely costs of development and integration of the necessary components compared to the institution’s budget.

ii) If the available funds are not enough to meet the costs of all the needed components, what software component[s] can the institution start with?

Option 3: Build using COTS software components
With the requirements of the e-learning software needed already known (that is output of step 3 above), the institution may select, purchase and assemble e-learning COTS software components that can support the identified e-learning activities in the blend. However, the process of identifying the right COTS software components that will fit together and reduce on the cost and time of software development presents a good number of challenges. In addition, even the COTS software components selected might need some glue-ware during their integration to get the e-learning software [Bhuta and Boehm 2005], which means more costs.

Available literature provides a wide range of COTS selection methods, many of which just focus on the functionality and cost aspects than the quality aspect. For example, Bhuta and Boehm [2005] present a method that focuses on selecting compatible COTS software components. This means that if such a method is used by the institution of learning in selecting COTS software components for the e-learning software, then integration of the selected software components will need less input on glue-ware, hence lowering the costs and time of the e-learning software development. The disadvantage with this method of compatible COTS selection presented by Bhuta and Boehm [2005] is that it focuses more on the functionality aspect than the cost aspect and, the method does not provide for negotiation between the COTS vendors and the institution of learning, meaning that if the method is used, then, the institution can negotiate with the vendors after selecting the compatible COTS.

Some researchers like Wanyama et al. [2007] have proposed a better COTS selection method that tries to incorporate all the COTS evaluation aspects. The functional requirements of the framework for COTS selection proposed by Wanyama et al. [2007] were identified based on the challenges of COTS selection process. However, this framework only focuses on selecting a single COTS software component rather than
concurrent selection of COTS for different modules that can make up the COTS-based e-learning software. Much as this might delay the COTS selection process, the framework still remains useful especially if there are a few COTS software components needed to make the e-learning software. This implies that an institution that wishes to start blending with few e-learning activities can use the framework proposed by Wanyama et al. [2007] to select the COTS software components needed to build the e-learning software.

In addition to the above factors to consider in each of the options for acquiring the e-learning software in step 4 above, the institution should also consider the characteristics of an effective e-learning software presented by Harrasim et al. [1995] and Westone and Amundsen [2000].

**Model Validation**

To validate the proposed method, user validation approach was used. A team of 10 blended learning experts were selected from 4 institutions of learning in Uganda that were involved in the study done in section 3 above. The selection criteria for these institutions (out of the 14 involved in the study) was based on whether the institution currently uses any specialized e-learning software in its blended learning environment and according to the results in figure 1 above, these institutions were; Makerere University, Kyambogo University, Uganda Martyrs University Nkozi and Gulu University.

The major tasks in the validation were to test for completeness of each of the 4 steps of the model, test the logical arrangement of the 4 steps of the model and also suggest how the model can be improved.

**Testing for completeness of the steps of the model**

The completeness of the 4 steps that make up the model was ranked by the validation team members using a scale of 1 to 5 as 1-Very incomplete, 2-Incomplete, 3-Average, 4-Complete and 5-Very complete. The table below shows the validation results of this aspect.

<table>
<thead>
<tr>
<th>Method Step</th>
<th>Average Rank (out of 5)</th>
<th>Comment (based on the scale used)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>4.2</td>
<td>Complete</td>
</tr>
<tr>
<td>Step 2</td>
<td>4.1</td>
<td>Complete</td>
</tr>
<tr>
<td>Step 3</td>
<td>3.6</td>
<td>Above Average</td>
</tr>
<tr>
<td>Step 4</td>
<td>3.2</td>
<td>Above Average</td>
</tr>
<tr>
<td>Overall Average rank of the model</td>
<td>3.78</td>
<td>Above Average</td>
</tr>
</tbody>
</table>
On average, the completeness of the whole model of the proposed method for e-learning software acquisition was ranked at 3.78 out of 5 (75.5%) which implies “above average” according to the scale used in the validation.

**Testing for logical arrangement of the model**
The logical arrangement of the steps in the model was ranked by the validation team members using the scale of 1 to 5 as 1-Very weak, 2-Weak, 3-Average, 4-Good and 5-Very good. On average, the logical arrangement of the steps in the model was ranked at 4.1 out of 5 (82.0%) which implies “good” according to the scale used to validate this aspect.

**Suggestions from the validation team**
The validation team members were also requested to give their suggestions on how each of the steps of the model can be improved to make it complete and valid. Out of the 10 members of the validation team, only 6 members responded to this question and the following were their suggestions all put together;

a. That in step 1 of the model, evaluating experience and teaching styles of the course instructors and knowing the characteristics of the students may not be enough. Instead, in addition to these factors, the institution may consider the willingness of the prospective players (the course instructors and students) to participate in the e-learning activities.

   Secondly, that issues concerning resistance to change and possible organizational politics should be considered at such an early stage of blended learning implementation.

b. That in step 3 of the model, it is possible to find that not all the e-learning activities identified in step 2 of the model will be run using the e-learning software. Therefore, the requirements determined should be for all the blending process and not only the e-learning software. However, our focus (or the research scope) was only on the e-learning software to use in the blended learning environment and therefore it was assumed that all the e-learning activities identified in step 2 would be run using the e-learning software.

c. That in step 4 of the model, it would have been good if the options were presented in the order of recommendation so that the institution knows best of the three options. However, we could not present the recommended options in step 4 in the order of recommendation because of the varying budgets from one higher institution to another. We felt that the factors to consider in each of the recommended options (as stated in the model) were enough to guide the higher institution of learning on the choice of the option.
Conclusion and Future work

Conclusion
This research focused on proposing a method for acquiring e-learning software to use in blended learning environments for higher institutions of learning in developing countries (using Uganda as a case study) that operate on limited budgets.

To achieve this, we investigated the state of blended learning practice in higher institutions of learning in Uganda with the aim of understanding the e-learning tools these higher institutions are currently using to blend.

The method proposed has been validated by a team of blended learning experts and the validation results indicate that the proposed model is on average both complete and well logically arranged.

The method proposed in this research does not state how much of the cost of e-learning software acquisition will be reduced due to a number of factors. For example, the results of step 1 of the proposed method (see figure 7) may vary from one higher institution to another and hence a different blend ratio. However, it is hoped that the higher institution that uses the model to acquire the e-learning software will be able to start blending with what it can afford (basing on its budget) and thus reducing on the initial cost of blending which is normally high if for example the institution opted to buy proprietary e-learning software.

Future Work
As stated above in the conclusion, the proposed model does not state how much percentage of the cost of e-learning software acquisition will be reduced as well as how much the minimum cost of blending is. Future work should focus on building a linear model whose dependent variable is the minimum cost of implementing blended learning in higher institutions of learning in Uganda and the independent variables are the factors that determine the minimum cost of blending. Among these independent variables in the model could be the minimum cost of the e-learning software needed in the blended learning environment.

References
MUILENBURG L.Y AND BERGE Z.L 2005. Student Barriers to Online Learning: A factor analytic study, in Distance Education, Vol.26 [1], pp. 2948, May 2005
Emergence of Robust Information Security Management Structure around the world wide Islamic Institutions: A Multifaceted Security Solution

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Abstract
Polarizing the views on the emergence of Information security around the campus arenas of Islamic institutions is of utmost importance in Muslim nations in this post catastrophic era of September 11, 2001 where the unthinkable is now potentially a daily reality with root causes of information breaching, misusing and thereby initiating terrorism which have presented the world with many challenges in accommodating peoples’ personal and work lives to a changed environment.

To bring the resources of the academic world to bear on both national policy and on the individual responses and so thus to cope with and to mitigate such riskier environments, various IT security approaches have been proposed. While among them Soft IT Security approach (SITS) is highly lucrative now-a-days due to its simplicity and effectiveness in the sector of Information security especially in higher education, it is unable to secure all types of educational environment using a general framework due to most of these environments’ not being homogeneous as well as little or no focus on cultures and beliefs of Muslim nations. Addressing this issue, a new security management scheme namely Robust IT Security Balancing (RITS-B) Approach is proposed in this paper which is focused on developing such strategic framework of security environment where facts, national and religion perspectives will be merged to lead to a proactive leadership and information security system without violating the freedom and openness that is at the very heart of the academia.
The quantitative survey has been conducted and the security facts and findings are compared with the three basic survey questionnaires which look at whether they are more secure than two years ago, whether the system is secure and whether the security program is successful with a 4 point Likert scale. The analyzed data shows that institutions which implemented RITS-B approach in their arena either partially or fully feel more secure in the above three domains than the others and thus, it increases the application area of the soft security solutions.

Keywords: Soft and Hard IT interventions, Information Security, Governance, Strategies, Practices, Islamic Cultures and Beliefs.

Introduction
Information technology security in higher education institutions is the process of securing the higher education environment without disrupting the openness, accessibility, academic and intellectual freedom which is at the very heart of this environment. It is one of the fundamental processes towards the broader security because the further processing steps depends on what types of security breaches have occurred and what strategies are in place to deal with these. Despite the numerous functionalities of security, IT security in Higher education is still a subject of on-going investment and it cannot be conclusively stated that the education field is highly secured because of the application, technological and intrusion’s diversity. As a consequence, the task of choosing the best method which will not only ensure mission critical level security to each bit of higher education information but also not compromise its core missions is still a difficult challenge. Several survey papers (Arabasz & Pirani, 2002; Kvavik & Voloudakis, 2003; Yanosky & Salaway, 2006) cover the major Information Technology Security Approaches available in the literature. Most of the security schemes can be roughly categorized into two approaches:

- The Hard i.e. Technical Method
- The Soft i.e. Non-Technical Method

Basically, the first approach explores the information security technologies used by the higher education institutions. What tools have they chosen to install, to prevent harm to their information assets? The security levels are then deduced from the boundary of these installed high functional tools. The usual tools that are employed in hard methods include antivirus software, SSL for web transactions, centralized data backup, network firewall, enterprise directory, VPN for remote access, intrusion detection and prevention tools, encryption, content monitoring/filtering, electronic signature and shibboleth. The first approach fails to gain total effectiveness in the higher education information security process due to the following reasons: (a) Money matters when developing IT security strategies but much depends on how, when and where it is used, by whom and with what level of effort and skill. (b) Integrating adopted technologies with current
and future practices is more important than just selecting it. (c) And peoples’ troubles in understanding the adopted technologies (Yanosky & Salaway, 2006).

The strategies for the second approach exploit the importance of soft IT interventions (e.g. organization, Cultural aspects, awareness program, training programs, policies, executive attention etc.) to produce a secured campus environment around the educational institution and having the advantages such as: (a) It is very simple in nature (b) It evaluates all the spatial properties of Information security. (c) Representation of security patterns is much more effective and well structured than only technology based security processing. (d) It gives dynamic and formalized solutions to security concerns. (e) It is based on the belief that openness and accessibility of higher education environment will not only be preserved but also be secured. The features of this approach provide well organized security solutions with some limitations on concerns and generalization because of academic and departmental diversities.

To improve the security scheme, a strategy consists in combining these approaches in order to obtain a robust security by exploiting the advantages of one method to overcome the limitations of the other one. It is called Robust IT Security Balancing (RITS-B) Approach and is presented in this paper. This is an attempt to unify different methods of higher education information security approaches under a common topology based on both hard and soft interventions with that of Muslim culture and beliefs. This RITS-B Approach considers all the soft aspects of information security i.e. information security policies, Awareness, Leadership and Practices for the user community on the acceptable use of technological tools to develop such strategic framework of security environment where facts, national and religious perspectives will be merged to lead to a proactive leadership and information security system without violating the freedom and openness that is at the very heart of the academia. In the RITS-B approach, soft security aspects are used not to describe which contents they should have, rather what should be the status of these in place security aspects and what characteristics should they bare for the acceptable use of the existing security tools and technologies to the campus community so as to secure their information arena.

A quantitative survey on 6 engineering universities of Bangladesh shows that institutions which implements the proposed RITS-B approach either fully or partially in their arena characterized their security program’s success much more higher than others and also reported that their data, networks and applications are more secure and feel more secure today than it was two years before.

This paper is organized as follows: the literature review related to the basic idea on higher education IT security around the Muslim nations and various hard and soft aspects of security to secure their arena including their advantages and disadvantages is detailed in section II. The RITS-B approach is presented in section III. The quantitative survey results are provided in section IV and finally section V shows some concluding remarks.
Literature Review

Though there are huge numbers of Information security balancing approaches in the literature [Executive Guide, 1998; Fender, 2006; Gray, 2005; Rivlin, 1995] the Soft IT Security (SITS) approaches on the acceptable use of security hard interventions are only considered in this paper. For this reason, the related literature based on the SITS approaches is presented as follows.

Basic Idea on Higher Education Information Technology Security around Muslim Nations

By far the most commonly used meaning for information security is the preservation of [Dark et al, 2006; Voloudakis & King, 2003; Ward & Hawkins, 2003]:

(a) Confidentiality or protection from unauthorized use or disclosure of information.

(b) Integrity, ensuring data accuracy and completeness through protection from unauthorized, unanticipated, or unintentional modification, and including authenticity.

(c) Availability, making data available to the authorized users on a timely basis and when needed and

(d) Scalability, scaling the belief of Islam from that of other religions and stimulating Ummah’s interest to contribute in the field of information security concerns while preserving oaths and mandates of our beloved Holy-Quran.

We can, in turn, characterize each of these seven protection categories: confidentiality, integrity, authenticity, scalability, non-repudiation, accountability, and availability-by levels of sensitivity: high (serious injury to an institution), medium (serious injury), and low (minor injury). These hints are significant for higher education, where much information used for teaching and research requires the highest level of integrity and availability but low level of confidentiality and for Muslim nations, a flexible sense of scalability also needs to be defined. And to ensure such levels an institution has two choices: either to follow the security approach (a) or (b) as mentioned in section I or go for the use of a blended approach- balancing the features of (a) and (b) according to its academia’s beliefs, needs and constraints to foster the institution’s security goal. This balancing scheme requires the exploration of the following issues (Bellovin et al, 2006; Albrecht & Caruso, 2003; Pirani, Sheep Pond Associates, Voloudakis, Ernst & Young, 2003):

1. Make IT security a priority.
2. Select security controls and products.
3. Define and empower acceptable behavior [by students, faculty, and staff].
4. Preserve the academia’s religion, regional and cultural beliefs.
5. Revise instructional security policy and improve the use of existing security tools.
6. Make consistent, timely, and cost-effective management decisions.
7. Improve security for further research and education networks.
8. Integrate work in higher education with national effort to strengthen critical infrastructure and
9. Empowering [members of the institution's community to do their work] securely.

All these are the pledge of the higher education institutions to gain success in openness and privacy in the field of information security.

**Security Management by Hard/Soft Interventions**

Balancing IT security approaches by ‘Hard’ interventions is a procedure that groups the technological requirements and academia’s culture and needs into a broader area. The simplest approach is the security technology aggregation, which starts with a set of “Hardware/ tools” requirement around the campus boundary. From these, security collaboration grows by appending the functionality of each tool with that of the next tools having specified security properties, in a sense, to smoothen the system execution, intrusion detection and prevention, client secrecy preservation and thereby client comfort maximization. But, it is suffering from the following six immediate problems [Ellen & Luker, 2000; Kvavik & Voloudakis, 2003; Visa Inc., 2004; Sieberg, 2005]:

- Academia's resource and budgetary constraints
- IT security does not appear to be high on most Islamic institutions’ executive agenda
- The “transient” nature of the higher education’s constituents complicates the IT security management
- The rapid changing nature of the intrusions.
- Resources may become a burden and garbage if they are hard to use and understand.
- Because of the security solution which seems to be convenient for a particular educational environment at time ‘t’, it may become inconvenient at time ‘t+1’ because of the transient nature of threats and academic requirements.

When no a priori information about which types of security breach attempts may happen, the procedure consists in categorizing the security incidents into a unified pattern according to a similarity criterion, where the selection of the similarity criteria depends on the pattern and types of intrusions that already occurred in the field of education i.e. on the problem under consideration. Several examples where this method has been applied can be found in [Yanosky & Salaway, 2006; Rezmierski, Rothschild, Kazanis & Rivas, 2005].

Security balancing by soft interventions is just opposite to the hard one. It largely varies from that of the cultural aspects i.e., policy, organization, leadership, awareness and practicing structure of a particular institution, where, the association of these soft aspects with the ongoing campus security process is governed by a value criterion that must be satisfied in order to implement this framework around the arena. The value
criterion is academia dependent and may be dynamic within a given academia. But in general this largely focuses on the preservation of academia’s values i.e., freedom, openness and the academia’s beliefs. If any of these soft features contradicts with the values criterion, it should be reviewed and revised but not be purged, where a compromise in any one of these issues may cause a total loss. This procedure continues until each of these cultural aspects fully relay with the defined value criterion of an academia and should not be a conclusive one because of the transient nature of the academia’s constitution and rapid changing nature of the intrusions and technologies.

The main drawback of this method is that it is very hard to make people believe that we are not Big Boss but rather twin brothers. Also, solutions may not be global and the time lag between deployment of technology and the development of legal and policy framework for its appropriate use can also hinder the security outcomes [Pirani, Sheep Pond Associates & ECAR, 2003].

**Proposed Model**

To enhance the performance of the security balancing process and to address the drawbacks of only having the hard i.e. technological aspects of security solution as mentioned in Section II with the light of the concept of the soft security patterns as discussed above, this section presents a newly developed security balancing scheme called Robust IT Security Balancing (RITS-B) approach to better the technological aspects over their acceptable use around the campuses of worldwide Muslim nations.

The three main constituent parts of this RITS-B approach is: (a) definition of the scope of information security in that particular school arena (b) looking at what types of security tools academia is currently installing (c) and then trying to determine a soft layout for them to know how best to practice, when to practice, by whom and at what level, how and what to be aware of, how to cope up with the incidents i.e., in a single word how to merge the institutions cultural layout with that of its existing hard framework to satisfy the following requirements: (a) Technology i.e. security tools (b) Policies (c) Awareness (d) Leadership (e) Practices and (f) Academia’s values and beliefs which has produced the requirements of these fivees and other consequent security requirements generated by these ethical concerns.

In this RITS-B approach, information security balancing process is summarized into four (04) stages: Identification-Prioritization-Revision-Dynamicity which is briefed as follows to fulfill the requirements of (1) to (9) of section II. (1) Identification- Identify the existing higher education environment. (2) Prioritization- Prioritize the IT security issues around the academia and administrative arena of that environment. (3) Revision- Revise instructional security governance, strategies and practices and improve the use of existing security tools and (4) Dynamicity- Keep with the paces of the educational and environmental changes rather being to be conclusive.

Since definition of the security scope and strategies is the first stage of the proposed RITS-B approach, it is detailed in the next section.
**Definition**
For an institution to make its security environment more reliable and sophisticated to breach, its scope of application along with the strategic scale for assessment must need to be defined. The following subsections depict such definitions.

**A.1 Define the institution’s information security scope**
In a bigger sense, scope is something that helps an institution find out its field and purpose of application and flexibility to sustain. For an institution, this scope definition involves two preliminary phases that needs to be done before heading further and these are:

- Develop a framework of security environment where facts and national perspectives will be merged to lead to a proactive leadership and cyber security system without violating the freedom and openness that is at the very heart of our academic values.
- Identify what security policies, tools, and procedures are currently in place and which pattern needs to be practiced to ensure a high degree of cyber security around the campuses of higher education institutions of Muslim nations.

**A.2. Define the IT Security Strategic Assessment Scale**
Based on the use of the technological and cultural aspects, the following four major strategies scales or approaches (Figure 1) can be used to find out the institution’s existing security status, thereby securing them on the basis of their strength in each arena. And these are: (i) Reactive (ii) Cultural (iii) Technology Centric and (iv) Fortified.

Reactive approaches tend to have relatively little investment in either (a) or (b-e) while cultural approaches have higher investment on (b-e) but relatively little in (a). The technology-centric approach is just opposite to the cultural one having high on (a) but very little in (b-e), where relatively higher investment in both (a) and (b-e) is the scheme of the fortified approaches. Most of the IT security approaches use about all of these six requirements. Value criterion is used to find out the academia’s believes and needs and (a-f) are blended in a proportionate fashion based on the academia’s requirement to secure its environment and this blending scheme should not be a conclusive one and also should not be one way traffic to become responsive to the changing environmental nature. Rather it should fall in the above circular shaded area.

After defining the scopes and scale of intended institution’s security concern, a documentation of its hard interventions is needed to formulate an acceptable soft layout on them to gain robustness in the process of information security and secrecy. And this documentation stage is presented in the next section.

**Document the institution’s technological needs**
It is very difficult to identify what exact enterprise security processes or technological tools are needed to strengthen the IT security infrastructure around the campus arena of higher education because tools are dynamic in nature and depends on the application area
and types of breaches. For this reason, one tool is appropriate for execution of one type of application or the identification of one type of intrusion while it may not be suitable for other applications and intrusions and this raises an open question: “Which sets of technical aspects are suitable for which type of application and intrusion?” Section I depicts some of these commonly used tools. However, among these technical tools few are chosen optimally to form the standards for application and system development. Different higher education institutions’ IT security approaches use different set of tools. The ultimate goal is to fulfill the requirements of (1) to (9) of section II.

The next step is to formulate an exact soft security layout on the documented security hard interventions with that of the scope. The following section depicts this step of formulation.

**Formulation of Acceptable Soft Security Layout**

The soft stage of the proposed RITS-B approach contains six main constituent parts which are applied on the institutions hard layout with that of the scale to assess and scope to apply and improve and are: (i) Management structure of IT security, (ii) Organizational Structure of security (iii) Policies and plans (iv) Communication and awareness (v) Security practice pattern and (vi) Security end user use scheme.

**Figure 1: It Security Approach**

![Diagram of It Security Approach](image)

**C.1. Model Management System Information Security on campus**

The model management system campus information security is based on the context of Define-Implement-Analyze-Improvement i.e. DI-AI methodology as presented in the following figure.
Define the scope, objective and significance of the existing security concerns along with that of institution’s value and similarity criterions as described above and make a plan to implement. Then go for its implementation while at the same time monitor and analyze the implementation process and outcomes respectively. Do possible maintenance and if necessary, take necessary improvement actions to gain inclusiveness in the process of campus information security.

For the institutions to proceed on the above mentioned DI-AI methodology in this security balancing process, they should follow the standards of NBR ISO/IEC-27001:2005, “Management System Information Security”. In the light of this standard, institutions should designate an individual to be responsible for IT security and these key responsible personnel should report to their respective senior management in a periodic fashion and should bare a certain level of security certification. Even though certification doesn’t prove knowledge, it shows that concerned personnel has put their time and effort to gain the specialized skill. The institutions also need to have a well defined salary structure for these IT security personnel.

Institutions are also recommended to apply this methodology on the resources of infrastructure services provided by their respective Data Centers to ensure the assistance of the Information Security Policy and its objectives in this robust security balancing process, which were defined by the High Authority.

### C.2. Model Information Security Organizational Structure

The next step towards the implementation of the above mentioned management system is to shape a well defined security organizational structure. Absence of a robust security
organizational structure may hinder the security implementation. The modeling of this security organizational structure should follow the following scripts:

1. Establish a central security office.
2. Decentralize the functionalities of this office into two wings: the Information Technology Policy Office (ITPO) and the Information Technology Security Office (ITSO).
3. The ITPO will handle IT policy development, dissemination, and education, and the ITSO will handle security analysis, development, education, and guidance for respective institutions’ information assets and IT environment.
4. Institutions should have at least some dedicated security staff to fulfill the functionalities of the above two wings.

C.3. Development of security plans and policies

To implement the above mentioned management and organizational system, it is essential to have a well defined security policy and plan with the rules on servitude and degree of practicum across the institutions.

It is important to note that a significant drawback of SITS approach is that it may inhibit the academic freedom by limiting access to certain necessary information, so people may not comply with the security process towards its implementation. Moreover people may find it difficult to understand the derived policies. Absence of a periodic review pattern on the existing policies can create further damage. So the development of a robust security policy and process should have the following scripting as enlisted below:

1. Consider the value criteria of a particular educational institution while driving policies where policies dictate processes, procedures, and standards; and security should implement those.
2. Policy should be accessible - clear and easy to read - consistent across the institution – enforced - regularly updated - and comprehensive.
3. All the campus community’s users are instructed to understand their participation in the care that the information security policy.
4. Involve Senior Management in information security Policy and Plan development phase. And a discussion needs be done among representatives from all sectors of the institution and should be done periodically.
5. Evaluate the just-in-time suitability of the existing security policies during the critical analysis of the Management System Information Security and where appropriate, revise it and if possible re-train all the security employees and make the user community aware about it.
6. Finally, provide a framework to merge all of the above to gain robust scalability, sustainability and secrecy in this policy derivation-codification-modification and application process.
And for ensuring the policy’s implementation, institutions must have either a partial or comprehensive plan in place. One thing to keep in mind is that institutions’ IT security policy and plan should not only support academic freedom but also ensure ready and timely access to information to authorized users and its smooth execution while preserving the academy’s most important values. A good security policy and plan can play an important role in liability abatement by demonstrating that the institution has taken appropriate and necessary precautions to protect its information assets.

C.4. Communication and awareness
A policy cannot be effective by itself. Neither it nor the IT security organizational structure produces a subjectively appropriate security until there are some awareness programs regarding these. The following two depict how the awareness activities should look like.

1. Institutions must conduct awareness activities for users to ensure they understand and trust the policy and for staff members who configure and use security technologies in a periodic fashion.
2. To further build confidence, continuous security education is likely to be one of the most cost-effective and important defensive strategies for an institution to take.

The lack of attention to security is a long-standing situation and has led to a huge awareness gap. The biggest concern is that very large portions of the people who connect to the network have no concept of security and are showing up with improper setups. That’s why institutions should invest in a very high degree of awareness. Awareness building does not have to cost a lot of money, but it definitely needs attention.

C.5. Model the pattern of institutional IT Security Practices
The next step towards the implementation of the RITS-B approach is the definition of IT security practices i.e. Methodology for Analysis and Evaluation of Risk of Information Security, for Updating and Maintaining Systems and for access Control Procedure and Detection-Monitoring Process. Since we are dealing with security, or in any branch of human activity, it is natural to know the risks involved. This will be done through a deep analysis.

The Risk Assessment and Audit (RAA) is performed by a Work Team with representatives from relevant areas. The development of the RAA should follow the following script:

1. Identification of assets related to the institution within the scope as described in section B;
2. Determination of threats that may be related to the Assets;
3. Identification of damage that can cause problems and compromise the security of information according to figure 03.
4. Use the following risk assessment methodology to categorize the identified menaces into four (04) broader categories: (a) Internal and accidental- Internal
users’ unintentional security breaches. (b) External and accidental- external users’ unintentional security breaches (c) Internal and intentional- Intentional attacks from internal users and (d) External and intentional- willful attack by an external hacker. The possible sets of actions are shaded in each of the respective blocks to avoid these willful or accidental breaches (see figure 04).

5. Identify and scale the vulnerabilities that can make the menace is emerging.
6. Describe the existing prevention of control to prevent damage.
7. Describe the controls before detection of threats to cause damage;
8. Document the SPW in the light of the identified risk-vulnerabilities and their occurrence and impact ;
9. Prioritize the risks of treatment with the SPW according to the academia’s culture, value, beliefs and constraints to determine the implementation of controls that address risks;
10. Redo the RAA in accordance with the actions taken and use these in the existing SPW to formulate its new versions. While the Risk Assessment and Audit (RAA) will happen when following the cycles of SPW at least once a year at the moment of security incidents are identified.
11. And a report from RAA should be conducted with the approval of the High Direction and should be used with entry to the completion of treatment of risks i.e. incident handling and response.

C.6. Implementation of security Easy to Use Scheme
One of the major limitations of SITS approach is that people may find it difficult to use and thereby not comply. Given the university community’s apparent willingness to act securely, if it proves convenient, institutions can take several approaches to make it easier for their users to behave in a secure fashion. Some of these are simple and low cost, where others require more effort to implement and maintain but also promise better returns. Because the more you make it easier for people to do the right things, the more successful you will be. These proposed approaches are enlisted below:

1. Create easy-to-follow instructions- to secure commonly used systems and applications and make them easily available on the Web.
2. Provide links of commonly used IT security tools such as antivirus software, personal firewall software, or secure communications tools like SSH or SFTP in an internal website and make them easy to find and install.
3. The institution should create its own installers for commonly used operating systems and applications with all desired security modifications included and distribute them to campus system administrators and users on either an intranet server or physical media such as CDs.
4. Use automated system configuration tools to monitor individual systems’ configurations and automatically push updates out to them as necessary.
Figure 3: Risk Assessment And Audit (Raa)

- **Assessment Identification**
- **Menace**
  - **Damage Identification**
  - **Survey of Vulnerability**
  - **Prevention**
  - **Detection**

**Security Practice Wings (SPW) for Actuation of Risk**

**Figure 4: Risk Assessment Methodology**

- **Accidental Threat**
  - **Awareness**
  - **Training**
  - **Policies**

- **Intentional Threat**
  - **Background Checks**
  - **Policy Enforcement**
  - **Physical Security**
  - **Technology**

- **Source**
  - **Internal**
  - **External**

- **Software Development Policy**
  - **Awareness**
  - **Training**
  - **Policies**
  - **Technology**
  - **Policy and Legal Enforcement**
**The RITS-B Approach**

The proposed RITS-B approach is detailed in Roadmap 1. It consists of nine (09) steps those were grouped into three basic modules as discussed in section A, B and C to achieve the sustainability in the process of higher education secrecy and security for Muslim nations. An institution is defined by its value criterion as discussed above where its security challenges lies on its scope and scale- to assess the security concerns. The heterogeneous and diverse nature of institution and academia fuel the further processing needs of security in the domain of technology and generic soft interventions that is presented in section B and section C respectively. If the institutions are in the need of security then put the above mentioned nine steps under the same umbrella of secrecy where the institution’s cultures, beliefs and values show the light towards the journey on robust security and sustainability in this complicated and insecure world environment.

**Roadmap 01: Robust IT Security Balancing (RITS-B) Approach**

---

**Precondition:** Institutions to be secured  

**Post condition:** A more secured higher education environment

1. Define the institution’s information security scope  
   a. Develop a framework on fact and national perspective for campus security  
   b. Identify security policies, tools, procedure and practices

2. Define IT Security Strategic Assessment Scale  
   a. Reactive  
   b. Technology Centric  
   c. Cultural  
   d. Fortified

3. Document the institution’s technological needs  
   a. Technology/Tools vary  
      i. with that of application and intrusions  
      ii. with that of institutions wants, needs and abilities  
   b. Main purpose: is to fulfill the requirements of (1) to (9) of section II

4. Model the Management System Information Security on campus  
   a. Based on: DI-AI methodology  
   b. Should follow the standards of NBR ISO/IEC-27001:2005

5. Model Information Security Organizational Structure  
   a. Formulate a centralized office  
   b. Decentralize it into ITPO and ITSO  
   c. Have some dedicated staffs

6. Development of security plans and policies

7. Communication and awareness

8. Model the pattern of institutional IT Security Practices

9. Implementation of security Easy to Use Scheme
Quantitative Survey Result

In analyzing the security performance of the RITS-B approach, the responses of 6 senior university administrators— the majority of whom were Chief IT Officers and other director of CICT (Centre of Information and Communication Technology) / academic/administrative computing along with 66 academic personnel at 6 engineering institutions of Bangladesh were synthesized, from a June 2010 survey as reported in Information Technology Security Management in Engineering Universities in Bangladesh by Jahidul Arafat under the supervision of Dr. Che Kum Clement for the Department of Instructor Training and General Studies, Islamic University of Technology, A subsidiary organ of OIC, Bangladesh. The existing security trends of these institutions were queried by the respective researcher and in the light of the findings the RITS-B approach is developed and later the surveyed institutions were asked to implement this newly developed security scheme in their arena. The impact of the implementation status of this RITS-B approach at those institutions were further analyzed against three survey questions to assess respondents’ opinions on the success of their IT security outcomes (Likert scale ranging from: 1= strongly agree, 2= agree, 3= Disagree, and 4= Strongly Disagree):

• How would you characterize your program success?
• Are data, network, and applications that are your responsibility secure?
• Is your institution more secure today than it was two years ago?

Table 1: Impact of rits-b’s implementation status over institution’s it security outcomes

<table>
<thead>
<tr>
<th>Implementation Status of RITS-B Approach</th>
<th>IT Security Outcomes</th>
<th>More Secure than 2 years ago</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Program is Successful</td>
<td>Systems are Secure</td>
</tr>
<tr>
<td>Fully Implemented</td>
<td>WA</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>S.Div.</td>
<td>-</td>
</tr>
<tr>
<td>Partially Implemented</td>
<td>WA</td>
<td>2.25</td>
</tr>
<tr>
<td></td>
<td>S.Div.</td>
<td>0.500</td>
</tr>
<tr>
<td>Didn’t Implement</td>
<td>WA</td>
<td>3.50</td>
</tr>
<tr>
<td></td>
<td>S.Div.</td>
<td>0.707</td>
</tr>
</tbody>
</table>


And the table 1 shows that institutions which implemented the proposed RITS-B approach in their arena either fully or partially rate their IT security outcomes higher than those which didn’t. This thereby dictates the significance of having this newly
developed security model in the campus arena to gain robustness in the process of secrecy and security without violating the freedom and openness.

**Conclusion**

The Soft IT Security (SITS) approach is a useful and important technique in higher education information security. In spite of its excellent persona such as simplicity, effectiveness and incident supervision, it is unable to achieve global optimum because of academic and departmental diversities and as because Muslim Ummah’s interest and beliefs are not reflected here. On the other hand, the proposed Robust IT Security Balancing (RITSB) Approach considers the stages of Identification-Prioritization-Revision-Dynamicity for an acceptable use of soft security issues over the hard interventions and on the end user community while considering the academia’s diversities, beliefs and constraints. In the RITS-B approach, the degree used for merging the hard and soft security concerns with that of the institution’s belief, culture and constraints are derived dynamically based on similarity and value criterions of the regions and institutions. For these reasons, the RITS-B Approach is able to present the institution’s security concerns from a holistic position. The quantitative survey results show that the institutions which had implemented this proposed security solution in their arena feeling more secure than two years ago. They also rated their system’s security and program’s success much higher than that of others. This increases the application area of the SITS approach where the robustness and dynamisms are needed.

**References**


Part 5: Emergence of Robust Information Security Management Structure


PIRANI, J.A., SHEEP POND ASSOCIATES & ECAR. 2003. Incident response: Lesson Learned from Georgia Tech, the university of Montana & University of Texan at Austin, Case Study, ECAR, No. 7.


Factors that impact on the successful integration of ICT in schools in Cameroon

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Abstract

ICT integration in secondary schools in sub-Saharan Africa is still at an early stage and already faces several setbacks that may undermine the various initiatives undertaken by governments and the private sector to promote the use of computers in schools. Identifying the various factors affecting the adoption of ICT in schools will help redefine the approach used by decision makers and stakeholders of ICT in schools. This paper reports on findings of the study which had the objective of establishing guidelines for a successful adoption of ICT in schools in the Western Region of Cameroon. The paper identifies the enabling and opposing factors to ICT integration in schools. Factors opposing or enabling ICT in schools in Cameroon were identified from the case study of the Western Region where four secondary schools were selected from a group of 15 schools recommended by the Regional Department of Education according to the readiness of the school authorities to facilitate the study. The study was conducted in secondary schools in the region in order to appraise the extent of ICT in schools; the findings could be useful for all the schools in the region. The paper reports on how the findings can enable more focused actions on ICT adoption in schools.

Keywords: Improved learning, ICT integration, infrastructure plan, technology use, technology access, developing countries.
Introduction

In the educational sector, ICT is shaping the future of education and learning [Khan 2008]. ICT will largely contribute to achieving universal education through the delivery of education and training of teachers, as well as the offering of improved conditions for lifelong learning. Such lifelong learning involves people that are outside the formal education process, and thus also their improving professional skills [UNESCO 2005].

ICT can improve critical thinking, information handling skills, the level of conceptualization, and problem-solving capacity [Bransford et al. 2000]. When used appropriately, different ICTs are said to help extend the access to education, strengthen the relevance of education to the increasingly digital workspace, and raise educational quality by helping make teaching and learning into an engaging, active process connected to real life [Tinio 2003; Whitworth and Berson 2003].

Several cases of successful ICT integration into the classroom are reported but most of these have been in technologically advanced countries [Jhurree 2005]. On the contrary, little or no statistics are available from developing countries to ascertain the level of ICT integration into education in these countries. The limited research reports that are available on developing countries and in Sub-Saharan Africa in particular, however indicate that the implementation of ICT is currently increasing and has been introduced in varying degrees at all levels from preschools to university [ERNWACA 2006].

In Cameroon, a typical Sub-Saharan African country, a report released by the National Agency for Information and Communication Technologies – a body established to monitor and promote the integration of ICT in the society - concluded that despite the substantial efforts undertaken so far in the educational sector, the level of ICT mastery in an emerging knowledge-based society like Cameroon vis-à-vis other countries at the same level of growth still remained very low; and that it may not be able to guarantee adequate training in the mastery and usage of ICTs by the citizens of the country [National Agency for Information and Communication Technologies 2008].

Frameworks and models have been put in place to ease the numerous aspects of ICT integration such as ICT and its uses, teaching, the curriculum and schooling [Robertson et al. 2007]. Some very successful cases of ICT Integration in developing countries were based on frameworks, guided by research and done by means of a scientific approach. Most of these cases were based on careful planning and how policy makers understood and appreciated the dynamics of such integration [Kok 2006]. Based on literature and other research [Jhurree 2005; ENWARCA 2006; Farell and Isaacs 2007] the setbacks faced by countries in Sub Saharan Africa when integrating ICT in school can be attributed to the fact that no guidelines for proper ICT adoption in secondary schools exist and most integration cases were done haphazardly with no systematic approach based on existing frameworks or tailored towards the real context in the schools concerned.
Based on the successful frameworks of ICT adoption in schools in developing country, this paper will present the basic requirements for ICT adoption in schools in developing countries and the various trends and challenges experienced in sub Saharan African countries.

**Basic Requirements For Ict Adoption In Schools**

Several models and frameworks [Clarkson and Oliver 2002; Fluck 2003; Pornpun 2006; Balanskat and Blamire 2007] have been formulated to provide a better understanding of the ICT integration process and evaluate the positive effects of technology on learning or investigate the kind of enhanced learning environment that technology provides in the classroom. ICT development is seen as a continuum along which an educational system or an individual school can pinpoint the approach that relates to the growth of ICT for their particular context [UNESCO 2002]. A model proposed by Fluck generally specified the stages of effective ICT Integration and has the advantage of being sufficiently general and simple. It accurately describes the integration process in three stages: the introductory, the integrative and the transformative. Table 1 provides a summary of the status of key components of ICT integration at each phase.

A cross sectional examination of the available reports from Sub-Saharan African countries [Farell and Isaacs 2007; Nangue 2010] has shown that a vast majority are yet to engage in the ICT integration in school process or are still at the introduction phase of the process. The next section examines the context of developing countries and highlights the trends and challenges in the adoption of ICT in schools.

**Table 1: Summary of the key phases of ICT in School development [Fluck 2003]**

<table>
<thead>
<tr>
<th>Policies and Vision</th>
<th>Introduction Phase 1</th>
<th>Integration Phase 2</th>
<th>Transformation Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technology Literacy, student enrolments, ICT Skills</strong></td>
<td>Improving understanding and problem solving skills of students. Connecting school learning to real-world problems and contexts</td>
<td>Emphasis on Knowledge Creation, continuous learning.</td>
<td></td>
</tr>
<tr>
<td><strong>School organisation</strong></td>
<td>Hierarchical structure Standard classrooms</td>
<td>Structural flexibility over curriculum implementation. More time for Projects, planning and collaboration</td>
<td>Schools become a learning organization. Continuous innovation from teachers</td>
</tr>
</tbody>
</table>
### Part 5: Factors that impact on the successful integration of ICT in schools in Cameroon

<table>
<thead>
<tr>
<th>Staff Development</th>
<th>Introduction Phase 1</th>
<th>Integration Phase 2</th>
<th>Transformation Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICT literacy programs predominate.</td>
<td>Teachers building skills to manage and guide students through collaborative work</td>
<td>Teachers are model learners responsible for their own and each other’s development as colleagues and mentors.</td>
<td></td>
</tr>
<tr>
<td><strong>Curriculum</strong></td>
<td>Computers taught as a separate subject. Learning about ICT</td>
<td>Applying Knowledge. ICT used to solve complex real-world problems</td>
<td>Collaboration, inquiry, information management, creativity and critical thinking skills developed.</td>
</tr>
<tr>
<td><strong>Infrastructure</strong></td>
<td>Purchase/donation of computers hardware and software. Low ratio of computers to students.</td>
<td>Simulation and Multimedia are in use. More dedicated and sophisticated hardware in place</td>
<td>Pervasive technologies and social networks.</td>
</tr>
</tbody>
</table>

### Ict In Schools

ICT integration - or the use of computers in the teaching and learning process - could be seen as a whole configuration of events, activities, contents, and interpersonal processes taking place in the context that ICT is used [Lim 2002]. However, the right conditions need to be in place before the educational benefits of ICT can be fully harnessed, and a systematic approach is required when integrating ICTs into the education system. This fact is often overlooked and, in their eagerness to jump on to the technology bandwagon, many education systems end up with technologies that are either not suitable for their needs or cannot be used optimally due to the lack of trained personnel [Ng et al. 2009]. ICT integration in education should be seen as support to “attain objectives that have not been attained efficiently otherwise, such as: expanding access, promoting equality, improving the internal efficiency of educational systems, enhancing the quality of education, and preparing new and old generations for a technology-driven market place” [Jhurree 2005]. Developing countries have recognised the fact that successful knowledge economies will require additional skills to productively transform knowledge and information into innovative products and services. Providing greater access to basic education and ensuring quality education are two paradigms imposed on developing nations seeking to subscribe to the concept of knowledge-based societies.
Improving the quality of education and training is a critical issue, particularly at a time of educational expansion [Tinio 2003]. Tinio further states that “for developing countries ICTs have the potential for increasing access to and improving the relevance and quality of education. It thus represents a potentially equalizing strategy for developing countries”. The potential of ICT use in education however opens up major concerns to developing nations such as if developing countries do not align with the quest towards new technologies adoption, they will further be isolated [World Bank 1998].

Several issues have been raised from literature pertaining to the adoption of ICT in schools in developing countries. Well known issues relate to financial constraints whereby low-income developing countries such as those in Sub-Saharan Africa have obvious difficulties in escaping from the low-income, low-technology equilibrium to enter into the ICT realm [Lee 2001; Addo 2001] and the lack of human capacity. Lee questionably states that “even if free computers and free Internet access are available, they are useless to those individuals who are illiterate or lack the know-how. The application of ICT technologies requires human capabilities to handle such technologies”. Apart from these known issues, ICTs use in education in developing countries is facing additional questions and challenges. These include:

i) The rush to adopt the new technology in education: Developing countries often find themselves in situations where there is pressure to acquire and adopt new technologies because of the claims of what these technologies could do to aid and leapfrog their development, without really understanding the potential and reach of the technologies, or without having analysed their environments and contexts for appropriateness, applicability and impact [Swarts n.d.].

ii) The Focus on technology: More often than not, computers are installed into schools around the world without sufficient thought given to how the computers will be used [Hawkins 2002]. Discussions and planning for ICTs in education are driven by a technological imperative with little thought being given to the wider educational context within which the technology is to be used. The appropriateness of the technology for the purpose is often overlooked in the rush to acquire technology.

iii) Technology generated learning: This widespread notion may lead to a lot of wasted money, with technologies put into schools either unused or used poorly [Swarts n.d.]. For the new technologies to actually contribute to learning, much more thought needs to be put into issues of pedagogy, curriculum, professional development of teachers, software, maintenance, scheduling, and other issues.

iv) Taking into account informal learning: Students, even in developing countries have considerable skills in the manipulation of new technologies, sometimes more so than their teachers [Swarts n.d.]. Research findings seem to indicate that informal contact and communication is the most prevalent form of transferring ICT knowledge [Pelgrum and Law 2003].
v) Technology not replacing traditional classrooms: Fears, anxiety, and concern that teachers have about change must be addressed. Using technology as a teaching and learning tool in the classroom does bring fear anxiety and concern to a greater extent since it involves both changes in classroom procedures and the use of the often-unfamiliar technologies [Bitner and Bitner 2002]. Knowledge is expanding rapidly and most of it is available to teachers and students at the same time. This puts an unavoidable burden on teachers to continue updating their knowledge and exposing themselves to modern channels of information. Most teachers now have to learn how to cope with the new technologies in their classrooms, how to compete with students in accessing the enormous body of information (particularly via the internet), and how to use the hardware and software to enhance the teaching and learning process. Most often, students are more advanced in and are more adept at using the new technologies than their teachers [Swarts n.d.].

vi) Technology and content: Content development is a critical area that is too often overlooked. The lack of culturally-appropriate educational content, particularly for developing countries, poses challenges. Cultural differences affect learners’ ability to fully understand and benefit from the lessons and their intended learning outcomes. It is therefore clear that content produced in one context cannot be adopted without some modification into another context. The bulk of existing ICT-based educational material is likely to be in English or of little relevance to education in developing countries especially at the primary and secondary levels [Tinio 2003].

Kozma [2003] identified three levels of factors influencing the ICT use in education namely i) A Macro-level refers to system factors, such as cultural norms, social context, educational policy, and curriculum standards, etc; ii) a Meso-level refers to school factors, such as the ICT infrastructure, Technical support, ICT integration plans, school organisation, school leadership, parents, etc; iii) a Micro-level refers to individual factors for teachers - pedagogical practice, classroom organisation, educational background or experience with technology - and for pupils -experience with technology, social and cultural background, skills, etc.

Case Study of Schools in Cameroon

The intention of this research was to gather data regarding the perspectives of research participants (stakeholders in schools) about the phenomenon of ICT Integration in schools and the factors that promote or hinder this process. The purposive sampling technique was used in the selection of schools with basic ICT infrastructure as a key criterion. The selection of the schools in the chosen region was further influenced by the availability of ICT resources, the school readiness to support the research conducted by granting access to resources and information, and the limited funds available to cover schools in regions far apart. Fifteen schools were shortlisted, selected from within the case
the Western Region - by the Regional Department of Education. These schools were recognized as the most advanced schools in the region in terms of ICT infrastructure. A further assessment was then made to streamline the number of participating schools to four, based on criteria such as the accessibility and the willingness of leaders to adopt the ICT in education change as listed in Table 2 in no specific order.

Table 2: Selected schools in Western Region of Cameroon

<table>
<thead>
<tr>
<th>Name of School</th>
<th>Type of School</th>
<th>No of Students</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lycée Bilingue de Baham</td>
<td>Public</td>
<td>1700</td>
<td>Semi-Urban</td>
</tr>
<tr>
<td>Lycée Classique de Dschang</td>
<td>Public</td>
<td>2500</td>
<td>Urban</td>
</tr>
<tr>
<td>Lycée Classique de Bangangte</td>
<td>Public</td>
<td>2000</td>
<td>Semi-Urban</td>
</tr>
<tr>
<td>Collège St Thomas d’Acquin De Bafoussam</td>
<td>Private</td>
<td>1000</td>
<td>Urban</td>
</tr>
</tbody>
</table>

Data Gathering methods

In this study, three major sources of evidence were used: documentation, surveys and interviews. Existing reports, administrative documents, circulars and decrees were reviewed and a total of 100 respondents were investigated from all four schools. Four (4) of the respondents were the principals of each school, four (4) other respondents were the ICT coordinators of each of the schools (in charge of both educational and technological support), forty two (42) teachers, and fifty (50) students.

Initially, a preliminary survey had to be conducted in recommended schools to obtain information about if ICT was actually being used in the school in any form and if the decision makers had an established drive to use ICT for improved learning in the near future. Such information obtained included: the type of School (public or private, the existence of a computer Lab, the purpose of the Lab, the number of computers used at school, the availability of Internet access, and the number of students in the school).

The aim of the study was to establish the current level of ICT integration in schools in Cameroon, to identify factors that affect ICT integration in schools in Cameroon and to suggest guidelines that will allow for proper ICT integration in schools; some sets of questions were devised to guide interviews aimed at addressing these objectives. These interviews focused on the major components of ICT integration such as the school ICT Policies and organization, the ICT infrastructure, ICT use and access, Curriculum content and delivery, teachers/staff readiness and Support. Principals, ICT coordinators, teachers, and students from each school were the major respondents during the four series of interviews.

Table 3 provides a summary of the data collection methods used in the study.
Table 3: Data collection methods summary

<table>
<thead>
<tr>
<th>Method</th>
<th>Data Collection Instrument</th>
<th>Resultant data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surveys</td>
<td>Preliminary Survey</td>
<td>School overview</td>
</tr>
<tr>
<td>Documentation</td>
<td></td>
<td>Basic ICT Infrastructure</td>
</tr>
<tr>
<td>Surveys</td>
<td>Student Questionnaire</td>
<td>Access to ICT</td>
</tr>
<tr>
<td>Survey</td>
<td>Teachers Questionnaire</td>
<td>Use of ICT</td>
</tr>
<tr>
<td>Surveys</td>
<td>Coordinators semi structured</td>
<td>Support</td>
</tr>
<tr>
<td>Interviews</td>
<td>Interviews</td>
<td>Infrastructure</td>
</tr>
<tr>
<td>Surveys</td>
<td>Principal Semi-structured</td>
<td>Curriculum</td>
</tr>
<tr>
<td>Surveys</td>
<td>Interviews (telephone and face-to-</td>
<td>Policies, Vision</td>
</tr>
<tr>
<td></td>
<td>face)</td>
<td>Expectations</td>
</tr>
<tr>
<td>Surveys</td>
<td></td>
<td>Strategies</td>
</tr>
<tr>
<td>Surveys</td>
<td></td>
<td>School context</td>
</tr>
<tr>
<td>Surveys</td>
<td></td>
<td>Funding</td>
</tr>
</tbody>
</table>

Reliability and Validity
The construct validity test was applied in this research through the use of multiple sources of evidence such as documentation (policy and strategy documents), interviews (teachers, ICT coordinators and principals), observations (laboratory structure and environment) and surveys (students). The use of these multiple sources of evidence provided for converging lines of inquiries or a process of triangulation. As information was collected from multiple sources of evidence but aiming at corroborating the same phenomenon, there was a triangulation of data sources (data triangulation). In this case, structured interviews (surveys) with close-ended questions were used to obtain quantitative data from students and teachers that validated the data collected from semi-structured interviews with principals and ICT coordinators.

Data Triangulation
Recognizing the imperfections in each data collection method, a triangulation approach was used to cross-check gathered data. Data collected from interviews with key informants such as Principals and ICT coordinators on access to and use of ICT infrastructure, curriculum implementation or staff professional development were verified against data gathered from teachers and students’ surveys. Secondary data gathered from existing literature and the ministry of education decrees were checked against key informants’ interviews. These interviews were conducted to corroborate and complement findings from the literature as well as teachers and students’ surveys. The study however relied on a single collection method for some data.
Findings and Results

In the course of the analysis, enabling and opposing factors of ICT in schools were considered in each key component of ICT development in schools. The lack of ICT infrastructure, the absence of ICT policy documents to guide the integration process, and the lack of training and support were among the prominent opposing factors identified. While dealing with these factors was the key challenge to overcome in order to achieve ICT adoption, several unnoticed ICT driving factors also emerged. They included a very positive attitude of teachers and staff towards the use of ICT in teaching, and the possibility for ICT procurement through parent-teachers’ associations. The following section reports factors influencing each of the major components of ICT development in schools.

Table 4: provides a summary of the various enabling and opposing factors found in the investigated schools

Table 4: Summary of enabling and opposing factors to ICT in schools in Cameroon

<table>
<thead>
<tr>
<th>Component</th>
<th>Driving factors</th>
<th>Opposing factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curriculum</td>
<td>• Existence of a National Syllabus for ICT in school.</td>
<td>• Lack of ICT infrastructure hinders teachers from using ICT in teaching.</td>
</tr>
<tr>
<td></td>
<td>• Teachers’ positive feeling about using ICT to teach their subjects.</td>
<td>• The lack of proper training to use ICT in the curriculum.</td>
</tr>
<tr>
<td>Infrastructure and access</td>
<td>• ICT infrastructure procurement could be funded through parent-teachers’ associations</td>
<td>• The non availability of digital resources from the Ministry of Education</td>
</tr>
<tr>
<td></td>
<td>• A continued decrease in the cost of hardware and software could make procurement easier.</td>
<td>• The Lack of administrative/technical support prevents the use of ICT in teaching.</td>
</tr>
<tr>
<td></td>
<td>• Students’ access to ICT is possible from home (42.0%) and from other places such as cybercafés.</td>
<td>• The lack of ICT infrastructure leads to the high ratio of student to computer observed in all schools.</td>
</tr>
<tr>
<td></td>
<td>• 54.8% of teachers own a computer at home</td>
<td>• The lack of ICT infrastructure plan does not allow for the right priorities to be set.</td>
</tr>
<tr>
<td></td>
<td>• There is enough room for expansion within the school for additional computer laboratories.</td>
<td>• Donated computers often become quickly obsolete.</td>
</tr>
</tbody>
</table>
### Component: Teachers Professional Development

<table>
<thead>
<tr>
<th>Driving factors</th>
<th>Opposing factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Most teachers agree to have basic knowledge of computers and admit that learning about computers is useful.</td>
<td>• Only 26.2% of the teachers have actually attended a formal training course which may cast doubts on the actual skills possessed by the teachers.</td>
</tr>
<tr>
<td>• Teachers admit that computers will be key for the future of their job and that students will learn better if ICT were used.</td>
<td>• The non-existence and inaccessibility of ICT infrastructure, as well as the lack of training and technical support prevents the use of computers in preparing lessons.</td>
</tr>
<tr>
<td>• Teachers agree that a new pedagogical approach will be required when using ICT in teaching which will facilitate the infusion of new pedagogical skills.</td>
<td>• Teachers are still not fully aware of the challenges they will be facing when undergoing full integration of ICT in the curriculum.</td>
</tr>
<tr>
<td>• 92.7% of teachers admitted to being ready for the ICT uptake in their teaching</td>
<td>• Teachers (68.3%) still believe they will need ready-made digital content in order to use ICT in the curriculum.</td>
</tr>
</tbody>
</table>

### Component: School Policies, vision and Organisation

<table>
<thead>
<tr>
<th>Driving factors</th>
<th>Opposing factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Strong commitment from parents towards the uptake of ICT in schools.</td>
<td>• The lack of School ICT policies.</td>
</tr>
<tr>
<td>• There is a positive perception of ICT and readiness from teachers within the schools.</td>
<td>• The non-existence of an ICT integration plan</td>
</tr>
<tr>
<td>• Existence of a minimum budget to plan for ICT infrastructure procurement.</td>
<td>• The reliance on sponsors and donors which could not always be guaranteed.</td>
</tr>
<tr>
<td>• A positive commitment to embark on ICT uptake from the school leadership despite setbacks.</td>
<td></td>
</tr>
<tr>
<td>• A driving desire to stay competitive</td>
<td></td>
</tr>
</tbody>
</table>

The factors are discussed in more detail in the following section.

**Factors relating to the curriculum:** The curriculum in the schools was identified to be at the initial introductory phase of ICT integration mainly characterised by ICT being taught as a separate subject. Enabling factors included i) the existence of a National Syllabus for ICT in school and ii) the teachers’ positive feeling about using ICT to teach their subjects (Table 1.1 of Appendix A). Opposing factors to the development of ICT in the schools included i) the lack of ICT infrastructure hindering teachers from using ICT in teaching their subjects, ii) the lack of proper training to use ICT in the curriculum,
(iii) the non availability of digital resources from the Ministry of Education, and (iv) the lack of administrative and technical support as seen in Table 1.3 of Appendix A).

**Infrastructure and access related factors**: ICT infrastructure at the initial stage of ICT adoption in schools remains the most significant challenge and has the potential to affect all other components. The shortage of ICT infrastructure could have a negative impact on the entire Integration process. Enabling factors influencing this component were: i) Parents Association provided a minimum budget for ICT infrastructure procurement on a yearly basis, ii) a continuing decrease in the cost of hardware and software could make procurement easier iii) students’ access to ICT is possible from home (42.0%) and from other places such as cybercafés as shown in Table 1.5 and Table 1.6 of Appendix A; iii) 54.8% of teachers own a computer at home and this could possibly leverage the need for basic infrastructure, and iv) the availability of space for expansion within the school for additional computer laboratories according to all school principals interviewed. Opposing factors included: i) the lack of ICT infrastructure with high ratio of student to computer observed in all schools, ii) the lack of ICT infrastructure plan which prevents setting the right priorities (Table 1.4 of Appendix A), and iii) the donated computer which often becomes quickly obsolete.

**Factors from Teachers Professional Development**: Teachers play a crucial role in the adoption and implementation of ICT in education since they are the key to making learning happen. It is widely believed that all education professionals need to be equipped with technological skills and capabilities to support the delivery of high quality education in the 21st century [BECTA 2009]. The identification of the factors influencing teachers’ adoption of ICT is important for the successful implementation, and adoption of ICT in schools. Enabling factors relating to this component are: i) 83.3% of teachers agree to have basic knowledge of computers and admit that learning about computers is useful (which could facilitate any literacy programme put in place), ii) all Teachers interviewed admitted that computers will be a key for the future of their job, iii) 90.2% of the teachers interviewed believed that students will learn better if ICT were used, and iv) the wide acceptance by the teachers that a new pedagogical approach will be required when using ICT in teaching will greatly facilitate the infusion of new pedagogical skills within the teachers’ community. Opposing factors regarding this component included i) the fact that only 26.2% of the teachers have actually attended a formal ICT training course despite claims of being computer literate (Table 1.1 Appendix A), ii) the inexistence and inaccessibility of ICT infrastructure, as well as the lack of training and technical support prevents the use of computers in preparing lessons, iii) despite the positive belief about ICT in their careers, there is still 56.2% of teachers that think or remain undecided as to whether ICT will be an extra burden on their daily task (this could be justified by the fact that teachers are still at the early phase of ICT adoption and are not fully aware of the challenges they will be facing when undergoing full integration of ICT in the curriculum), iv) a considerable percentage of
teachers (68.3%) still believe they will need ready-made digital content in order to use ICT in the curriculum.

**School Policies, vision and Organisation:** The school policy or vision of ICT is perceived from literature as the most crucial point from a strategic perspective. A whole-school ICT policy sets out the rationale for the teaching and learning of ICT and the aims and objectives for ICT use within the frameworks of the school. It gives clear guidance on the types of equipment, programs and measures that need to be in place if the requirements of the policy are to be met. Enabling factors with regard to policies and school organisation include: i) the strong commitment from parents towards the uptake of ICT in schools, ii) the positive perception of ICT and readiness from teachers within the schools, iii) a possibility for a minimum budget to plan for ICT infrastructure procurement (Table 1.4 Appendix A), iv) a positive commitment to embark on ICT uptake from the school’s leadership despite setbacks, and v) a driving desire to stay competitive. Opposing factors here include i) the lack of School ICT policies, ii) the inexistence of an ICT integration plan, and iii) the reliance on sponsors and donors which could not always be guaranteed.

**Conclusion**

This study was conducted in four selected schools in the Western Region of Cameroon, a region generally known for its high level of literacy. Findings here are results of considering the answers that the participants indicated or said in relation to their use of ICT and the only verification of such data was made by matching data from different categories of respondents. For example, the self–perceived “ICT –literate” from teachers could have been understood as having once used a computer. ICT integration in schools is clearly a complex issue being influenced by numerous factors at macro level (National policies, etc.), meso-level (school level) or micro-level (individual level). The focus in this study was limited to factors at school level that could allow the schools to complete the early stage of ICT integration and move to the second level, the integration stage. The study was the first study of its kind to be conducted in secondary schools in the region in order to appraise the extent of ICT in schools and suggests guidelines for the integration of ICT in schools. A situation similar to the one described in the above schools could be expected from other schools in the region. Also, the findings from this study will enable a more focused adoption of ICT in schools as opposing factors found here could be separately addressed and enabling factors encouraged in those schools already engaged in the process. As this is the first exploratory study conducted in the region, further studies might evolve from the findings to refine, extend and/or challenge this research. There are matters of generalisation and verification that could lead to further research.
Bibliography


Appendix A

A few Tables used in the study aimed at providing Guidelines for ICT integration

Table 1.1 Teachers ICT literacy status

<table>
<thead>
<tr>
<th>Reason</th>
<th>School 1 (14)</th>
<th>School 2 (11)</th>
<th>School 3 (9)</th>
<th>School 4 (8)</th>
<th>Total No (42)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Know how to use computers (TQ2.1)</td>
<td>11</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>35 (83.3%)</td>
</tr>
<tr>
<td>Have attended a formal computer training course (TQ6.2)</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>11 (26.2%)</td>
</tr>
<tr>
<td>Strongly Agree that knowing how to use computers is very useful (TQ4.12)</td>
<td>13</td>
<td>10</td>
<td>7</td>
<td>5</td>
<td>35 (83.3%)</td>
</tr>
</tbody>
</table>

Table 1.2 Student to computer Ratio

<table>
<thead>
<tr>
<th>Ratio of student to computers</th>
<th>School 1</th>
<th>School 2</th>
<th>School 3</th>
<th>School 4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Students</td>
<td>1700</td>
<td>2000</td>
<td>2500</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>Number of Computers</td>
<td>15</td>
<td>21</td>
<td>35</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Student to computer ratio</td>
<td>133:1</td>
<td>95:1</td>
<td>71:1</td>
<td>50:1</td>
<td>87:1</td>
</tr>
</tbody>
</table>

Table 1.3 Reasons for not using ICT

<table>
<thead>
<tr>
<th>Reasons for not using ICT?</th>
<th>School 1 (10)</th>
<th>School 2 (9)</th>
<th>School 3 (9)</th>
<th>School 4 (8)</th>
<th>Total No (27)</th>
</tr>
</thead>
<tbody>
<tr>
<td>non-existence</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>18 (66.7%)</td>
</tr>
<tr>
<td>Inaccessibility</td>
<td>3</td>
<td>6</td>
<td>2</td>
<td>3</td>
<td>14 (51.9%)</td>
</tr>
<tr>
<td>Don't know how to use them</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>3 (11.1%)</td>
</tr>
<tr>
<td>I lack skills to use them</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>10 (37%)</td>
</tr>
<tr>
<td>I lack technical support</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>14 (51.9%)</td>
</tr>
<tr>
<td>No time</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2 (7.4%)</td>
</tr>
<tr>
<td>Others</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2 (7.4%)</td>
</tr>
</tbody>
</table>
Table 1.4 ICT infrastructure plan

<table>
<thead>
<tr>
<th>ICT infrastructure plan</th>
<th>School 1</th>
<th>School 2</th>
<th>School 3</th>
<th>School 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is there any ICT infrastructure plan for the school? (PQ2.1)</td>
<td>✕</td>
<td>✕</td>
<td>✕</td>
<td>✕</td>
</tr>
<tr>
<td>Do you have a minimum budget for ICT infrastructure procurement (PQ2.2)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Do you have in place an appropriate budget for ICT maintenance (CQ3.5)</td>
<td>✕</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Does the existing ICT Infrastructure align with the school’s needs? (PQ2.3)</td>
<td>✕</td>
<td>✕</td>
<td>✕</td>
<td>✕</td>
</tr>
</tbody>
</table>

Table 1.5: Other students’ access to ICT?

<table>
<thead>
<tr>
<th>Other students’ access to ICT?</th>
<th>School 1 (16)</th>
<th>School 2 (10)</th>
<th>School 3 (13)</th>
<th>School 4 (11)</th>
<th>Total No (50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access to computers at home? (SQ2.4)</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>10</td>
<td>21 (42.0%)</td>
</tr>
<tr>
<td>Access to computers outside school or home? (SQ2.5)</td>
<td>14</td>
<td>4</td>
<td>10</td>
<td>11</td>
<td>39 (78.0%)</td>
</tr>
</tbody>
</table>

Table 1.6 Access to ICT outside school or home (SQ2.6)

<table>
<thead>
<tr>
<th>Access to ICT outside school or home</th>
<th>School 1 (14)</th>
<th>School 2 (4)</th>
<th>School 3 (10)</th>
<th>School 4 (11)</th>
<th>Total No (36)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cybercafé</td>
<td>5</td>
<td>4</td>
<td>9</td>
<td>10</td>
<td>28 (71.8%)</td>
</tr>
<tr>
<td>Friend’s place</td>
<td>6</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>19 (48.7%)</td>
</tr>
<tr>
<td>Private training centres</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3 (7.7%)</td>
</tr>
<tr>
<td>Others</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>7 (18%)</td>
</tr>
</tbody>
</table>

Intelligent Language Learning Model: Implementation on Runyakitara

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Abstract
This paper describes a design and implementation of an intelligent language learning system on Runyakitara. The motivation for this study is to design and implement quality digital content of Runyakitara to be used by Runyakitara learners both locally and internationally. The system makes use of a morphological parser, disambiguation and an extensive lexicon of the language. The strength of this system is that the learner is not restricted regarding vocabulary to use in learning. The model system employs an independent language learning approach proposed by Hurskainen [2009] for learning complex language structures.

Key words: Language Learning, Intelligent Computer Assisted Language Learning, Language Learning Model, Runyakitara, Intelligent Systems

Introduction
Intelligent Computer Assisted Language Learning (ICALL) systems have been cited as instrumental for language pedagogy, aiding learners in understanding language
forms and rules [Amaral & Meurers, 2006]. This is made possible because they provide additional practice outside the formal classroom and focus on grammatical forms. Given that computers have become more powerful, faster, easier to use, more convenient and cheaper, and that they can process, store and transfer much more data than ever before, provides greater possibilities for developing powerful language learning systems and also an opportunity for less documented and studied languages as well.

Educators recognize that utilizing computer technology and its attached language learning programs can be convenient to create both independent and collaborative learning environments and provide students with language experiences specifically, as they move through the various stages of second language acquisition [Kung, 2002].

Lai & Kritsonis [2006] discuss the advantages of computer technology in second language acquisition, specifically pointing out that they provide language learners with more independence from classrooms, allowing them freedom to learn any time anywhere. Further, the computer-based language learning programs can enable students to practice through experimental learning. They motivate learners, enhance student achievement, increase authentic materials for study, and encourage greater interaction between students, teachers and peers. They also emphasize individual needs, regard independence from a single source of information and enable understanding and knowledge sharing from global corners.

The increasingly global nature of life increases the need for language learning, and therefore, creates need for more language learning systems even for those languages that are not well documented.

Sharlaan [2005] observed that most language learning systems have been, by far, developed for English, followed by Japanese, French and German. Most African languages are not part of the ICALL development. Sharlaan calls for more research that combines natural language processing techniques with language learning systems. Bantu languages have received less attention when it comes to language learning systems dedicated to their structure.

This paper describes a model of an Intelligent Computer Assisted Language Learning system tailored to learning Runyakitara language structures, specifically the concord structure and word order. Runyakitara is a name given to four closely related languages: Runyankore, Rukiga, Runyoro and Rutooro, with similar language structure and word order.

Related research
Considerable research has been done on Bantu languages in general, such as Computational Morphology, Hurskainen [1992]; Muhirwe [2007]; Elwell [2006]; Pretorius & Bosch [2003]; Okemwa & Ng'ang'a [2008]; Karttunen [2003]; Speech Recognition Systems Badenhorst et al, [2009]; Gumede & Plauché [2009]: A Swahili Language Manager [Hurskainen, 2004], and Parallel Corpus for English and Swahili, [De Pauw & Wagacha, 2009]. These technologies contribute to the underlying technology of language learning.
However, efforts to carry them further to levels of language learning have been limited. Because of such limitation, we provide an account of language learning systems that have employed morphological analyzers.

Amaral & Meurers, [2006] discuss an intelligent system [TAGARELA] tailored to teach Portuguese language. The system has four basic models: expert, instruction and feedback, and student models. The system’s expert module is composed of a lexicon, content modules and shallow parser. Instructional model includes activity information, and error information. Student model captured students’ personal information, and finally the system has a feedback module. The strength of the TAGARELA system is in its ability to provide individualized feedback on spelling, missing words, agreement and word order as well as in listening exercises.

Dickinson & Herring [2008] employed the TAGARELA to develop online ICALL exercises for Russian. The aim of this system is mainly to train basic grammar to learners of Russian. The strength of this system is mainly on the provision of audio and video exercises which bring real life listening and observing practice outside classroom. The other advantage is that the system is Internet-based. Therefore, learning any time and anywhere is possible. The weakness of such a system, however, is that exercises tend to have fixed content, and thus limit learners on the very content the developer put in the exercise.

Related work was also done by Sharlaan [2005] on an intelligent computer assisted language learning system for Arabic learners. This system employs a morphological analyzer, sentence analysis, course material, feedback analysis and multi-media exercises. The aim was mainly to teach Arabic grammar to students at primary schools and learners of Arabic as a second/foreign language. The strength of this system is in multi-media and detailed feedback. In addition, learners are encouraged to produce sentences freely in various situations and contexts. The weakness of this system is that it follows a strict school curriculum for primary level which may not be suitable for foreign language learners.

GLOSSER [Nerbonne & Dokter, 1999] is another system that extensively utilizes a morphological analyzer in language learning. The major components of this system include a morphological analyzer for French, part-of-speech disambiguation system, a bi-lingual dictionary, aligning bilingual corpora and www technology. The aim of this system was to provide intelligent assistance to Dutch students learning to read French. The strength of this system lies on individualized instruction and provision of additional learning resources such as a dictionary. The focus however is vocabulary learning which should be acquired separately from reading exercises.

From the above brief analysis of some Intelligent Computer Assisted Language Learning [ICALL] systems, and a review of published literature, it is clear that ICALL systems for Bantu languages are limited, thus the current study.
Literature provides one intelligent system of Bantu language learning [Hurskainen, 2009] and its revision [2010], on the implementation to Kiswahili. The method of learning reported in this research is partly employed in the Runyakitara model.

**Highlights on Runyakitara grammar and consideration for computation**

We describe specific features of Runyakitara grammar that are of interest to this study. As earlier noted, Runyakitara is composed of four languages; therefore, its grammar is a bit complex. In this paper we concentrate on phrases that may include nouns, possessive pronouns, demonstrative pronouns, adjectives and verbs. Concord patterns and word order are important in these phrases. The class of the noun defines the concord pattern of the other constituents of the phrase.

**Nouns and their classification system in Runyakitara**

As all Bantu languages, Runyakitara has a noun class system. Researchers in Bantu languages agree that noun class features are determined by grammatical number, semantics, [that is, whether they are human/animal/non-living things]; and in other cases arbitrarily [Aikhenvald 2006; Katamba 2003]. Although Bantu languages have a general noun classification system, each language has its own unique sub-classification system. Runyakitara noun classification system has twenty noun classes according to Ndoleriire & Oriikiriza [1990]. A revision of this system, a detailed description accounting for the numbering system, can be found in Katushemererwe & Hanneforth [2010].

Important to this discussion is that nouns in Runyakitara are associated with initial vowels as pre-prefixes to the noun prefix. These are a (a-ba-ntu: people), e (e-ki-tookye: banana) and o(o-mu-ntu: person). As discussed by Ndoleriire & Oriikiriza [1990], there are rules that govern the occurrence of the initial vowel although it has other syntactic functions. If the noun class prefix has the vowel a, e.g. ba, ma, the initial vowel will be a, thus, a-ma-te (milk) a-ba-kazi (women). When the noun prefix has i or -, the initial vowel is e, for example e-ki-tookye (banana) e-mi-ti (trees) etc. The initial vowel is o when the noun class prefix has u, o-mu-ntu [person], o-mu-ti [tree]. At morphology level, the initial vowel does not have any other role other than just a description of the class prefixes it affects. At syntactic level, the initial vowel plays some role, for example, when a noun is preceded by a preposition such as omu (in) aha (at), the initial vowel is dropped in phrase and syntactic operations e.g. omu muti (in the tree), and not omu omuti. These facts shed light on understanding the initial vowel in nouns because learners will meet it in the learning process.

Although the pre-prefix has rules governing it in nouns and would play certain roles in syntactic constructions, the morphological analyzer of Runyakitara onto which we are basing the learning system takes a pre-prefix and a prefix as one unit called a noun prefix. Therefore, a noun like abantu is taken as aba[NPREFIX1/2] ntu[NROOT]. This means that aba is a noun prefix belonging to class 1-2 and ntu is a noun root. Noun classification is basic in understanding the concord patterns.
Concord patterns in Runyakitara

Concord patterns in Bantu languages have been extensively discussed in the pioneering work of Meeussen [1967], although he based most of his discussion on Kiswahili. According to Nurse and Phillipson [2003] noun class prefixes are at the heart of an extensive system of concord. The head noun takes a prefix marking its class and other words in construction with it take an appropriate matching prefix. In Runyakitara, this is no exception.

Although there is no detailed description of concord patterns in Runyakitara, the syntactic description given in Taylor [1985] and insights from other Bantu literature [Hurskainen, 2009] can shed more light to enable one understand concord patterns in Runyakitara. In Runyakitara, all constituents of the noun phrase, such as adjectives, numerals, verbs and pronouns, take on a class prefix according to the class of the noun. Specifically, the agreement is in one or all of the following:

i. A possessive pronoun prefix agrees with a noun prefix
   o-mw-ana wa-ngye [my child]
   a-ba-ana ba-ngye [my children]

ii. An adjective prefix agrees with a noun prefix
   o-mw-ana mu-kuru [a big child]
   a-ba-ana ba-kuru [old children]

iii. A subject prefix of a verb agrees with the noun prefix
   o-mw-ana a-rya (a child eats)
   a-ba-ana ba-rya (children eat)

iv. A noun, pronoun and an adjective prefixes all agree
   a-ba-ana ba-ngye a-ba-kuru (my big children)

v. A noun, pronoun, adjective and verb prefixes all agree:
   a-ba-ana ba-ngye aba-kuru ba-rya (my big children eat)

vi. Concord in a long sentence
   A-ba-ana ba-ngye ba-ahika aha ba-gambire ba-ije ba-ndeebe.
   (When my children arrive here, tell them to come and see me).

There is evidence that concord or agreement patterns in Bantu language have proved difficult to learn by non-Bantu language speakers, yet it forms a basis of communicating in the languages. A Swahili learner observed: “One of the most difficult aspects of learning Swahili is its system of nouns…” www.transparent.com/learn-swahili/overview.html

Therefore, following this observation, and other informal observations from Luo speakers in Uganda, it is important to develop a language learning model to help learners learn concord patterns in Runyakitara.
**Word-order in Runyakitara**

There is extensive literature regarding word order in Bantu languages [Nurse & Phillipson 2003; Marten, et al, 2007, and Mchombo, 2004] According to these authors, the dominant word order is SVO (Subject Verb Object) but also languages with SOV, VSO and OVS do exist.

In Runyakitara, the unmarked word order has been reported as SVO [Morris & Kirwan, 1972]. Although Taylor [1985] does not give a specific general order for all words, his approach of word order is preferred because it handles specific constituents of specific word classes. To our observation, word order in Runyakitara is flexible and this is mainly caused by the argument structure, emphasis and topicalisation. For example, in the following simple sentence, words may change the order as:

i. Omwegi yaashoma ekitabo (a student read a book) (SVO)
ii. Omwegi ekitabo yaakishoma (a student indeed read a book)(SOV)
iii. Yaakishoma ekitabo omwegi (VOS)
iv. Yaakishoma omwegi ekitabo (VSO)

The above illustration shows a lot of flexibility when it comes to word order in Runyakitara. In this study, we will follow guidelines provided in Taylor [1985] regarding word order of specific constituents. Our scope of word order covers the combinations of constituents in noun phrases, including the verb. However, we exclude such noun phrases, where the noun is not the first member of the phrase. Examples of phrases are given below.

i) Noun and demonstrative pronoun – omuntu ogu (this person).
ii) Noun and a possessive pronoun – omuntu wanye (my person).
iii) Noun and adjective – omuntu murungi (a good person).
iv) Noun and verb – omuntu areeba (a person sees).
v) Noun, possessive pronoun and demonstrative pronoun – omuntu wanye ogu (this person of mine).
vi) Noun, possessive pronoun, demonstrative pronoun, and adjective – omuntu wanye ogu omurungi. (this good person of mine)

Note: The order of the above constructions can also change, for example in (i) above, as ogu muntu or owangye omuntu. The change is usually caused by context especially when pragmatics sets in. In this study, we treat the basic order as demonstrated above.

**Design of the learning system**

Our aim in designing the learning system was that it should help the learner (a) to identify spelling errors, (b) to assist in getting the correct word order in phrases, and (c) to control that the concordance in phrases is correct. These three items should function globally, so that any words of a given word class could be used in training.
On top of the non-guided learning, we have also implemented a series of so-called guided tours, where in each learning phase the learner is guided how to continue. These tours were implemented for learning the concord patterns of each noun class. Below, we present a design model that was implemented:

**Fig. 1: Architecture of Runyakitara ICALL system**

![Architecture of Runyakitara ICALL system](image)

**Morphological Analyzer**

The basic tool in the learning system is a morphological analyzer of Runyakitara. The analyzer for Runyakitara was developed using the Finite State Automata in implementation [Hanneforth 2009]. It was tested at various levels of development and presently it analyzes newspaper corpus at 78% recall and 72% precision. Some results of the Runyakitara morphological system can be found in Katushemererwe & Hanneforth [2010]. Normally, the morphological analyzers are designed to include all linguistically significant information about the word. In various applications, however, only part of this information is needed. In our case, we removed all such tags that are not needed either for programming the learning system or as useful information for the learner. In addition to removing certain tags, we also abbreviated some long tags to make the output shorter. All this was done using a reformatting tool. The reformatted output of a Runyakitara morphological analyzer is illustrated below:

<table>
<thead>
<tr>
<th>Word</th>
<th>Analyzed Tag</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>amaisho</td>
<td>ama[N-5/6P]isho</td>
<td>[eyes]</td>
</tr>
<tr>
<td>amakye</td>
<td>ama[ADJ-6]kye</td>
<td>[small/few]</td>
</tr>
<tr>
<td>rireeba</td>
<td>ri[V-5][VERB-PREF]reeba[IND][it sees]</td>
<td></td>
</tr>
</tbody>
</table>
All word categories have been described in the morphological analyzer. However, for purposes of the learning system, the following were considered:

- Nouns – classes 1-18
- Possessive pronouns
- Demonstrative pronouns
- Adjectives
- Verbs

There are at least two ways of making use of the morphological analyzer in the learning system. In one method, the analyzer is an integral part of the learning system, so that each time the learner enters a text string, the system performs a morphological analysis of that string. In another method, that we have applied here, a list of analyzed word-forms, described in the analyzer, is extracted and used as a basis for constructing the learning system. The first type of system is more encompassing but at the same time prone to function errors. In the latter approach, for practical reasons it is necessary to restrict the number of verb forms, which are easily counted in millions.

For a learning system, however, even a modest amount of verb forms is sufficient, provided that most commonly occurring verb forms, together with their analyses, are listed. We compiled such a list by extracting all verb forms from a newspaper corpus, analyzed them, and included them to the list of analyzed word-forms.

In order to make use of this morphologically analyzed word list in the interactive learning system, we constructed a pattern matching system that enriches the keyed-in string with analysis tags. When the learner enters words from the keyboard, they are plain words without analysis. These words are matched with similar words in the morphologically analyzed lexicon. For example, omuntu is matched with omuntu : omu[N_1/2]ntu {person}.

**Dealing with ambiguity**

There are several types of ambiguity in the analysis. The most important types, to be solved in the learning system, are the noun class ambiguity and the part-of-speech ambiguity. Examples of noun class ambiguity are in [1].

[1]
yangye : ya[POSS_PRON_4]ngye [mine]
yangye : ya[POSS_PRON_9]ngye [mine]

egi : egi[DEM_PRON_4] [this]
egi : egi[DEM_PRON_9] [this]

nungi : mi[ADJ_4]rungi [good]
nungi : n[ADJ_9]rungi [good]

These are forms of the classes 4 and 9. Therefore, they can be combined with nouns of the classes 4 and 9, as in (2).
When such ambiguous word-forms are entered into the learning system, we get both interpretations, as in (3).

Note that ambiguous readings of each word-form belong to the same part-of-speech category. There are two ways of dealing with the problem. Either we disambiguate the output and select the correct interpretation [or alternatively remove the wrong one], or we under-specify the interpretation of class-ambiguous readings. In our system we have chosen the latter alternative. When using under-specified marking, we get the result as in (4).

Note that yangye has been described as POSS_PRON_4/9 and not POSS_PRON_9. This kind of output makes it possible to write concord rules without choosing or deleting any output.

Another type of ambiguity lies in the realm of part-of-speech. In this, the word-form belongs to two or more word classes. Examples are in (5).

To handle these ambiguities we have chosen to use disambiguation rules instead of under-specification. Because the learning system is restricted to noun phrases, it is possible to use the correct word order as a criterion for disambiguation rules. Examples of such rule types include:

Remove the noun reading if a non-ambiguous noun is on the left.
Remove the verb reading, if it is not the last member of the phrase.
Remove the noun reading, if it is not the first member of the phrase, with the exception of the demonstrative pronoun that can be before the noun.

Remove POSS_PRON reading, if followed by a non-ambiguous POSS_PRON.

**Controlling spelling**

The control of spelling errors was implemented so that if the word has no output, it is considered wrongly spelled. Also such correct words that are not in the system are considered spelling errors. Examples of misspelled words are in [6].

[6]

ontu??
ente en[N_9/10SP]te zaany??
omuntu ogu omu[N_1/2S]ntu wange?? ogu[DEM_PRON_1/3] N+DEM_WO

**Controlling word order**

Word order in Runyakitara is quite flexible, and it is challenging to construct a covering system of word order rules. There is a set of core rules that cannot be violated. In addition, there are several cases, where word order depends on stress and other prosodic features. All different types of word order can be implemented in the learning system, and it is the question of learning priorities which types of word orders should be learned first and what types in later stages of learning.

We implemented the basic word order that should be followed in normal language use. For example, a modifier of the noun, such as adjective, possessive pronoun, demonstrative pronoun and numeral, comes after the noun in the noun phrase. If more than one modifier is attached to the noun, these modifiers follow a certain order as shown in (7).

[7]

Noun+Poss-Pron+Dem-Pron+Adj+Verb

An alternative order is in (8):

[8]

Noun+Poss-Pron+Adj+Dem-Pron+Verb

The place of the demonstrative pronoun can also be before the noun. The location of other constituents cannot be changed in normal language use.
The rules for controlling word order were implemented in two phases. In the first phase, only the correctness of the word order is checked. If the word order is correct, the rule gives an output of the word order, as in (9).

[9]

$ echo amaisho gangye aga amakye gareeba. | rlearn

If the word order is wrong, the output is as in (10).

[10]

$ echo amaisho aga gangye. | rlearn

Note that the module for controlling word order produces the word order tag, as shown in examples [8] and [9] above. If the word order is correct, the tag ends in _WO. If the word order is wrong, the tag ends in _WO [10]. On the basis of these word order tags it is then possible to give appropriate feedback to the learner. This is the second phase in controlling word order. Examples are in (11).

[11]

$ echo amaisho gangye aga amakye gareeba. | rlearn
Word order is correct!

$ echo amaisho aga gangye. | rlearn
Demonstrative pronoun cannot be before a possessive pronoun!

Controlling concordance [Concord Module]

In a noun class language such as Runyakitara, learning the correct concordance patterns for all noun classes requires a lot of training. With the help of grammar books, it is possible, but troublesome, to find out what the pattern should be in each case. Runyakitara, unfortunately, does not have grammar books specifically for training the concordance patterns. A learning program that identifies errors and gives appropriate feedback is useful.

We implemented the system for controlling concordance patterns in two phases. In the first phase, the concord of each constituent is checked, and if all constituents have
the correct concord tag, the system outputs a corresponding summary tag. For example, if the structure has five constituents and each constituent has the correct concord, the output is CONC5. This is demonstrated in (12).

[12]

$ echo omuntu wangye ogu murungi ashoma. | rlearn
Word order and concordance are correct!

omuntu wanye ogu murungi ashoma omu[N_1/2S]ntu wa[POSS_PRON_1/3]angye
ogu[DEM_PRON_1/3] mu[ADJ_1/3]rungi a[V_1][VERB_PREF_PR]shoma[IND]
N+POSS+DEM+A+V_WO CONC5

On the other hand, if the concordance is wrong, the learner is warned about it. Reporting on the mistakes can be implemented in various ways. One method is to give the same warning message for all types of mistakes. An example is in (13). If no concordance tag is produced, the concordance is wrong.

[13]

$ echo omuntu zangye ogu murungi ashoma. | rlearn
Word order is correct but concordance is not!

omuntu zagye ogu murungi ashoma omu[N_1/2S]ntu zi[POSS_PRON_4/9]angye
ogu[DEM_PRON_1/3] mu[ADJ_1/3]rungi a[V_1][VERB_PREF_PR]shoma[IND]
N+POSS+DEM+A+V_WO

In addition to this simple warning system, we also implemented a system that gives more detailed information and shows the words where mistakes lie. First, for each word with wrong concord, a tag indicating wrong concord pattern is produced. Consider examples in (14).

[14]

$ echo omuntu bangye. | rlearn
omuntu bangye omu[N_1/2S]ntu ba[POSS_PRON_2]angye N+POSS_WO CONC_iPOSS

$ echo omuntu bangye aba. | rlearn
omuntu bangye aba omu[N_1/2S]ntu ba[POSS_PRON_2]angye aba[DEM_PRON_2]
N+POSS+DEM_WO CONC_iPOSS CONC_iDEM

$ echo omuntu bangye aba murungi bashoma. | rlearn
omuntu bangye aba murungi bashoma omu[N_1/2S]ntu ba[POSS_PRON_2]angye
aba[DEM_PRON_2] mu[ADJ_1/3]rungi ba[V_2][VERB_PREF_PR]shoma[IND]
N+POSS+DEM+A+V_WO CONC_iPOSS CONC_iDEM CONC_iVERB

We see that for each word that does not agree with the noun, a tag indicating a mistake is produced.
On the basis of these tags and their combinations it is then possible to give appropriate feedback to the learner. The examples in (14) are reproduced in (15) with appropriate warning messages.

[15]

$ echo omuntu bangye. | rlearn
Concordance of possessive pronoun is not correct!
omuntu bangye omu[N_1/2S]ntu ba[POSS_PRON_2]angye N+POSS_WO CONC_!POSS

$ echo omuntu bangye aba. | rlearn
Concordance of possessive pronoun and demonstrative pronoun is not correct!
omuntu bangye aba omu[N_1/2S]ntu ba[POSS_PRON_2]angye aba[DEM_PRON_2]N+POSS+DEM_WO CONC_!POSS CONC_!DEM

$ echo omuntu bangye aba murungi bashoma. | rlearn
Concordance of possessive pronoun, demonstrative pronoun and verb is not correct!

Learning applications
The learning system based on morphological analysis makes it possible to develop several kinds of learning applications. The tags found in the result of the analysis range from the low level tags (e.g. word lemma) to high level tags (e.g. part-of-speech). These tags enable the developer to construct a whole range of learning applications. To simplify matters in this paper, we describe only two types of applications, free interactive dialogues and guided tours.

Interactive dialogues
The system makes it possible to use the whole lexicon of the language in training. Any words of the relevant part-of-speech categories in the language can be used in training, provided that the words are listed in the lexicon. The system controls three kinds of mistakes as described above, that is, spelling errors, word order errors, and concordance errors. An error in any of these categories prompts a relevant feedback message. In case of word order errors, detailed guidance is given, showing the place where the mistake lies. In case of concordance errors, detailed feedback is more difficult, mostly because of the ambiguities in analysis results. If the noun reading is non-ambiguous, or it can be disambiguated, the decision is easier, because the noun decides the noun class for the agreement pattern. In the current learning system the ambiguity of nouns can normally be resolved. Therefore, detailed feedback can be given also for concordance errors.
Guided tours
Although the learning system with almost unlimited vocabulary may seem fascinating, the learner also needs some guidance, so that all relevant topics will be covered. Such tutoring can be arranged on various levels. The most elementary level is to guide the student to construct noun phrases for each noun class. The guidance can be detailed, so that after each successful step the student is asked to add a given word. Such guided learning exercises can be expanded so that instead of specific words, the student is asked to use a word from a given selection. By using various vocabulary groups the student will learn the vocabulary, and at the same time get practice and guidance in constructing noun phrases. The overall learning process is demonstrated below:

Learning procedure

Fig. 2: The learning procedure of Runyakitara ICALL

The learning sequence on the system follows: the learner first inputs a word from among words s/he knows as nouns, pronouns, adjectives and verbs. The learner then receives feedback indicating whether a word is correct or wrong. The learner then is supposed to decide whether to learn using guided tours or to learn using grammatical dialogues. In either case, the learner is provided with feedback on the correctness of the concord patterns, word order and spelling.

Learning with interactive grammatical dialogues
1. When the learner inputs a word, the system checks for the word, and once the word is correct, the following is reported:
   $ echo omukazi. | rlearn
   This is a correct word in Runyakitara.
   What do you like to learn?
   If you want guided simple practising of various noun classes, type one of the following:
   omuntu, abantu, omuti, emiti, eihamba, amaisho, ekimuri, ebimuri, ente, orutaro, entaro, akabaaho, obubaaho, oturo, oburo, okuguro.
   Each of these is an example of a certain noun class.
   If you want to use your own vocabulary, please go ahead.
   In that case you will be reported on the correctness of three things, that is, spelling, word order, and concordance.
2. **Noun and adjective**: If the learner chooses the interactive dialogue, s/he is supposed to start inputting phrases of his/her choice. The following is feedback for concord and word order when one inputs a noun and an adjective:

```
$ echo omukazi murungi. | rlearn
Word order and concordance are correct!
```

```
omukazi murungi omu[N_1/2S]kazi mu[ADJ_1/3]rungi N+ADJ_WO CONC2
```

**Note** that the text below the feedback contains phrases with their tags. **Noun and possessive pronoun**: For the noun and possessive pronoun when correct, the same feedback is reported

```
$ echo omukazi wangye. | rlearn
Word order and concordance are correct!
```

```
omukazi wangye omu[N_1/2S]kazi wa[POSS_PRON_1/3]angye N+POSS_WO CONC2
```

3. **Noun and demonstrative pronoun**:

```
$ echo omukazi ogu. | rlearn
Word order and concordance are correct!
```

```
omukazi ogu omu[N_1/2S]kazi ogu[DEM_PRON_1/3] N+DEM_WO CONC2
```

4. **Noun, possessive pronoun and demonstrative pronoun**:

```
$ echo omukazi wangye ogu. | rlearn
Word order and concordance are correct!
```

```
omukazi wangye ogu omu[N_1/2S]kazi wa[POSS_PRON_1/3]angye ogu[DEM_PRON_1/3] N+POSS+DEM_WO CONC3
```

5. **Noun, possessive pronoun, demonstrative pronoun and adjective**:

```
$ echo omukazi wangye ogu murungi. | rlearn
Word order and concordance are correct!
```

```
```

6. **A wrong verb shoma instead of ashomma is included**:

```
$ echo omukazi wangye ogu murungi shoma. | rlearn
Please check spelling!
```

```
```

7. **Wrong input**:

```
$ echo wangye omukazi ogu murungi ashomma. | rlearn
Possessive pronoun cannot be before a noun except in certain contexts!
```

```
```
The above input calls for the appropriate grammatical feedback which the learner is supposed to learn from so that s/he understands that under normal circumstances, a possessive pronoun does not precede a noun.

The grammatical dialogue exercises are on a one to one basis where the learner interacts with the system and learns from the feedback.

Learning with guided tours
The learner is supposed to input a word which the system has instructed him/her to input, then follows the guidance that is given to him on the screen. The following is an example of a learner in a guided tour:

a. $ echo omuti. | rlearn
   OK. Add to this the possessive pronoun ‘angye’! Please add a full pronoun.
   omuti omu[N_3/4S]ti N_INIT_EXE_3_4

b. $ echo omuti gwangye. | rlearn
   OK. Add to this string a demonstrative pronoun ‘ogu’!

c. $ echo omuti gwangye ogu. | rlearn
   OK. Add to this the adjective ‘hango’!

d. $ echo omuti gwangye ogu muhanga. | rlearn
   Please check spelling!

e. $ echo omuti gwangye ogu muhango. | rlearn
   OK. Add to this the verb ‘kura’!

f. $ echo omuti gwangye ogu muhango gukura. | rlearn
   OK. This is a full sentence with a long noun phrase. Now do the same exercise using plural forms. Continue by typing ‘emiti’!

In learning guidance (d) the learner made a typing error on the word and typed muhanga instead of muhango. The system prompted the learner to check the spelling by putting
two question marks on the incorrect word. This alerts the learner to check the word and correct the spelling as it is a case in (e).

Conclusion
We have shown that the morphological analyzer can provide vast learning input for the language learning system, and is an important tool for morpho-syntactic learning in Bantu languages.

We have devised learning applications to train difficult-to-learn structures of Bantu languages commonly known as the concord patterns.

We have provided an alternative to exercise based learning where the vocabulary is limited on how the developer put it in the system. Here, the learner can choose freely on his/her vocabulary to use while learning.

We have also provided an alternative to classroom learning where learners can strengthen their knowledge through an interactive digital learning environment.

Guided tours also provide an alternative to learning systems which are usually implemented in exercise based systems. The method used in developing guided tours is clear enough that many guided tours can be developed for many purposes.

Future work
We intend to develop a user friendly learning environment so that learners are fully motivated by usability factors.

Technically, future work can be directed to cover the concord patterns of any subject and object constructions as well as relative constructions. In the current system, that is not catered for.

References

DICKINSON, M., & HERRING J., 2008. Developing online ICALL exercises for Russian. Proceedings of the third workshop on innovative use of Natural Language Processing for building educational applications. Columbus, Ohio, pp. 1-9


Part 5: Intelligent Language Learning Model: Implementation on Runyakitara


## Appendix A

Runyakitara noun classes and their respective concord markers

### Table showing concords in Runyakitara

<table>
<thead>
<tr>
<th>Class</th>
<th>Noun prefix</th>
<th>Pronominal prefix</th>
<th>Verbal prefix</th>
<th>Adjective prefix</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Possessive prefix</td>
<td>Demonstrative prefix</td>
<td>1st person</td>
</tr>
<tr>
<td>1</td>
<td>mu</td>
<td>wa</td>
<td>ogu</td>
<td>n</td>
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<td>ba</td>
<td>ba</td>
<td>aba</td>
<td>tu</td>
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<td>3</td>
<td>mu</td>
<td>gu</td>
<td>ogu</td>
<td>gu</td>
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<td>ya</td>
<td>egi</td>
<td>e</td>
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<td>eri</td>
<td>ri</td>
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<td>egi</td>
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</tbody>
</table>
An E-Voting Framework For Improving Democracy in Uganda

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Abstract
There are no public administration tasks more central to guarding democracy than providing for elections that accurately reflect voters’ intentions and ensure public confidence. Elections are viewed as one of the most important indicators of democracy in a consensus-based country and electronic voting can be one of the drivers of this democracy. The current Ugandan voting framework still leaves a gap for promoting distrust of the results due to inadequate security controls existing in voting procedures. This paper proposes an e-voting framework that can be used to replace the existing framework for free and fair elections in Uganda. This framework is based on the basic requirements of a secure e-voting framework, theoretical analysis of the existing voting frameworks and experts’ opinions. The framework can be a stimulant for further development and research especially those interested in the subject.

Key Words: (Democratic elections, E-Democracy, E-voting, Trust, Voting Framework)

Introduction
E-democracy is the use of modern electronic communications and information technology as instruments to empower people to set agendas, establish priorities, make important policies, participate in their implementation and most importantly, to give the public leverage in self-governance through e-participation and e-voting fields, [Keith P., 2004]. E-voting is a term which refers to various voting processes where computers
or digital devices are used to count and cast votes. It can also involve transmission of ballots and votes via public networks. Therefore, an electronic voting framework is a voting framework in which the election data is recorded, stored and processed primarily as digital information.

This paper is divided into four sections: Section 1 is the introduction; Section 2 gives a more detailed background on e-voting, section 3 consists of a review of some of the existing e-voting frameworks, and section 4 gives the findings and a structure of the proposed e-voting framework.

**Background**

E-voting has been adopted by many private organizations such as corporations and banking institutions to conduct their elections, and is increasingly used in the public sectors. E-voting was used in USA in March (2000) when the Arizona Democratic Party held its primary elections as reported by Katharine, [2008] and Ian Urbina, [2007]. In France e-voting has been in use since [2003], Sébastien Lévy, [2010], and in other countries like Estonia in [2006]. According to Breuer, and Trechsel, [2006] Estonia is believed to have held the world’s 1st ever successful e-voting election in (2006). In India it was introduced in 1982 and was used on an experimental basis in the North Parur assembly constituency in the State of Kerala, Aditya, (2004). Following legal approval in 1989 e-voting has been used in many state elections. Japan adopted e-voting for local elections in (2002), such as mayor and councillor election of Niimi city in Okayama region in June 23, 2002; mayor election of Hiroshima city in February (2003); and mayor election of Kyoto city in February (2004). In Belgium elections for the Federal Parliament was held in May 18, 2003. In Brazil E-voting was used in 1998 among others.

These countries have yielded a lot of benefits out of e-voting like increasing voter turnout, decrease of invalid votes, lower election and fraud.

**E-voting frameworks**

In terms of elections, there are various voting frameworks used by different countries ranging from paper-based to electronic. Each of them has its own advantages and disadvantages and some might be considered fairer than others. These include Internet Voting framework, public voting framework, standalone voting framework and mixed voting framework.

**Internet Voting Framework**

In this e-voting framework, voters are allowed to use a more genetic technology such as the Internet, to register or cast their votes from any preferred place be it from the home, from the office or even from an Internet cafe while traveling abroad Mugisha, (2008).

Identification and authentication: On the voting day, a registered voter activates the voting client interface to the web server which requests for identification. The voter identifies himself/herself with a personal Login ID and password, the system authenticates his/her identity basing on the password and login ID. On confirmation,
the voter is required to request for a Certificate to allow him download an electronic voter form, which he fills in and casts his ballot which is encrypted using his private key. He is then required to submit his digital signature to increase the security of the ballot data. The digital signature is provided by the Electoral Body’s Certificate Server which is VERIFIED by the Certificate Authority (CA). The Digital Signature is used to authenticate the identity of the Voter (the signer and sender of the vote), and possibly to ensure that the original contents of the vote have not been changed while on transmission to the Database Server. The results are then computed electronically and reports made about the outcome of the voting process.

**Standalone Voting Framework**

This particular voting is popular in India and is been adopted by other developing and developed countries. It was first introduced in 1982 during an experiment in the North Parur assembly constituency in the State of Kerala, in 2004, Aditya, [2004]. In this framework, voting machines called EVMs are used. These machines are not connected to any network and do not share resources with any other computers, which is an advantage as it can make the whole voting process more secure compared to other voting frameworks.

Slightly bigger than a laptop, the EVM comes in a reusable carry pack, and can operate on a battery power source in remote areas. It comprises two units which are the Control Unit that is used by the polling staff and the balloting unit for use by the voters. Figure 1 shows an example of the EVM. It can be observed that the two units are joined by a five-meter cable with the Control Unit supposed to be managed by a Presiding Officer or a Polling Officer and the Balloting Unit are placed inside the voting compartment. The balloting unit requires voters to press the button next to the candidate’s name and symbol and the control unit records the vote.

**Figure 1: The EVM machine**
Instead of issuing a ballot paper, the Polling Officer in-charge of the Control Unit presses the Ballot Button. This enables the voter to cast his vote by pressing the blue button on the Balloting Unit against the candidate and symbol of his choice. The machine presents a ballot, listing the names of candidates horizontally. Each party’s candidates are listed on its own line. Internal counters are connected with each lever through straps in the back of the machine. As each vote is cast, the counter records one vote in the corresponding position. At the end of the voting, the counters are read and the totals are manually recorded on a tally sheet.

This framework consists of the following major processes:

**Registration process:** Preparation of the electoral forms through a process of intensive revision where house-to-house enumeration is done to collect the information about the voter. This is also an opportunity to update the records by including, deleting or modifying voter details.

**Voting process:** This is done using the following steps:

**Stage 1:** Voter presents voters’ ID to Polling Officer who is in-charge of the marked copy of the electoral roll for authentication. He then proceeds to the second polling officer for finger marking, serial number recording and signing in the appropriate column in the voter Register. He is then presented with a signed voter’s slip.

**Stage 2:** Voter proceeds to the third polling officer, who presses the “Ballot” button on the control unit of voting machine and directs him to the voting compartment where he records his vote on the balloting unit of the voting machine.

**Stage 3:** Inside the voting compartment, the voter presses the blue candidate button on the Balloting Unit against the name and symbol of the candidate of his choice. The red lamp glows against the name and symbol of that candidate, then a beeping sound heard to indicate that the vote has been recorded and the busy lamp goes off in the Control Unit.

**Stage 4:** Then the polling officer presses the result button in the presence of all voters to reveal the results. These results are recorded manually in the presence of all the parties’ agents and sealed for the electoral commission.

**Voting in Uganda**
Since Independence up to date, Uganda has been using the traditional voting framework. There is no technology used in this type of voting and all election processes are conducted manually. The voter picks the ballot paper from the presiding officer and proceeds to mark it in secrecy at the marking table. He uses a tick or a thumb print against the symbol or the picture of the candidate of his choice and folds it. He then proceeds to the voting box and inserts the ballot paper through the slot at the top of the box. After this the voter goes to the presiding officer responsible for marking the voter’s thumb with indelible ink to show that he has already voted. The voter then leaves the
polling station and waits for the counting of the votes which is also done manually. An illustration of this process is shown in Figure 2.

Figure 2: Traditional Voting in Uganda

Step 1: Paper marking

Step 2: Paper Folding

Step 3: Paper Casting

However, this voting framework has failed to address problems associated with the threats and failure to deliver election services to voters’ satisfaction. It is associated with security problems like fraud, inconsistencies, ballot box stuffing, bribery, voter intimidation among others. The ballot papers are expensive in terms of printing and distribution and they are only used once. Also, one has to be physically present in order to vote.

The Electoral Commission in Uganda announced a new voter registration system ahead of the presidential and Parliamentary elections scheduled for 2011 by the German firm called Muelhbauer High Tech International [Bailur, 2009]. This system was supposed to have a biometric system to do away with the problems found in the ballot-paper framework, i.e. multiple registrations and voting by easily detect duplicates. The system was supposed to capture all fingerprints on both hands and store them in the voters’ databank. However, this system was not delivered due to logistical /political constraints and what was delivered so far still had some problems associated with voter registers that have to be addressed. These are:

1. Names missing from the voters list. This includes those whose names were previously on the voter register but were missing on the voting day.
2. Names appearing multiple times in a single list or in multiple lists.
3. “Ghost” names, that is, names of un-known people appearing on the list.
4. Mismatch between voter lists and electronic Photo ID Cards.
5. Poor management of specific urban issues like shifting of residences, migration, and environmental factors like rain which delayed some voters from registering because they had to be physically present in order to vote.
Findings
This work has identified the loopholes in the e-voting system of Uganda and proposes to improve on the current situation by proposing an e-voting framework that can be applied to a country like Uganda. First, a comparison of the existing voting frameworks was carried out in order to determine the shortfalls of each of the frameworks that are in place. Key e-voting requirements were identified and three of the available frameworks were analysed in respect to compliance of these requirements. The results of this comparison are provided in Table 3 which shows a tick for positive compliance and a dot for the reverse. It can be seen that none of the frameworks satisfies all the key requirements for an e-voting application. Specific weaknesses include:

- Some frameworks do not offer guaranteed voter secrecy to protect the voter from intimidation and also to prevent the selling of votes. Others are not auditable (especially the ballot-paper),
- Some voting frameworks are not secure enough and hence do not protect their votes with good standard practices such as digital signatures, checksums, or strong encryption systems as the ballot data flows through the system.
- Ballot-paper based and manual voting system has no governed procedures to protect the integrity of the vote and it is too costly in terms of time, manpower, ballot-paper printing, and the government has to bear the financial expenses for these purposes.
- Again the authority itself may be corrupted and can allow some fake voters to participate for example in standalone voting system whereby the polling agent activates the machine for the voter, there is a possibility of that same agent to reactivate it again for the same voter.
- With the manual voting system, if any voter stays abroad or misses the registration processes somehow due to prior obligations or unavoidable circumstances, he or she wouldn't be considered as a voter unless or until she/he informs the authority and in this case most of the time people don’t show any interest in this process.
- Voters cannot verify whether their vote was included in the final tally.

Table: 4.1: Existing Frameworks’ Analysis against the Requirements on Ugandan basis

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Traditional voting (Ballot paper)</th>
<th>Internet Voting</th>
<th>Standalone Voting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authentication</td>
<td>•</td>
<td>✅</td>
<td>✅</td>
</tr>
<tr>
<td>Adaptability</td>
<td>✅</td>
<td>•</td>
<td>✅</td>
</tr>
<tr>
<td>Vote secrecy</td>
<td>•</td>
<td>✅</td>
<td>✅</td>
</tr>
</tbody>
</table>
Part 6: An E-Voting Framework For Improving Democracy in Uganda

<table>
<thead>
<tr>
<th>Availability</th>
<th>✔️</th>
<th>✔️</th>
<th>✔️</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost effectiveness</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Auditability</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Uniqueness</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Convenience</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Security of the vote</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Assurance that vote has been counted</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
</tbody>
</table>

Proposed E-voting Framework

After reviewing the problems with the current paper based voting system in Uganda and those related to the existing e-voting frameworks, the following voting framework is suggested. The proposed framework is web-based with unique features to provide the required solutions to the identified problems. Data flow chart is used to design the framework and it is composed of all the election processes. These processes are; Registration, voting and vote tallying as shown in the figure below.

Figure 3: Data Flow Chart depicting the registration process and other functionalities of the proposed Framework
**Registration Process**

The proposed framework suggests new voters’ registration procedures based on ICTs. This is aimed at improving the (PVRIS) for Uganda. This framework begins the voters’ registration process with registering all the citizens from birth and the profile kept in the population database. This database contains three types of databases.

**Population Database** for all the citizens. The population database should have two segments; the primary segment containing voters below the age of 18 and the secondary segment containing voters above 18 year.

**Voters’ database /archive for citizen of voting age.** The database system should be automated in such a way that, citizens are automatically migrated from the primary database to secondary database when they become 18 years. The EC after every one year takes the photographs and finger prints of the upgraded voters and provides them with voter's IDs. This goes down to LC level, supervised by the electoral officials. The electoral Commission consults this voters’ archive to get information about the candidates who intend to stand for different posts.

**Database for deceased citizens:** The system should automatically send the names of the deceased to this database/archive. The information is captured from Hospitals and Local Councils. These take responsibility of collecting births and deaths information about all citizens in their respective hospitals and villages.

**Voting Processes**

Voters’ bio-data including his photograph and finger prints are collected and kept in the voters’ archive. All voters should be issued with automated VoterIDs with a security number to be inserted in the system on the voting day. This number reveals voter’s bio-data on insertion in the system. This process has four system users, i.e. the electoral agent, voter, candidates, and the EC Administrator. These are already registered voters and their files appear in the voters’ archive. The agents login the system to assist voters who cannot use the system and the voter login to vote. Whoever logs in is authenticated by the system. The system displays the list of voters for the voter to click on the candidate of the choice. The system then prompts the voter to submit the ballot paper and in doing so, the choices of the voter are taken and recorded in the results database. The voting process is ended by the system congratulating the voter and taking him back to the starting page.

**Results tallying process**

The proposed framework automatically counts and tallies the election results and summarizes all the election information and keeps it in the election log for auditing. The number of voters per constituency plus the number of votes each candidate gets per constituency is recorded. The system indicates the number of voters each candidate has obtained from both genders in numbers and percentages, and the name of the winner so far. The results screen changes whenever another candidate gets exceeding votes.
The results may be taken as the final result but the electoral commission governing body has the mandate to announce the official results.

The data flow diagram below shows the authentication, voting and results tallying up to declaration of the winner in the proposed e-voting Framework.

**Figure 4:** Data Flow diagram depicting users’ interaction with the system during Voting Process

Advantages of the proposed e-voting framework over the existing Framework

- **Improved security:** The proposed framework has considerable security plans compared to ballot-paper framework especially the aspect of authentication for a user. The voter has to be registered at birth and is automatically upgraded to voters’ register by the system. This prevents impersonation.
- **Flexibility**: The framework is flexible in such a way that, the voter may vote from anywhere as much as he/she has a valid voterID number. It eliminates the possibility of invalid and doubtful votes which dominates ballot-paper voting.

- **Robustness**: The designed framework cannot easily be manipulated in favour of a particular candidate compared to ballot-paper voting in that, the system records the bio-data of every user who accesses it and the activity he/she has performed on it.

- **Cost effectiveness**: The framework cuts costs in terms of transportation, ballot-paper printing and manpower since it is an internet-based. However, the framework has to be protected from known computer insecurities like viruses, worms, human and technical attacks.

The framework is also adaptable, unique and results are easily availed to the various stakeholders from the voters to the election officials. Results can even be followed on the Internet since the system automatically increments the tally as soon as a vote is cast.

**Conclusion**

It has been demonstrated that there has been a lack of an e-voting framework that can satisfy the key requirements of an e-voting system. This work has proposed an e-voting framework that is capable of fulfilling all the key e-voting requirements as outlined in this paper. The framework consists of four major processes that together result in a more robust e-voting process. When applied in real life, this e-voting framework is capable of reducing on the election malpractices and work towards attainment of a free and fair elections in Uganda. It can improve democracy, voter turn-up while minimizing the overall expenditure on manpower and related logistics. It further increases voter confidence in the entire electoral process as the voter can verify that his/her vote has been used in the final outcome. The designed system uses existing technologies which are now available in Uganda to conduct free and fair elections. An e-voting system is feasible and can be used in Uganda to yield credible election results leading to a free and fair election.

**References**


Part Six

Software Engineering
Component-based Development of Software Language Engineering Tools

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Abstract
In this paper we outline how Software Language Engineering (SLE) could benefit from Component-based Software Development (CBSD) techniques and present an architecture aimed at developing a coherent set of lightweight SLE components, fitting into a general-purpose component framework. In order to give an impression on our development style, in this paper we demonstrate how to compose a syntax highlighter from a set of available SLE components using the NetBeans environment. Developing SLE tools as lightweight components that fit into general-purpose frameworks has advantages over the usual trend in which SLE tool development is towards large special-purpose frameworks. It facilitates incorporation of language processing tasks into all kinds of applications and makes SLE techniques available to occasional or first-time users with little effort.

Categories and Subject Descriptors D.2.11 [Software Engineering]: Software Architectures—Data abstraction; D.2.3 [Software Engineering]: Reusable Software; D.2.6 [Software Engineering]: Programming Environments—Graphical environments; D.3.2 [Programming Languages]: Language Classifications—Specialized application languages; D.3.4 [Programming Languages]: Processors—Translator writing systems and compiler generators
Introduction and Motivation

Software Language Engineering (SLE) is a recently coined name [SLE] for an old and well-established field, viz. that of methods and tools for manipulation of artificial languages in software engineering. The field has an extensive body of solid theory on subjects like grammars and automata [Hopcroft et al. 2006], a wealth of algorithms, a large collection of tools, and a broad range of applications. Tools range from the classic Lex [Lesk and Schmidt 1975] and Yacc [Johnson 1975] and their follow-ups to sophisticated meta-environments aimed at generation of entire compiler front-ends or Integrated Development Environments (IDEs) such as Stratego/XT, Eclipse IMP, ELI, The Meta-Environment and ANTLR [Stratego; Eclipse; Eli; Meta-Env; ANTLR].

Component-Based Software Development (CBSD) is a major approach for software development. CBSD aims to build software systems by combining and configuring existing software components. Such an approach helps to build systems more rapidly and reduces software development costs by composing a system from existing components instead of building it from scratch. It also enables software reuse since components can be reused in developing many systems. CBSD is based on the assumption that certain parts of software systems reappear in many applications and that software should be assembled through reuse rather than rewriting. Each software component is dedicated to a particular task (i.e. can work as an independent unit) and has (a) well defined interface(s), appropriate documentation and a defined reuse status. Software components fit into a so-called component framework, an architecture which provides facilities for customization of and cooperation between components [Szyperski 2002]. Some well-known component frameworks are NetBeans [NetBeans], Eclipse [Eclipse], Microsoft .NET framework [Microsoft] and Delphi with its Visual Component Library (VCL) [Delphi].

In principle, the SLE field lends itself well to application of component-based methods because:

- It consists of well-defined tasks such as scanning, parsing, tree building, syntax highlighting and others [Aho et al. 2006]. We can define the tasks as components (with simple interfaces), and embed them into a general-purpose component framework to be combined in different ways while building applications for different purposes.

- Each task has good theory and a variety of well-studied algorithms for implementing it [Aho et al. 2006; Aho and Ullman 1972; Grune and Jacobs 1990; Wilhelm and Maurer 1995]. We can define the existing algorithms as components so that users have a variety of components per task at their disposal.
Historically speaking, much work on SLE theory and tooling has preceded work on CBSD, and therefore existing SLE tools have not utilized the full benefits [Szyperski 2002] of CBSD. Many SLE tools are incorporated in special-purpose systems [Stratego; Meta-Env; ANTLR]. Although these systems are very effective in the hands of experts, they can be rather complex and inaccessible to non-experts or occasional users that have modest knowledge of SLE technology.

We are investigating how development of SLE tools can benefit from consciously exploiting CBSD techniques. Rather than designing a large special-purpose framework, our main goal is to develop a coherent set of small SLE components and generators, where each component is dedicated to a single well-defined SLE task. The components should fit into a general-purpose component framework like NetBeans, and it should be possible to manipulate them inside an IDE like NetBeans or Eclipse, just like any other component.

We do so for the following reasons:

- **Lightweight** - Many kinds of applications do some language processing as a necessary but subordinate task. For instance, an interactive theorem prover does some scanning, parsing, tree building and formatting of logical formulae, but its core business is proof construction. In such cases, using a large special-purpose SLE framework for the SLE tasks is overkill and distracts from the main tasks. Using some lightweight SLE components seems a better solution.

- **Ease of use** - Many software developers use an IDE which supports a drag-and-drop style for application development from components. This style is very effective for design of graphical user interfaces, but can also be used for handling non-visual or domain-specific components. In fact, the IDE can handle any components that comply with the supported component model in a uniform way. Thus, when a developer has a set of compliant SLE components available, he can use SLE technology without the problems of learning to use a large special-purpose SLE environment and relating it to his application.

- **Variety** - Having at one’s disposal a variety of components for a certain SLE task (e.g. several parser components with the same interface but parsing according to different strategies) makes it easier to experiment with different techniques and to pick the component most suited for the task at hand. This can be a great asset in an educational environment.

To achieve our goal, the following research problems have to be solved:

1. Design the architecture for the SLE components and their interactions.
2. Study and selection of algorithms to be implemented as SLE components.
3. Describing the algorithms in a uniform way, making use of common data structures etc.
4. Realization of the SLE components in a concrete development environment like NetBeans to demonstrate the usability of our design.

In this paper we focus on the first and fourth research questions.

The paper is organized as follows: In Section 2, we present the architecture of our SLE components. In section 3 we illustrate the use of our SLE components in the form of a step-by-step development of a syntax highlighter. In Section 4, we explain how our SLE component framework differs from the present SLE tools. In Section 5, we describe current status and future work.

SLE Components Architecture

The SLE component framework supports software development styles (i.e. drag-and-drop and wizards) commonly found in modern IDEs like NetBeans, Eclipse and Delphi. It is also geared towards the following front-end SLE tasks:

- **Lexical Scanning** - the process of partitioning an input string into consecutive substrings such that each substring represents a token according to some lexical grammar. Typically, tokens are reserved words, identifiers, numbers, punctuation characters, single and multi-character operators, comments etc. The main approaches to lexical scanning are based-on: Finite Automata [Aho et al. 2006; Thompson 1968] and ELL (1) recognition programs [Lewi et al. 1979; Wirth 1976].

- **Parsing** - the process of analyzing an input string in order to determine its grammatical structure (syntax tree) with respect to a given context free grammar. Traditionally, there are two categories of parsing techniques: Top-down (LL) and Bottom-up (LR) parsing. Good descriptions of the techniques can be found in [Aho et al. 2006; Grune and Jacobs 1990].

- **Tree building** – process of constructing a tree (e.g. concrete syntax tree (parse tree) and/or abstract syntax trees (ASTs)) from a set of nodes. Tree building may be top-down or bottom-up.

- **Flattening** – the translation from a syntax tree to a sequence of tokens.

- **Pretty printing** – transformation of a syntax tree to a well formatted string.

Generally, the SLE framework provides a collection of components that deal with transformation of language terms from a concrete textual form to abstract syntax trees (ASTs) and the converse transformation from abstract to concrete. This includes components for:

- Representing language terms in various forms (plain text, sequence of attributed symbols, parse tree, abstract syntax tree, etc.);

- Standard transformations between these forms (lexical scanning, parsing, tree building, pretty printing and flattening)

- Viewing and editing the various term representations and other related data (scan tables, coloring schemes, etc.)
Somewhat unusual, it also contains components for representing language specifications (lexical syntax, context-free syntax, abstract syntax, etc.). Other components can observe such a language specification component and adapt their own state and behavior to it. This mechanism is known as the Observer design pattern [Gamma et al. 1995] and will be described in more detail in the rest of this section.

In the following subsections 2.1 - 2.5 we shall describe the intended use of our SLE components, their general characteristics, component interfaces, data flow management between SLE components and composition. In subsection 2.6 we discuss compatibility of the SLE component model with some existing component models.

**Intended Use**

The SLE component framework supports development of language front-ends in ways commonly found in modern IDEs like NetBeans, Eclipse and Delphi:

- It allows a drag-and-drop development style for quick and easy construction of large parts of a language front-end with little or no coding. Components are dragged from a palette and dropped on a form; their properties are set by means of property editors and/or customizers.

- It provides wizards that allow a user to rapidly generate language-specific pieces of code. The user is guided through a multi-step dialog to set his preferences, which are then used to customize some existing SLE components and/or generate some specialized source code-based SLE components.

**General Characteristics of SLE Components**

The general characteristics common to all SLE components are:

- **Properties** - All SLE components have properties through which their appearance and behavior can be customized. Properties range from standard types (such as string, integer, font) which can be edited using property editors, to SLE-specific data, such as grammars or formatting rules. We provide customized editors for editing such data at building (design) time. However, data can also be edited at run time via getter and setter methods. Properties may also be references to other SLE components.

- **Persistency** - SLE components are persistent. Their state can be customized in the IDE at design time and then saved to storage and reloaded later.

- **Composition** - SLE components may have recursive structure, following the Composite design pattern [Gamma et al. 1995]. In this way, a group of cooperating SLE components may be turned into a new SLE component.

- **Event handling** - An SLE component can be both observer and observable of other SLE components, in the sense of the Observer design pattern [Gamma et al. 1995]. SLE components may observe a state change in another SLE component and adjust their own state accordingly.

- **(Non-) visual** - There are both visual and non-visual SLE components. Typically, non-visual components hold data like text, parse tables or
parse trees, whereas visual components provide certain views and editing capabilities, such as (language specific) text editors, tables or tree views.

**Component Interfaces**

SLE Components have simple well-defined interfaces. Each SLE task has an interface to capture the essentials of that task and one or more components implementing that interface. For instance, for the parsing task, the interface would provide facilities for recognizing the main syntactic categories and for communicating with a scanner and a tree builder. For each of these interfaces, there may be several components implementing that interface according to different strategies. For instance, for scanning there could be both a Lex-like scanner based on finite automata [Aho et al. 2006; Thompson 1968] and an ELL (1)-based scanner [Lewi et al. 1979; Wirth 1976]. For parsing there could be parsers using simple and efficient strategies (such as recursive descent (LL) and Simple LR (SLR) [Wilhelm and Maurer 1995] as well as parsers employing more general methods like Generalized LR (GLR) [Scott et al. 2000]. The visual environment aids in the process of linking the different SLE components together through their interfaces.

**Data Flow between SLE Components**

Our SLE framework implements the Observer design pattern [Gamma et al. 1995] to maintain consistency and to aid the flow of information between varieties of cooperating SLE components. Typically, when the state of an SLE component changes, its observers are informed about the state change so that they can adapt to it. The amount of information may vary widely. For small changes, a “push” model is used, whereby the observable component sends observers detailed information (e.g. symbol value to “while”, color attribute for keywords changed to red) about the change, whether they want it or not. Then, the observers may adjust their own state directly. For more involved changes, a “pull” model is used in which the observable sends nothing but the most minimal notification, and observers ask for details explicitly thereafter (“pull” model).

This kind of data flow allows users (e.g. occasional and designers of small languages) to design and develop applications easily by adjusting properties of one component and all other SLE observer components are adjusted automatically. We explain one such interesting aspect: Consider a language specification (e.g. consisting of a lexical and a context-free grammar) held in a component and scanner and parser components with their own “hidden” generators which are observers of the language specification. When the language specification changes, scanners and parsers can adapt to the change immediately by calling a hidden generator implicitly.

As an example, consider the following configuration of SLE components, which together achieve syntax highlighting:

- **Language** - an observable component holding a lexical and context-free grammar;
• **Scanner** - a Lex-like table-driven scanner; it observes the Language component;
• **ColorScheme** - a mapping from the symbols of the language to font and color attributes; it observes the Language component;
• **RichTextView** - a text editor with text coloring capabilities; it uses both the Scanner and ColorScheme components and observes their changes.

When the lexical part of the Language component changes, a property change is observed by both the Scanner and the ColorScheme components. The following two scenarios take place:

- The **ColorScheme** component reacts to the observed property change of the Language component by adjusting its domain of valid symbols to that of the new language. The ColorScheme in turn sends a property change notification to its observers. In this case RichTextView observes the change and reacts by using the Scanner to scan its text and display the symbols recognized according to the new mapping in the ColorScheme.
- The **Scanner** component reacts to the change in the Language component by invoking its hidden scanner generator to regenerate its scan tables for the new language. The change in the Scanner is in turn observed by the RichTextView, which uses the adjusted scanner to highlight its text according to the new language.

In section 3.1 we return to this example and elaborate it in the concrete setting of the NetBeans IDE.

**Composition of SLE Components**

Components are meant for composition. Therefore, our SLE components have a recursive structure. In this way, a group of cooperating SLE components may be turned into a new SLE component, which may subsequently be used just like any other SLE component.

As an example, reconsider the syntax highlighting example of subsection 2.4. As this task may occur more often, a new component SyntaxHighlighter might be constructed for it, containing the Scanner, ColorScheme and RichTextView as subcomponents. The new SyntaxHighlighter as a whole may be an observer of a Language component, whereas it internalizes the collaboration between Scanner, ColorScheme and RichTextView.

In section 3.2 we return to this example and elaborate it in the concrete setting of the NetBeans IDE.

**Compatibility with Existing Component Models**

The SLE component model above has been described without reference to existing programming languages, component models, or IDEs. It can be realized in various environments. In the following subsections, we discuss two such realizations.
Java, JavaBeans and NetBeans

The JavaBeans APIs define a software component model for the Java programming language. According to the JavaBeans API specification [Java Beans 1997]:

“A JavaBean is a reusable software component that can be manipulated visually in a builder tool.”

The typical distinguishing features are:

- Support for introspection so that a builder tool can analyze how a bean works.
- Support for customization so that when using an application builder a user can customize the appearance and behavior of a bean.
- Support for events as a simple communication metaphor that can be used to connect up beans.
- Support for properties, both for customization and for programmatic use.
- Support for persistence, so that a bean can be customized in an application builder and then have its customized state saved away and reloaded later.

To create and use JavaBean components one can directly and easily make use of all these features via JavaBeans-compliant application builder tools such as Eclipse, JBuilder, NetBeans and others. In our research we focus on NetBeans and its GUI design tool. NetBeans allows users to rapidly construct applications by dragging and dropping components on a form. Users can combine components into applets, applications, or composite components. These components range from the default components from AWT and Swing libraries to user-developed components. All components are stored on the component palette. To construct an application, the user drags and drops one component at a time from the palette on to the form, edits the desired component properties and makes appropriate connections among the components. Additionally, NetBeans provides a number of wizards that assist a user to rapidly build complex pieces of code.

Considering the above features of JavaBeans and their builder tools, JavaBeans provides an attractive component model for realizing most of the requirements of our SLE components. In particular, the most interesting aspects are:

- The JavaBean’s events model [JavaBeans 1997] nicely accommodates the implementation of observer/observable behavior of our SLE components.
- Persistence of data elements is offered through automatic Java serialization mechanism [JavaBeans 1997].
- The Java interfaces give a nice implementation concept to realize the idea of interface definitions of our SLE components.

Object Pascal, VCL and Delphi

Delphi is a RAD (Rapid Application Development) environment based on the programming language Object Pascal. Among its features are: a visual Form Designer
and a large Visual Component Library (VCL). The latter is essentially an Object Pascal layer on top of the Windows Win32 API. VCL components can be picked from a palette and placed on a form, have their properties edited using the Object Inspector, or can be edited as a whole by a Component Editor. VCL components have support for event handling and for persistence.

As this summary suggests, most of the facilities required by our SLE components can be realized in Delphi using the VCL and the Form Designer. The main points of attention are:

- Delphi’s persistence mechanism - based on streaming published properties of VCL components to and from form files - is geared towards visual components and simple data types for properties. Streaming non-published properties and properties of more complex types can be done, but involves some extra work.

- The Observer/Observable mechanism is not a priori available, but can easily be realized by having suitable classes in the SLE class hierarchy, implement the IObserver and IObservable interfaces.

Concrete Example

In order to give an impression of the development style of our SLE component set and their intended usage, let us reconsider the syntax highlighting example in subsection 2.4 and illustrate how to assemble a simple syntax highlighter using the NetBeans IDE environment. When we open the NetBeans IDE (see Figure 1), we see on the component palette among others the following components that suit our purpose:

- **CLexicalGrammar** - This component holds a lexical grammar and maintains its consistency. It notifies its observers of changes in the grammar.

- **CDFAScanner** - This component is a lexical scanner, based on a DFA (Deterministic Finite Automaton). The component has a hidden scanner generator, based on the Lex algorithms [Lesk and Schmidt 1975]. The component also has a property lexicalGrammar, which is a reference to a CLexicalGrammar component. When the CDFAScanner component observes a change in the CLexicalGrammar component, it invokes its hidden scanner generator to regenerate its DFA tables and notifies its observers.

- **CColorScheme** - This component maps grammar symbols to symbol categories and symbol categories to font and color attributes. It observes a CLexicalGrammar component and maintains consistency between its own valid symbol domain and the symbols defined in the grammar.

- **CRichTextView** - This component is a text editor with facilities for different font and color attributes. It uses a CDFAScanner component to scan its text and a CColorScheme component to render the recognized symbols. When it observes changes in scanner or color scheme it re-renders its text.
Figure 1: The NetBeans IDE in design mode shows the component palette in the right upper window. The middle window contains a form on which SLE components can be dropped. Visual components may be accessed on the form itself; all components can be accessed from the Inspector window on the left lower side of the IDE. The right-lower window is a sample property editor for the ColorScheme component. The ColorScheme’s LexicalGrammar property shows a value cLexicalGrammar1 indicating that it is connected to the CLexicalGrammar component on the form.

Constructing a Syntax Highlighter from Existing Components
To construct a syntax highlighter from the SLE components mentioned we follow the following steps:
1. Select a CLexicalGrammar component from the Palette and drop it on the form. Note that CLexicalGrammar is a non-visual component, therefore it doesn’t show on the form but can be accessed from the inspector window (See Figure 1) of the NetBeans IDE. Click the CLexicalGrammar component (from the inspector window) and use its property editor to set the grammar. The property editor shows two properties: lexicalGrammarStructure (represents the internal structure of Lexical definitions) is used to open a customizer for editing parts of the lexical grammar and lexicalGrammarText (represents the grammar in text
form) is used to set the grammar in text form. Use any of the two properties to set the grammar. The following updates take place:

- It checks that the grammar is well-formed and computes analysis information (i.e. first, follow and nullable sets).
- Maintains consistency between lexicalGrammarStructure and lexicalGrammarText properties of the lexical grammar.
- Sends a property change to any of its observers.

2. Select a CDFAScanner component from the Palette and drop it on the form. The component shows in the inspector window of the IDE. Connect it to the CLexicalGrammar component by setting its lexicalGrammar property to the instance of CLexicalGrammar placed on the form in step 1. If the connection is successful, the following actions take place:

- CDFAScanner is added to the list of observers of the CLexicalGrammar component.
- CDFAScanner invokes its hidden scanner generator to construct scan tables that correspond to the lexical definitions of CLexicalGrammar.
- Maintains consistency between the CDFAScanner properties, DFATableText (for textual representation) and DFATableStructure (internal representation).
- A property change is sent to the components observing CDFAScanner, if any.

3. Select a CColorScheme component and drop it on the form. Access the component via the inspector window and open its property editor. Connect it to the CLexicalGrammar component by setting its lexicalGrammar property to the instance of CLexicalGrammar placed on the form in step 1. Similarly, a successful connection causes the following actions:

- The CColorScheme is added to the list of observers of the CLexicalGrammar component. The component adjusts its domain of valid symbols to that of the grammar.
- Maintains consistency between the CColorScheme properties ColorSchemeText (for textual representation) and ColorSchemeStructure (internal representation).
- A property change is sent to the components observing CColorScheme, if any.

Use the ColorSchemeStructure property to open a customizer (see figure 2) and edit the list of symbol categories, set their desired color and font attributes and classify symbols into their appropriate categories. Alternatively, use the ColorSchemeText property to edit the CColorScheme settings in text form. Either way, the ColorSchemeText or ColorSchemeStructure properties will be updated automatically and in turn a property change is sent to the components observing CColorScheme, if any.
Finally, select a CRichTextView component and drop it on the form. Enter text in its text property. Connect it to the CDFAScanner and CColorScheme by setting its scanner and colorScheme properties (to the components placed on the form in step 2 and step 3) respectively. CRichTextView component reacts in the following way:

- It starts to observe changes in the CDFAScanner and CColorScheme components.
- It uses both the CDFAScanner and CColorScheme components to highlight the text according to the lexical grammar defined in CLexicalGrammar.

Note that the syntax highlighter has been constructed without writing a single line of code.

**Figure 2**: An example of a customizer for the ColorScheme component. Tab, Fonts and Colors lists the current symbol categories with their font and color properties. Tab, Symbol Classification lists the symbols supported by the syntax highlighter and their corresponding categories.

Making the Syntax Highlighter a New Component

With only slightly more effort, a syntax highlighter like the one developed above can be turned into a new component. We sketch the steps:

1. This time, start with a JPanel (a visual component that can contain other components);
2. Drop on it a CDFAScanner, a CColorScheme and a CRichTextView, and connect them as above;
3. Switch to the code view, and add two public properties to the JPanel: language, which is a reference to a CLexicalGrammar component, and text , which is a String. A few lines of code have to be added for the setters and getters of these properties. The setter of the language property has to pass its value on to the language property of both the CDFAScanner and the CColorScheme sub-components. The setter and getter of the text property will pass a string to and from the text property of the CRichTextView respectively.
4. Register the newly created component on the Palette. Thereafter it can be used just like any other SLE component.

Related Work
The idea of composing a language processing system from subsystems dedicated to specific tasks like scanning and parsing is an old one [Bauer and Eickel 1974]. A lot of research has gone in generating such subsystems from language specifications. Some of these tools, like Lex and Yacc [Lesk and Schmidt 1975; Johnson 1975], were designed to cooperate with each other and with other subsystems. They could be considered components avant la lettre.

Stratego/XT [Stratego] is a collection of components for transformation tasks, like parsers and pretty-printers. The XT components are executable tools: they can be executed from the command line and they can be composed into a pipeline. The tools in the pipeline exchange structured data in the form of annotated terms. The tools themselves can be implemented in different programming languages.

There exist several systems that aim to make language tools easier to use and easier to integrate in common programming environments. A well-known example is Eclipse IMP (IDE Meta-Tooling Platform) a project to support the development of richly-featured, language-specific IDEs in Eclipse [Eclipse]. It provides a.o. a set of language service-creation wizards, a run-time framework to encapsulate common language-processing infrastructure, and DSLs for easily implementing certain IDE services.

The components we propose are not separate executables and do not come with an elaborate infrastructure. They conform to standard component models like JavaBeans or the Delphi VCL and can be handled by any environment supporting such a component model. To the best of our knowledge, such a component collection does not exist yet.

Conclusion and Future Work
The research problems mentioned in section 1 are the subject of the PhD. Project of the first author. Starting point was an unfinished prototype in Delphi, developed by the second author.

As most of the design of an SLE component set can be done independently of a concrete platform, it was decided to make an abstract platform-independent design, accompanied by two concrete realizations: one for Java and NetBeans - developed by
the first author and one for Object Pascal - developed by the second author. There is method to our madness: most problems concerning the design of a coherent set of algorithms and data-structures for SLE tasks are much clearer and simpler at an abstract level (compare for example the algorithms in a book like [Wilhelm and Maurer 1995] with the code of some existing parser generators. Based on an abstract design, implementation in Java and/or Object Pascal is relatively easy.

This way of working also helps in separating platform-independent aspects from platform-specific ones.

The SLE component architecture has been realized as a prototype and tested on various examples in both the NetBeans 6.9 and Delphi 2010 environments. The experiments do not only concern the drag-and-drop style illustrated in this paper, but also the use of wizards to generate source code for components as described in section 2.1, but not elaborated in this paper.

Until now, the focus of our work has mainly been on:

- Identifying suitable characteristics of the SLE components framework;
- Investigating the best way of maintaining consistency and managing information flow among a collection of SLE components;
- Investigating how to handle source code generating SLE components in both Netbeans and Delphi environments.

The SLE framework currently has a limited number of components and wizards. These include components and wizards for:

- Lexical grammars (including views, editing, and grammar analysis);
- Various lexical scanner components (including views and hidden scanner generators for both ELL(1) and DFA methods);
- Syntax highlighting.

Currently we are working on a similar collection for parsing, including a family of recursive descent parsers with and without backtracking. This will be followed by components for tree building and flattening.

References

ANTLR. ANother Tool for Language Recognition, Internet WWW page, at URL: http://www.antlr.org/.
ELI. Eli project. Internet WWW page, at URL: http://eli-project.sourceforge.net/.

strengthening the role of ICT in Development
NETBEANS. NetBeans IDE, Internet WWW page, at URL: http://netbeans.org/.
STRATEGO. Stratego/XT, Internet WWW page, at URL: http://strategoxt.org/.
Bottlenecks in the Development Life Cycle of a Feature- A case study conducted at Ericsson AB

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Abstract
The increase in the lead time of software projects has been mainly attributed to long development cycles and changes in customer requirements. This has driven the development of a number of modern software development strategies to address the issue: Among them is streamline development - an in-house development framework at Ericsson AB inspired by lean principles. In this paper we explore the development life cycle of a feature to identify the possible bottlenecks - a term used in lean development denoting interruptions, re-work or any activities that hinder the development process, hence an increase in lead time. This paper is based on a case study carried out at one of the development units at Ericsson AB. The results presented here are after a qualitative interview study with one cross function team using streamline development framework. Using lean as a theoretical base, the results show that: process perception, feature context, competence, task switching, long communication chains, evaluation considerations, feedback and poor documentation are some of the possible bottlenecks that can increase the lead time of a software project.

Index Terms: Streamline development, Feature development, Software Process Improvement, Software bottlenecks, Lean, Software process

Introduction
The tendency of shifting from hardware to software has increased the market share of software in the business environment [Genuchten 2007]. This is leading many
organizations to join the software industry. Software development organizations are still suffering from the problem of long development life cycles as well as handling changes in the customer requirements [Holmström 2009]. These are causing late deliveries to market and sometimes delivering products which do not meet the customers’ expected requirements. This has called for the different techniques to improve software quality and to reduce the time to market of the software.

Recently, the lean principles have gained momentum in addressing the problem of long development life cycles; rapidly changing customer requirements, slow feedback and emerging of new technologies in software development industry. The lean methodology through its core principles of providing the highest customer value, maximizing flow and eliminating waste has a significant effect in addressing the above problems thus leading to increased productivity in software organizations and reduction of lead time [Mehta, et al., 2008]. The introduction of lean process principles which originates from the Toyota model of production was first identified by Womack and Jones [Womack, et al., 1991 and 1990; Womack and Jones [1996a]; Womack and Jones 1996b], in their five year study on why Japan’s automobile industry was doing better than the American automobile companies. They revealed that Japan was using fewer resources than American companies which possibly made their cost of production low. In the same report, they said Japan was lean on resources in that they minimized wastes in the consumption of resources to maximize their production without increasing the costs [Womack, et al., 1991 & 1990; Womack & Jones 1996a; Womack & Jones 1996b].

The Software development industry has picked upon a few concepts from the Toyota model of production [Womack et al. 1990], hence the emergency of the lean software process. It addresses the principle of reducing the development time by amplified learning, delaying commitment, delivering fast, empowering the team, building integrity in, seeing the whole, and removing non-value adding wastes in the process [Poppendieck & Poppendieck 2003; Mehta, et al., 2008; Shalloway, et al., 2010]. The principles of lean can be used as one of the best practices a company can acquire to improve its development process by reducing wastes as well as delivering fast [Shalloway, et al., 2010].

Based on a case study, this paper explores the development life cycle of a feature in one development team at Ericsson AB – one of the world’s leading providers of telecommunication and data communication systems. At Ericsson AB, development teams use a process called ‘streamline development (SD)’ which is a process developed at Ericsson inspired by lean principles. The development team in this study uses the streamline process in order to reduce lead time and maximize the end-to-end flow so that the customer, in the end, can receive fast delivery of high-quality software products. To achieve this, each development team focuses on one feature at a time, i.e. a distinguished characteristic of a software item [IEEE Std. 829-1998]. Within the framework of streamline development, each development team is responsible for developing the feature in the shortest time possible and with as few interruptions as possible.
This research investigates what is involved in developing a feature, i.e. what is involved in the development life cycle of a feature. By interviewing the members in one development team, we identify ‘bottlenecks’ - a term used in lean development denoting interruptions, re-work or any activities that hinder the smooth end-to-end flow strived for to reduce lead time. This will be used in future to improve the end-to-end flow by removing queues and updating practices. This will result into higher customer value as advocated in lean software development.

Theoretical background

Lean manufacturing
Since the early days of civilizations humans were concerned with optimizing efficiency and decreasing waste to achieve better end results. Among theories aimed towards efficiency improvement are time and motion study, Taylorism and Fordism [Robins, et al., 2003; Kanigel, 1999; Tolliday & Zeitlin 1987]. In the mid- 1940s, Toyota Motor Company stood in need of increasing production efficiency in order to stay competitive. At that time, American automotive industry companies were approximately nine times more productive than Toyota Motor Company [Ohno, 1988]. In order to find more efficient production ways, Toyota looked at American method of production which was based on traditional thinking of mass production [Wu and Wee, 2009; Ohno, 1988]. However, this approach was not appropriate to Toyota because of its demand constraints [Ohno 1988; Harvey 2004]. Using Ford’s theories, a new methodology for cars production was created and named Toyota Production System (TPS). TPS assumes prioritization of long term benefits over short term benefits. Its goal is the “absolute elimination of waste” [Ohno, 1988; Towill, 2006; Wu and Wee 2009], where waste is anything that does not add customer value. According to Likert [2004], results that are not waste in TPS can be achieved by working in a process that follows certain principles such as, continuous flow, adding value from demand in order to avoid overproduction, eliminating overburden of process participants, preventing quality problems as soon as detected, using stable methods to maintain the predictability, using robust technology that support people’s work, and using visual control to highlight problems.

Two pillars of TPS Management philosophy are ‘Respect for people’ and ‘Continuous improvement’ [Larman & Vodde 2008; Towill, 2006]. The former assumes that to add value to the organization respect for employees, partners and customers are required. The latter means that organizations adopting TPS should create a culture of continuous improvement, by allowing developers to experiment, repeat and learn.

Lean software development
TPS was formally documented around 1970 in Japanese and 1977 in English, however Western industries did not show interest in it until the oil crises when imports from Japan started to threaten domestic manufacturers [Holweg 2006]. In 1990 as a result of International Motor Vehicle Program, the term ‘lean’ was introduced in the book ‘The
Part 6: Bottlenecks in the Development Life Cycle of a Feature- A case study conducted at Ericsson AB

Machine that Changed the World’ by Womack, Jones and Roos [Womack, et al., 1990; Harvey 2004].

In software development industry, increasing globalization has brought out competitors with less costly development resources [Harvey, 2004]. Software systems are growing more complex and development organizations are becoming larger. This has led to a need to improve the development processes in place or invention of new processes [Berry, 2003; Everett, et al., 2009]. For the reasons of remaining competitive in the market, development organizations are in need of higher quality products, lower cost of production, and shorter delivery time of software [Harter, et al., 2000]. These however are addressed through the benefits of implementing lean such as lead time reduction, productivity increase and quality improvement [Kilpatrick, 2003]. Moreover lean proved to be universal and has been applied in fields such as health care, logistics and accounting [Zidel 2006; Baundin 2004; Maskel & Baggaley 2003].

Despite uniqueness of lean, to apply it in a particular field, its adoption to the new field is needed. Poppendieck[2002] translated the lean manufacturing principles into four principles for software development. These were later translated into seven principles to fully suit software development industry. For this research, seven principles of lean software development are presented under the four initial categories defined by Poppendieck [2002].

Add nothing but value

Eliminate waste

In order to add nothing but value and find wastes in software development, Poppendieck [2002] adopted seven wastes of manufacturing, identified by the creator of TPS [Ohno, 1988]; overproduction, inventory, extra processing steps, motion, defects, waiting, and transportation. According to Poppendieck [2002], features that lose their relevance and not used by the customer – extra features – are the source of overproduction. Another waste is an inventory or partially done work.

Build quality in

Shalloway [2010], claims that in lean software development, quality should be built in both the code and the process. In order to build quality in code, lean approaches simultaneous production of code and tests for the software and coding according to standards [Hibbs, et al. 2009; Shalloway, 2010]. It minimizes occurrence of initial error related defects [Hibbs, et al. 2009]. Among the ways to reduce defects, is to find them as soon as they occur [Poppendieck & Poppendieck, 2003. Another way to reduce defects is frequent integration of small parts. This is because smaller parts are less vulnerable to defects than huge amount of code. Quality in process can be built by defining acceptance tests early in the development process; it improves developers understanding about requirements and the final product.
Center on people who add value

**Empower the team**
Each member of development should be able to influence the process, make decisions on what to do and take responsibilities for these decisions. Poppendieck [2003] says that people involved in the process are “better equipped to make decisions”; however they should be supported and guided by management.

**Create knowledge**
Shalloway [2010] argues that software development is more a discovery process than a building process, therefore, creating knowledge that continuously perfects the product is essential. One way to amplify knowledge is to allow developers to experiment and improve relying on feedback obtained from iterations of the process. Learning to understand the process in which the work is done should be encouraged, so that the process can be improved by its users.

**Flow value from demand**

**Deliver early and often**
Early and often deliveries from short iterations, value can be delivered to the customer early on the development stage. It increases customer satisfaction and eliminates such waste as unnecessary features. For instance, after getting the most necessary features, a customer may realize that he or she does not need others. According to Shalloway [2010], early releases provide early revenue; it can cover later development costs.

**Delay commitment**
Delay commitment assumes giving a response in the moment when no more information can become available, still not too late to cause cost increase because of delays [Harvey, 2004]. The main idea behind deferring commitment is to allow changes in development project without negative consequences. Among the ways to delay commitment are: starting to discuss requirements from the most important to the customer and crucial for design solutions and constraining the implementation of design patterns to only those features that are current.

**Optimize across organization**

**See the whole**
Shalloway [2010] suggests focusing on flow in its entirety than step optimization. Sub-optimization may hide systems constructional errors, for instance measuring performance of working individuals may not reflect overall system performance, since problems may be due to the way the whole system works [Poppendieck, 2003]. Problems that can arise in transition process in between phases, such as poorly written design documents or integration errors, are most probably undiscovered when sub-optimizing.
Ericsson case: Background and research methodology

Streamline Development (SD)
Ericsson is one of the world’s leading providers of telecommunication and data communication systems among software development organizations. For the purpose of this research, a study was carried out at one of the development units. The purpose of the study was to follow the development life cycle of a feature in order to identify possible bottlenecks that can hinder the process. One feature was chosen and investigated throughout the development life cycle stages. At this development unit, the work is organized in cross function teams; where one of these teams was interviewed by the researchers while developing the feature. The team interviewed is using streamline development framework which is an in-house development process.

The introduction of streamline development framework was an inspiration from the core value of lean and agile [Holmström, 2009; Tomaszewski, et al., 200] such as providing the highest customer value, maximizing flow and eliminating waste. In this, Ericsson considered the following agile and lean principles: “(1) satisfying customer needs through iterative development and continuous delivery, (2) welcoming changing requirements, (3) short timescale frequent deliveries, (4) motivated individuals in project building and face-to-face communication, (5) simplicity and (6) teams involvement on the reflection of the development process” [Holmström 2009].

Streamline development was developed and tailored to meet particular needs for Ericsson i.e. to address the problems they experienced when using traditional software development process. Traditional software development methods are characterized with long development life cycles resulting into late deliveries to customers and failure to deliver the actual customer needs until late in the process [MacCormack et al.2003, Tomaszewski et al. 2007, Holmström 2009]. In addition, Ericsson was finding it difficult to handle customer changing requirements since they were exposed to changing market demands due to long duration of the projects [Holmström 2009]. In case of any customer changes in the requirements, it would result into high cost of handling requirement changes. This is because it was hard to deal with changes of already implemented function [Tomaszewski et al. 2007].

In order to deal with the fore mentioned problems, SD was developed as a process and a working framework. Its main objectives are, to reduce the time to market, having a flexible development set up, having more research and development during the project, having a better mechanism for scope setting and planning of the projects, creating a possibility to re-prioritize and re-plan at any time in the project and a greater focus on developing the right things.
As part of this study, the researchers followed the development life cycle of a feature which was developed using streamline development framework as shown in Figure 1.

In Figure 1, a feature is exposed to different states and decisions from inception to release i.e. the early phase loop where the project requirements are gradually and continually gathered in the requirement repository. These requirements come from either the customer, identified needs, change in needs, within the company or from standards. These requirements are divided into packages which are later divided into small projects as shown in the figure 1.

The small projects A, B, C. are assigned to cross function teams in the activity and release planning loop state. This is where the planning and feature decision are and it’s also where the program execution state begins i.e. where the actual execution of the feature is done. Here, all the cross function team members participate. The final stage is the project release state, where the features or small projects are integrated in the Late System Version (LSV) and released to the customer. The release manager is responsible for it.

**Cross Functional Team (Feature team)**

For the purpose of this research, a study was carried out to know the possible bottlenecks a team may be exposed to during the program execution state. The program execution phase is where all the team members (cross-functional team) are involved. As in streamline development, a cross functional team has the opportunity to have all
core competences such as design, test and system management with an architect, a team leader, system manager, function and system testers and designers as in figure 2.

Figure 2: Cross Functional Team (Feature Team)

![Cross Functional Team (Feature Team)](image)

Each of these members has core roles in the team as explained in the result section. It is also important to note that the team takes full responsibility of the development project during the program execution state. In this way, SD gives the teams more responsibility as well as freedom in their activities. This way of working creates an opportunity to share knowledge in the team. The feedback loop in the team is shortened since all people are working together. The ability to re-prioritize and re-plan in streamline development framework makes the team flexible to what is urgently required by the customer.

Research method

This research was approached by a case study method. A case study method has been chosen because identifying bottlenecks in a process requires an in-depth investigation of the process from the beginning to the end to understand the underlying principles and the problem that may be involved.

According to Yin [2009], there are six main sources of data: documentation, archival records, interviews, direct observations, participant observations and physical artefacts. For this particular study, the interviews were taken as the primary sources of data, and company presentations were the secondary source. In addition, company documentation and literature reviews helped in the validation of the results from the primary and secondary sources. The information collected during the entire research served as evidence of the report’s credibility. However, beforehand the un-disclosure agreement was signed in order to protect company’s sensitive data from outside world.

Research process

The research went through the following phases and activities as shown in the table 1 below.
Result

This chapter describes the results gathered from the interviews and presentations after Phase 3 in the research process. The results are categorized into:

1. Organization of work and roles in teams
2. Development process and phases
3. Lean principles
4. Reflection on streamline software development;

The reasons for having these categories are: (1) to identify each member’s role in a team, and dependencies of the roles, (2) to understand the development process which will allow mapping it to find out the underlying pattern, (3) getting the team members’ understanding of lean principles, and (4) perception of streamline software development. Each category includes perspectives of six roles in the team, i.e. team leader, system manager, operational architect, designer, system and functional testers’ perspectives.

Table 1: Research process (Phases and activities)

<table>
<thead>
<tr>
<th>Phases</th>
<th>Activities</th>
<th>Data Sources/ Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1</td>
<td>Literature Review</td>
<td>It was the first phase of the research; the researchers identified the topic on which this research was based. A literature review was carried out on</td>
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<td></td>
<td></td>
<td>similar researches. Especially on lean in software development. The purpose for this was to refine the research goals, to develop the realistic and relevant research</td>
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<td>question, select an appropriate method and identify potential validity threat of the research conclusion.</td>
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<tr>
<td>Phase 2</td>
<td>Presentations</td>
<td>Five presentations were carried out. The group was presented to Ericsson’s product and the feature under investigation. During this time, Streamline development framework was introduced to the researchers by the Process engineer. The team which was developing the feature was also introduced to the researchers and the way how feature teams work by the Team leader. The way of handling feature requirements, and architecture of features was presented by the System manager and the operation architect respectively. The result of the presentations was to get insights about streamline development and ways of working in feature teams</td>
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<table>
<thead>
<tr>
<th>Phases</th>
<th>Activities</th>
<th>Data Sources/ Goals</th>
</tr>
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<tbody>
<tr>
<td>Phase 3</td>
<td>Interview Studies</td>
<td>Six interviews were carried out with each lasting for approximately 1½ hours. The interviews were qualitative in nature and semi structured. The informants were the team leader, the architect, designer, system tester and functional tester. All the interviewees belonged to one feature team. They were documented and transcribed.</td>
</tr>
<tr>
<td>Phase 4</td>
<td>Data sources and Analysis</td>
<td>All the data collected was categorized and analysed into six categories; organization of work and roles in a team, development process and phases, lean principles and reflection on SD work</td>
</tr>
</tbody>
</table>

Organization of work and roles in teams

The idea of having cross functional teams is to provide each team with core competences which allow focusing on a specific feature and being responsible for it. The team which was investigated consists of team leader, system manager, architect, designer, three function testers.

The team leader has to identify dependencies of each team member; this ensures that the development process is going in the right direction as well as every team member is working according to the agreed strategy. Providing the team with the time plan which has to be followed or in case of necessary changes being modified according to the needs, is also one of the core functions of the team leader. This is aimed at improving work flow and to have a good overview of the project. Finding dependencies and having a good overview of the project empowers the team leader to remove barriers which can stop or negatively affect the team in achieving the main goals of the project.

In the feasibility phase of development, the main roles of the system manager include analyzing, describing and formalizing the requirements in a clear way for the team. The source of the requirements, come either from customers, standards or internally. If the requirements came from outside the company (i.e. customer) the system manager has to contact sales representative in case of misunderstandings.

Although the system manager influences the feature mainly in the early phase and the feasibility phase, the architect influences the feature throughout the entire project. The architect mainly interacts with the system manager during the feasibility phase. In this phase, the architect tries to find out if the feature can be implemented and how the feature will affect the whole architecture of the system. During the execution phase, the architect supports the designer with guidelines on how to implement the feature according to the architecture. He also answers questions the designer may have during the implementation. The Architect’s work depends on the complexity of the feature and the way the current feature influences the other parts of the whole system. In case of uncertainty the designer has to contact other architects or team members from other groups to map the dependencies and to transfer the knowledge to the right people.
The main role of the designer in the development process is to implement the feature in terms of actual code. The designer can start implementation as soon as the requirements are clear enough (this may happen during either feasibility or execution phases) and therefore late requirements directly impede his work. He also depends on function testers’ and system tester’s work, as some of the test results might cause rewriting the program code.

As some of the team members’ progress is tightly linked to the code or complete functioning feature, the designer’s delay directly impacts the whole feature. The system tester for instance is not able to start his testing procedures without having the feature itself or the function tester cannot execute tests without actual code. However, good collaboration between function testers and designer allows executing test cases in parallel with designers work and give feedback (trouble reports) immediately after faults have been discovered.

**Development process and phases**

Streamline development process has been adopted by the development unit at Ericsson for a number of reasons. “…main reasons are… improving time to market, more efficient research and development, shorter time to commitment, allowing development setup to be more flexible, possibility to change priorities and plans at any time … to develop the right things…” (Team member)

For the team, feature development starts after the “Go” decision has been made. They start with conducting feasibility analysis of the feature. After the analysis, “Commit” decision has to be made and the execution phase begins, which has a number of milestones and checkpoints. When the feature is ready, it is delivered to the latest system version (LSV). After that, the team continues with final tests for the feature and is ready to take over a new project.

Each team member has different input on each phase of the development process, as explained in the previous section. Specific documents have to be created and milestones to be met. Activities on each phase are highly linked to the results from previous stages; therefore any delays could result in to other delays.

The team leader has the main workload at the beginning and closer to the end of the project. In the mid stages of the project, the work mostly consists of checking the progress and the fulfillment of all the milestones and solving problems which could arise within the team. Creating a feasible time plan and setting up the right goals by the team leader at the beginning ensure the success of the project.

After the system manager has set out the requirements in the early phase, in the execution phase he or she reviews on each check point and helping team members to understand the feature in case of uncertainties. “… Efficiency in work is highly dependent on the requirements clarity and frequency of changes in the requirements which on its hand affects the performance of the project in general…” (Team member)
The architect is highly involved in all the phases of the development process particularly for those features which affect the current architecture of the whole system.

In the early phase, the architect helps the team to understand the scale of the feature, feasibility, requirements specification and suggests the ways of most efficient implementations of the feature. During the execution phase, the architect works closely with designers in order to help with design decisions which should be in accordance with current architecture. For the architect, it is a challenge to follow the dependencies on different teams’ work and to analyze the consequences which will affect the whole architecture after the feature is included in the latest system version (LSV).

The function tester is mostly involved in the execution phase when he/she works in close cooperation with the designer. “…The main idea for function tester is to find situations which were not thought of by designers or other team members…” (Team Member)

Streamline development allows for working on the tests in parallel with the designer. That helps to increase the productivity of the function testers, however there are other factors which may slow down the process, i.e. new testing framework which is more time consuming in relation to the execution of the test cases. As well as synchronizing, different branches usually cause in delays due to differences in implementation approach.

Similarly to functional testers, designers have the main workload during the execution phase. Apart from coding, a lot of documentation has to be created to explain/support the code. This documentation is mostly used by designers themselves or by function testers. According to the designer, the efficiency of the work is mostly dependent on the size, complexity of the feature and previous experience with projects in a similar area. One of the typical problems is to understand the requirements of the feature which is completely new.

System testers are mostly involved in the beginning of the project (analysis of the feature and requirements) and closer to the end of the project when the feature is ready and system tests can be run. According to the system tester, delays seldom occur during the tests, but one of the reasons for delays could be due to updates of the testing tool to be used for a specific feature.

**Lean principles**

The team members argue that lean principles are reflected during the entire development cycle of the feature. They have a positive impact on the development process in general and on the team work performance in particular. All team members agree that cross-functional teams allow immediate feedback from all the parties involved in the development process.

“…having all the team member close to each other is good, because it speeds up the information exchange in the team…” (Team member)
Collaboration and communication between the stakeholders improved significantly compared to the previous development process.

The shortage of particular resources within the team might lead to problems which were not feasible while using “waterfall” approach. One of the interviewees mentioned that, in some cases there is a tendency to move function tests to the design tests. This is potentially a negative move as designers will have to test their own code and might miss some faults.

Scaling the processes to fit different projects is essential in lean development. This allows reducing “waste” and focusing only on those activities which are necessary for specific projects.

“...Adopting the process to smaller features is the area which still can be improved...” (Team member)

However, delays may arise in cases where some documents such as test analysis or test specification have to be approved by the line manager. As there is only one line manager who is responsible for doing it.

All the interviewees expressed a need to reduce the external meetings as they are causing delays by disturbing the implementation process since sometimes it is difficult to get on track on where they stopped before the meeting.

Usually, the problems which arise during the project are reported to the management in the “conclusion exercises” never the less, not all of the aspects are considered by the management hence looping up to the next projects.

**Reflection on Streamline software development**

Adaptation of streamline development process had positively influenced the time required for releasing new features at the development unit. As for the team leader, streamline development allows for understanding the goals and activities in a better way, since it encourages communication and sharing knowledge among the team members.

“...Streamline process has a very good support for communication (information exchange) among the team members and among teams... it also allows having a better structure on how to work, how to share the work and it increases possibility of learning new things which is essential for improving teams’ performance...” (Team members)

Dividing the requirements into packages and then later assigning to cross function teams was appreciated by the team members because it reduces the work load. According to one of the team members, it was noted that having short projects is a good way to handle customer changes since the changes affect only specific features and not the entire project.

**Discussion**

Below, we describe the bottlenecks which were revealed in the qualitative interview study, company presentations and literature study. As the main purpose of the research is to
identify possible bottlenecks in the development life cycle of the feature, this chapter is categorizing such bottlenecks and presents them as challenges, but not problems for the team and management.

**Process perception**
Empowering the team is one of the core principles in lean software development which is adopted by the development unit. It allows the team to be more flexible in the development process by choosing tactics and development methods which are best suited for a specific case [Shalloway, 2010]. Streamline framework proposes high level description of the development process, while still leaving a space for the decisions on a detailed level. It is the team that decides the best way to implement the feature or to tailor the process.

However, team members were asked to describe the life cycle of the feature with a purpose of finding out the perception of the process from the team’s understanding. The results showed that team members whose work is not directly related to the management activities had difficulties with describing the process. Questions about the phases or stages of the feature development process were also challenging for the interviewees. This has made an impression that not all the team members had a clear understanding of the development process. Lack of common understanding of the process still indirectly influences the work. Without having a clear knowledge about the working process, it is difficult to suggest improvements to it. Therefore, most of the activities which are done throughout the development process were assumed to be best and members could not suggest further improvements to be done. As a mean to overcome this challenge, the management should organize short courses about the working process or rotation of roles in the team such that everyone in the team gets a chance to know what the other is doing.

**Feature context**
Some of the interviewees mentioned the limited knowledge of the feature usage and feature context as one of the problems they are facing at the development unit. This is mainly because most of the features implemented are part of big systems or are to be integrated in already existing systems. To speed up implementation, understanding of the usage scope is considered a necessity. Although the features can be coded efficiently without knowing their usage, the feature implementation can be technically correct but suboptimal. This can prevent the team from delivering the maximum value to the customer that is strived for in lean software development.

As a suggestion to this bottleneck, direct involvement of the customer with the team in the process can prevent this kind of complication as suggested by Hibbs [2009]. This can be in such a way that, short regular meetings with the customers’ representatives are arranged for the team members.
Competence
In streamline development, feature teams are organized as cross function teams with all the core competencies i.e. design, testing and management as explained in the SD section. This competence is used in development of the feature in the program execution state. The teams have full responsibility of the project during the program execution state. In this, SD gives the teams more responsibility as well as freedom in their activities to make decisions as recognized by Poppendick [2003]. This way of working creates an opportunity to share knowledge in the team and also the feedback loop in the team is shortened since all people are working together.

To check for core competence needed to develop a feature, in the “activity and release planning loop” resources are allocated to the feature. These may include tools, people and learning. However findings indicate that, delays are likely to occur due to lack of some competence in the team. One of the facts which may result into lack of competence may be attributed to the nature of the current volatile technological environment. New tools emerge from time to time implying that people have to gain competence to operate them. An example can be revealed in function testing where a new testing tool was introduced; this caused a deduction on the number of test cases produced in one week from five to one or two. The deduction in test cases, make it clear that lack of competence in a team is a potential bottleneck in the development life cycle of a feature. As means of curbing the situation, in streamline development, there is continuous analysis and knowledge creating activities Also, the company tries to introduce courses on each new technology introduced. However, adoption is a process which needs time and people’s acceptance to the change. This can be argued for from the technological adaptation curve by Bohlen, et al. [1957], where some people may take less time to adapt to new technologies while others may take a longer time.

Task switching
Streamline development encourages management commitment, for example regular meetings with the cross function teams or close contact and co-location with management during the process implementation. This can be both beneficial and can create some drawbacks. Lean philosophy describes this way of working as reducing the gap between the team and the management. It also encourages greater involvement of the entire organization in the production of software and in the process implementation [Shalloway, 2010]. On the other hand, at the development unit, it was mentioned by almost all the interviewees that, there are too many external meetings which sometimes results in delays throughout the whole process. This could be a possible bottleneck in the development life cycle of a feature in form of task switching as denoted in Lean philosophy. In this case external meetings interrupts the work flow of the process, the meetings which are considered unnecessary by the team members can be linked to waste in lean philosophy. The more unexpected and unwanted meetings are held during the feasibility and/or execution phases in the program execution stage, the more waste
is created in the whole development process. Waste in turn is a potential bottleneck that impedes development of a feature and creates delays.

The possible solution mentioned by one of the interviewees, was instead of the whole team attending the meeting, it is enough to have just one or two team members to participate in it and later share the information within the team.

**Communication chain**

Requirements elicitation is one of the most influential steps of development with regards to eventual success of a program. Problems introduced during requirements elicitation are the most expensive if not detected quickly. This is because later corrections require most rework and waste in form of defects [Walton, 1999; Poppendieck & Poppendieck 2003].

At the development unit, the system manager pre-studies the feature and analyzes the requirements in order to present them to the team in the most efficient way.

The management is the intermediate party between the customer and the system manager in the elicitation of requirements. Some interviewees suggested that, lack of direct contact between the system management and the customers can encumber the process of specifying requirements for the feature. According to interviewees, the level of details is varying depending on representatives between the customer and the system manager. Some management representatives are able to transfer the idea and required functionality from the customers in a sufficiently detailed and technical way to the system manager, but some are not. And in case of misunderstanding of the requirement in the team, the team has to contact the system manager, who will contact the management representative who will contact the customer hence creating a chain of communication. Long communication chains between customers and system management introduce handoffs of information. In turn, handoffs in functions can cause delays and increasing risks of information being misunderstood [Walton, 1999]. Conveyance of information might cause a loss of knowledge, as great amount of data remains with its carrier and never gets handed off to others [Poppendieck & Poppendieck 2003]. The longer the communication channel, the higher the chances are of missing some of the details. Allowing direct communication of the system manager with the customer could reduce the communication chain [Larman & Vodde 2009].

**Lessons learned (Evaluation considerations)**

In lean, perfection of the process is done via constant improvements. One of the conditions required to improve the development life cycle of the feature is to have the input from previous cycles.

At the end of each program execution stage (this is where the feature is delivered); team members create a report where suggestions to the management are made on how to improve the development process for the next iterations. One of the reasons for this is to have the team’s opinion on the activities which are done and share the good experience among other teams. This supports the process improvement throughout
the whole organization, by adopting one of the core lean principles such as knowledge sharing, which in this case drives forward another lean principle – perfection of the process.

However, some of the evaluations are not always considered by the management and therefore the team continues to work on the next feature having the same problems unsolved. This could result into a bottleneck during the next feature implementation if the team happens to find the same problems faced in the previous cycle. Considering and implementing all the evaluation results is a great challenge for the management as it requires in-depth analysis of all the requests made by teams and consequences of such requests. Although solving all may not be easy, an immediate solution to this bottleneck suggested in this research is to have or create a priority list of solving the problems mentioned. The list can be created by the team that faces the problem with the help of the management that is responsible for solving the problems.

**Conclusion**

This research has explored the development life cycle of a feature with the main purpose of identifying possible bottlenecks that are hindering the development process. Some solutions to the bottlenecks have been suggested where possible. The results presented here are after a case study with one of the development unit at Ericsson AB. Using lean principles as a theoretical base the following bottlenecks were identified: poor process perception, limited knowledge of the feature context and usage, lack of competence, task switching, long hierarchy communication chains, and inadequate evaluation considerations.

In addition to the above bottlenecks, the results also reveal that bottlenecks may also arise due to poor documentation of the crucial activities of work e.g. the architecture. Also, poor feedback to the team members from management may also arise into bottlenecks since some stages in development may fail to proceed without getting a confirmation hence delays.

The bottlenecks identified in this research can be taken as challenges which need to be addressed. Addressing them and looking for possible solutions can be beneficial in that it may result into a decrease in lead time and also improve the end to end flow.

One of the main challenges that could have been essential to this research is that some information was excluded from the report due to the company’s confidential agreement.

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References
IEEE Std. 829-1998, Standard for Software Test Documentation
LARMAN & VODDE, 2008, Scaling Lean & Agile Development: Successful Large, Multisite & Offshore Products with Large-Scale Scrum, Addison-Wesley, Ch.22
MEHTA M, ANDERSON, D, RAFFO. D, 2008 Providing value to customers in software development through lean principles. John Wiley & Sons, Ltd.
OHNO, T., 1988, Toyota Production System: Beyond Large-Scale Production. Translated by Productivity, Inc. New York: Productivity Press
POPPENDIECK, M., 2002, Principles of Lean Thinking, Poppendieck.LLC
WALTON, M., 1999. Strategies for Lean Product Development. Massachusetts Institute of Technology
WU, S. AND WEE, H.M. 2009. Dept. of Ford Production Syst. of Manufacturing Division., Ford Lio Ho Motor Co., Chungli, Taiwan
Discovery of Services Based on WSDL Tag Level Combination of Distance Measures

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Abstract
During discovery of services, a service request is compared with available services. A similarity measure is one of the techniques which can be used to quantify the comparison and to rank existing services according to their suitability to satisfy a given request. Similarity measures have varying strengths and are applied in isolation. We argue that we can have better ranking if we apply the strongest similarity measure to a specific element of the service description. That is, we can employ a number of similarity measures to a specific service. In this paper we experiment with application of a combination of similarity measures to specific elements in a WSDL document. We then aggregate the similarity values into a single metric that is used to give the overall ranking of the services. Also, in our approach, the contribution of each element in the WSDL document is weighted according to the significance of the element in describing the desired service.

Keywords: service matching, similarity measures, service discovery, web services.

Introduction
Agility, interoperability, incremental integration, re-usability and flexibility have created enormous research and industrial interest in the domain of web services [8, 32, 30, 27]. As a result of this research and industrial activity, a significant number of web services have been developed and made available on the World Wide Web. What is availed is the description of the web service including functional and non-functional semantics. There are various web service description languages such as WSDL [4], and semantically
enriched languages such as OWL-S [23], WSMO [7], WSDL-S [28], SAWSDL [18]. The availability of these web services has created a new challenge of identifying the most suitable web service to satisfy a given request. Service discovery is the process of locating existing web services based on their functional and non-functional semantics. Techniques to discover web services offer means of matching web service consumers with web service providers [29]. Most matchmakers compare the user request to the service description by looking at common patterns.

A common characteristic of most current matchmakers is that the matching between a request and service depends on application of a single technique or combination of techniques to the whole service description document. Most matchmakers treat the web service description document as one unit and they attach equal relevance to all elements therein. We argue that some elements in the web service description document are more informative than others. Also, some elements are more structured than others. At the same time, some similarity measures are more efficient on structured elements than others. These differences in the capability of different techniques and relative relevance of different elements of the WSDL document cannot be exploited if the description document is considered as a single unit.

Currently, for web service discovery, a given similarity measure is applied to the entire document and yet, different measures may be suitable for different segments of the documents. In this paper, we experiment by applying different combinations of algorithms to different sections of the WSDL to provide more accurate combined similarity measures. Specifically, we identify attributes within the WSDL documents and their significance in matching. We study and identify suitable algorithms to facilitate the matching of WSDL attributes to user requests. We further develop a functional platform independent implementation of a service selection and ranking of services. The choice of techniques applied is based on the accuracy of the individual algorithms. There are results of previous studies to gauge the suitability of the techniques under different situations. We also use some of the existing results to decide on the suitable algorithms for various situations. This implies that in the course of the study, we may vary the level of detail used through restricting the use of different techniques to specific parts of the document in order to improve recall or precision.

Related Work
The subject of service discovery is well recognized in the domain of service-oriented computing. The focus of research is centered on techniques that perform accurate matching between a service request and existing services. The approaches vary both in actual technique used and the type of information used. All existing work applies logic-based, non-logic-based approaches or a combination of both. Non-logic-based approaches do not perform any inferences in service semantics. Such approaches employ several techniques including syntactic similarity matching [17], structured graph matching [25], data mining, linguistic, numerical concept distance over a given ontology
Part 6: Discovery of Services Based on WSDL Tag Level Combination of Distance Measures

[3] and generally content based retrieval. Their accuracy is dependent on the features considered during matching. Alternatively, logic based approaches rely on some logic to represent both the request and the service. Logic based approaches exploit logic based inferences on the underlying logic that represents the request or description. Representative examples of these approaches include [2, 24, 31]. Hybrid approaches such as OWL-MX [15, 16] combine logic based matching and non-logic based matching. Similarity measures [6] form part of non-logical techniques and have widely been applied in matchmaking. They easily scale from semantic matchmaking that may involve linguistic semantics and texture descriptions to functional matchmaking as used in our case.

Compared to the logic based approaches, similarity measures do not suffer from the decidability problem and can be used at different levels of matching. Similarity measures rely on traditional Information Retrieval techniques. Such techniques include cosine based similarity, extended Jacquard-based similarity, intentional loss of information, Jensen-Shannon information divergence and many others. Registries such as UDDI provide lookup services that support keyword search. Non logic-based approaches include (a) graph matching (b) data mining (c) linguistics and (d) content based retrieval among others. Klusch [15, 16] provides a hybrid approach that combines implicit service semantics and logic-based approaches. They report results superior to any of the methods used in isolation. Under implicit semantics they select the most promising similarity metrics previously ranked by [6] on the basis of their recall precision. Particularly, they mix cosine based similarity, extended Jacquard-based similarity, intentional loss of information and Jensen-Shannon information divergence similarity retrieval (see[15, 16] for corresponding definitions). In all the work reviewed above, there is no evidence of investigation to exploit the varying strength of similarity techniques on specific elements in the WSDL document

Background
Upon describing the service, the request is systematically matched with the WSDL document. The techniques used to compare the request to the WSDL document are based on vectors. For this reason, both request and WSDL documents may be converted into vectors using the Vector Space Model (an algebraic model).

To convert both the request and the services into vector representations, we used Term Frequency Inverse Document Frequency (TF-IDF) [17]. The TF-IDF provides pointers to which terms should be assigned lower priority due to their repeated appearance in several documents. Common terms such as “a”, “the” and “and” would be assigned lower priority and hence have insignificant impact on the final result [9].

Similarity Coefficients
In this section, we highlight specific distance measures that were selected based on the current usage in different areas of information retrieval. The Jaccard similarity coefficient [11] is a metric used for comparing the similarity and diversity of sample
sets. It achieves this through comparing the intersection with the union of the sample sets, otherwise illustrated as:

$$J(A, B) = \frac{(A \cap B)}{(A \cup B)}$$

Consequently, are Jaccard coefficient of 1 implies perfect match while 0 implies no match.

The Cosine Similarity [13] is described as a measure of similarity between two vectors of n dimensions by finding the cosine of the angle between them. This may be illustrated with two vectors of attributes, A and B, where the cosine similarity, $\theta$, is represented using a dot product and magnitude as.

$$\text{similarity} = \cos(\theta) = \frac{A \cdot B}{\|A\| \|B\|}$$

The Hamming Distance measures the number of differences between two vectors [14]. Alternatively, the Hamming Distance may be likened to the number of differences between two words of similar length. If $q =$ number of variables with value 1 for the $i$th objects and 0 for the $j$th object, and $r =$ number of variables with value 0 for the $i$th objects and 1 for the $j$th object, we have: $d_{ij} = q + r$. Consequently, a zero Hamming Distance is symbolic of a perfect match while the further away from 0 the result is, the less the similarity between two adjacent vectors or words.

Named after the Russian Scientist Vladimir Levenshtein (responsible for its inception), the Levenshtein or Edit Distance refers to a measure of the similarity between two adjacent strings [10]. A Levenshtein Distance of 0 symbolizes a perfect match however the further away from 0 the value, the greater the deviation between the strings. The Damerau-Levenstein Distance is a generalization of the Levenstein Distance. It assigns weights to the modification operation, that is, weights are assigned to the deletion, insertion or transposition operations [12].

**Experimental Setup and Results**

We used a collection of 32 (See Table 1) web services by experimenting with their WSDL documents. From each WSDL document we extracted specific tag contents. We subjected the tags to a combination of distance measures. Figure 1 shows the interface used to obtain combinations of similarity techniques.
In order to rank multiple WSDL documents against a query or keywords, the contents of the WSDL documents were pre-loaded into a MySQL database. This was done to mitigate the challenges associated with loading more than one WSDL document at a time in order to perform a comparison. Multiple Algorithms were then integrated into the Brokerage System while ensuring that results from more than one algorithm were available for comparison. These algorithms included: i) Jaccard (J); ii) Cosine Similarity (C); iii) A merger of the Jaccard and Cosine Similarity (JC- This involved the application of the Jaccard to the “documentation” portion of the WSDL document, and Cosine Similarity to the other tags within the WSDL document); iv) A merger of the Cosine Similarity and Jaccard technique (CJ- This involved the application of the Cosine Similarity to the “documentation” portion of the WSDL document, and Jaccard to the other tags within the WSDL document); v) Hamming Distance (H); vi) Levenshtein Distance (L) and vii) Damerau Levenshtein Distance (DL). The keywords used for the request are “city distance”, parsed to the matching algorithm as an array of words “city” and “distance”.

**Tags and References**

A WSDL document is composed of different XML elements (see Table 2) that define different aspects of the service which it describes. The first three elements comprise the ‘logical part’ and the last two comprise the ‘concrete part’. The portType defines sets of operations to be exposed. The relevance of the tags is categorized as High, Medium, and Low with 5, 3 and 1 as the respective weights.
<table>
<thead>
<tr>
<th>#</th>
<th>WSDL</th>
<th>url</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>postcodeservices.asmx,</td>
<td><a href="http://ws.epostcode.com/uk/">http://ws.epostcode.com/uk/</a></td>
</tr>
<tr>
<td>2</td>
<td>placelookup.asmx,</td>
<td><a href="http://codebump.com/services/">http://codebump.com/services/</a></td>
</tr>
<tr>
<td>3</td>
<td>GeographicalCoord.asmx,</td>
<td><a href="http://www.discoverdance.co.uk/UKCoordinates/">http://www.discoverdance.co.uk/UKCoordinates/</a></td>
</tr>
<tr>
<td>4</td>
<td>Proximity.asmx,</td>
<td><a href="http://www.sircweb.cn/SircWeb/Services/Proximity/">http://www.sircweb.cn/SircWeb/Services/Proximity/</a></td>
</tr>
<tr>
<td>5</td>
<td>addresslookup.asmx,</td>
<td><a href="http://ws.cdyne.com/psaddress/">http://ws.cdyne.com/psaddress/</a></td>
</tr>
<tr>
<td>6</td>
<td>api.wsdl,</td>
<td><a href="http://6pp.kvdb.net/services/soap/">http://6pp.kvdb.net/services/soap/</a></td>
</tr>
<tr>
<td>7</td>
<td>location.asmx,</td>
<td><a href="http://www.annotatedearth.com/AELocationService/">http://www.annotatedearth.com/AELocationService/</a></td>
</tr>
<tr>
<td>8</td>
<td>locationByZip.wsdl,</td>
<td><a href="http://www.flash-db.com/services/ws/">http://www.flash-db.com/services/ws/</a></td>
</tr>
<tr>
<td>9</td>
<td>zipcodelookup.asmx,</td>
<td><a href="http://codebump.com/services/">http://codebump.com/services/</a></td>
</tr>
<tr>
<td>10</td>
<td>WebService.asmx,</td>
<td><a href="http://www.simplylookupadmin.co.uk/">http://www.simplylookupadmin.co.uk/</a></td>
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<tr>
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<td><a href="http://www.sircweb.cn/SircWeb/Services/">http://www.sircweb.cn/SircWeb/Services/</a></td>
</tr>
<tr>
<td>12</td>
<td>Distance.asmx,</td>
<td><a href="http://voservices.net/Cosmology/ws_v1_0/">http://voservices.net/Cosmology/ws_v1_0/</a></td>
</tr>
<tr>
<td>14</td>
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</tr>
<tr>
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<td>Nearest.asmx,</td>
<td><a href="http://www.allies-computing.co.uk/WebsoapNearest/">http://www.allies-computing.co.uk/WebsoapNearest/</a></td>
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<td>18</td>
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<tr>
<td>19</td>
<td>AustralianPostcode.wsdl,</td>
<td><a href="http://www.webservicex.net/">http://www.webservicex.net/</a></td>
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<td>20</td>
<td>EMBLNucleotide Sequence.wsd1,</td>
<td><a href="http://www.webservicex.net/">http://www.webservicex.net/</a></td>
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<td>21</td>
<td>GetISBNInformation.wsdl,</td>
<td><a href="http://www.webservicex.net/">http://www.webservicex.net/</a></td>
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<td>22</td>
<td>HCPCS.wsdl,</td>
<td><a href="http://www.webservicex.net/">http://www.webservicex.net/</a></td>
</tr>
<tr>
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<tr>
<td>26</td>
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</tr>
<tr>
<td>27</td>
<td>UKLocation.wsdl,</td>
<td><a href="http://www.webservicex.net/">http://www.webservicex.net/</a></td>
</tr>
<tr>
<td>28</td>
<td>USAAddressverification.wsdl,</td>
<td><a href="http://www.webservicex.net/">http://www.webservicex.net/</a></td>
</tr>
<tr>
<td>29</td>
<td>USAZipcode Information.wsd1,</td>
<td><a href="http://www.webservicex.net/">http://www.webservicex.net/</a></td>
</tr>
</tbody>
</table>
Table 2: A WSDL document’s primary attributes

<table>
<thead>
<tr>
<th>#</th>
<th>Tag</th>
<th>Relevance</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><code>&lt;portType&gt;</code></td>
<td>Medium</td>
<td>Assigned Medium priority because most portType attributes contain technical descriptions for port functionality e.g. “BuiltInTypeSoapPort”. Such descriptions provide little relevance to users during semantic matching.</td>
</tr>
<tr>
<td>2</td>
<td><code>&lt;message&gt;</code></td>
<td>Medium</td>
<td>Assigned Medium priority because most message attributes refer to technical descriptions for messages within the WSDL document e.g. “BasicComplexType”. Such descriptions provide little relevance to users during semantic matching.</td>
</tr>
<tr>
<td>3</td>
<td><code>&lt;documentation&gt;</code></td>
<td>High</td>
<td>Assigned High priority because documentation tags contain the most descriptive attributes of a WSDL document. These descriptions provide a lot of relevance to users during semantic matching.</td>
</tr>
<tr>
<td>4</td>
<td><code>&lt;targetNamespace&gt;</code></td>
<td>Low</td>
<td>Assigned Low priority URLs often contain few descriptive attributes of a WSDL document. As a result, URLs provide little relevance to users during semantic matching.</td>
</tr>
</tbody>
</table>

Ranking Similarity Combinations
To gauge the superiority of the different combinations of similarity measures, we applied a correlation coefficient. To provide basis for comparison, we first ranked the
services manually based on our judgment of the best service for the request. Then we used Pearson’s Correlation Coefficient to show how well a given combination of distance measures fared against the base ranking. In table 4, the column labeled HB represents the base ranking against which all other rankings are compared. The Pearson’s Correlation Co-efficient measures the strength of association between two variables or range of variables [26]. The correlation coefficients can be interpreted as follows: -1.0 to -0.7 strong negative association; -0.7 to -0.3 weak negative association; -0.3 to +0.3 little or no association; +0.3 to +0.7 weak positive association; +0.7 to +1.0 strong positive association.

Table 4: Interpretation of results

<table>
<thead>
<tr>
<th>#</th>
<th>WSDL</th>
<th>HB</th>
<th>J</th>
<th>C</th>
<th>JC</th>
<th>CJ</th>
<th>H</th>
<th>L</th>
<th>DL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Catalog.wsdl</td>
<td>1</td>
<td>30</td>
<td>17</td>
<td>17</td>
<td>29</td>
<td>27</td>
<td>22</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>BibCode.Query.wsdl</td>
<td>2</td>
<td>3</td>
<td>13</td>
<td>19</td>
<td>3</td>
<td>28</td>
<td>19</td>
<td>28</td>
</tr>
<tr>
<td>3</td>
<td>USAZipcodeInformation.wsdl</td>
<td>3</td>
<td>2</td>
<td>7</td>
<td>13</td>
<td>1</td>
<td>26</td>
<td>9</td>
<td>27</td>
</tr>
<tr>
<td>4</td>
<td>USAAddressverification.wsdl</td>
<td>4</td>
<td>31</td>
<td>32</td>
<td>32</td>
<td>32</td>
<td>32</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td>5</td>
<td>UKLocation.wsdl</td>
<td>5</td>
<td>32</td>
<td>31</td>
<td>26</td>
<td>31</td>
<td>31</td>
<td>2</td>
<td>31</td>
</tr>
<tr>
<td>6</td>
<td>MediCareSupplier.wsdl</td>
<td>6</td>
<td>29</td>
<td>20</td>
<td>31</td>
<td>19</td>
<td>29</td>
<td>3</td>
<td>29</td>
</tr>
<tr>
<td>7</td>
<td>ICD-10-CM.wsdl</td>
<td>7</td>
<td>8</td>
<td>10</td>
<td>16</td>
<td>4</td>
<td>25</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>8</td>
<td>ICD-9-CM.wsdl</td>
<td>8</td>
<td>1</td>
<td>8</td>
<td>10</td>
<td>2</td>
<td>20</td>
<td>29</td>
<td>25</td>
</tr>
<tr>
<td>9</td>
<td>ICD9tolCID10.wsdl</td>
<td>9</td>
<td>10</td>
<td>6</td>
<td>5</td>
<td>10</td>
<td>8</td>
<td>5</td>
<td>21</td>
</tr>
<tr>
<td>10</td>
<td>ICD9Drug.wsdl</td>
<td>10</td>
<td>5</td>
<td>4</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>11</td>
<td>HCPCS.wsdl</td>
<td>11</td>
<td>6</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>21</td>
<td>18</td>
</tr>
<tr>
<td>12</td>
<td>GetISBNInformation.wsdl</td>
<td>12</td>
<td>10</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>7</td>
<td>28</td>
<td>19</td>
</tr>
<tr>
<td>13</td>
<td>NucleotideSequence.wsdl</td>
<td>13</td>
<td>18</td>
<td>2</td>
<td>1</td>
<td>14</td>
<td>1</td>
<td>32</td>
<td>16</td>
</tr>
<tr>
<td>14</td>
<td>AustralianPostcode.wsdl</td>
<td>14</td>
<td>7</td>
<td>5</td>
<td>2</td>
<td>12</td>
<td>2</td>
<td>27</td>
<td>15</td>
</tr>
<tr>
<td>15</td>
<td>AirportInformation.wsdl</td>
<td>15</td>
<td>24</td>
<td>25</td>
<td>22</td>
<td>26</td>
<td>16</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>16</td>
<td>RoadDistance.wsdl</td>
<td>16</td>
<td>17</td>
<td>26</td>
<td>24</td>
<td>21</td>
<td>18</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>17</td>
<td>OligoSelection.wsdl</td>
<td>17</td>
<td>19</td>
<td>28</td>
<td>28</td>
<td>23</td>
<td>19</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>18</td>
<td>locationByZip.wsdl</td>
<td>17</td>
<td>10</td>
<td>9</td>
<td>4</td>
<td>15</td>
<td>4</td>
<td>26</td>
<td>14</td>
</tr>
<tr>
<td>19</td>
<td>Nearest.asmx</td>
<td>17</td>
<td>14</td>
<td>12</td>
<td>8</td>
<td>16</td>
<td>6</td>
<td>30</td>
<td>13</td>
</tr>
<tr>
<td>20</td>
<td>runnercalculator.asmx</td>
<td>17</td>
<td>16</td>
<td>15</td>
<td>11</td>
<td>17</td>
<td>9</td>
<td>25</td>
<td>12</td>
</tr>
<tr>
<td>21</td>
<td>Distance.asmx</td>
<td>17</td>
<td>20</td>
<td>18</td>
<td>12</td>
<td>18</td>
<td>11</td>
<td>17</td>
<td>11</td>
</tr>
<tr>
<td>22</td>
<td>RoutePlanner.asmx</td>
<td>17</td>
<td>27</td>
<td>24</td>
<td>23</td>
<td>27</td>
<td>15</td>
<td>13</td>
<td>7</td>
</tr>
<tr>
<td>23</td>
<td>WebService.asmx</td>
<td>17</td>
<td>25</td>
<td>23</td>
<td>20</td>
<td>24</td>
<td>14</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>24</td>
<td>locationByZip.wsdl</td>
<td>17</td>
<td>22</td>
<td>21</td>
<td>14</td>
<td>20</td>
<td>12</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>25</td>
<td>zipcodelookup.asmx</td>
<td>17</td>
<td>23</td>
<td>22</td>
<td>18</td>
<td>22</td>
<td>13</td>
<td>15</td>
<td>9</td>
</tr>
<tr>
<td>26</td>
<td>location.asmx</td>
<td>17</td>
<td>21</td>
<td>30</td>
<td>30</td>
<td>25</td>
<td>22</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>27</td>
<td>api.wsdl</td>
<td>17</td>
<td>9</td>
<td>16</td>
<td>25</td>
<td>7</td>
<td>30</td>
<td>7</td>
<td>26</td>
</tr>
<tr>
<td>28</td>
<td>addresslookup.asmx</td>
<td>17</td>
<td>15</td>
<td>11</td>
<td>9</td>
<td>11</td>
<td>10</td>
<td>31</td>
<td>17</td>
</tr>
<tr>
<td>29</td>
<td>Proximity.asmx</td>
<td>17</td>
<td>13</td>
<td>19</td>
<td>21</td>
<td>13</td>
<td>24</td>
<td>23</td>
<td>22</td>
</tr>
</tbody>
</table>
Conclusion

The wide adoption of WSDL and other text based description frameworks for describing services makes it incumbent that new ways of extracting relevant details are designed. In this paper, we provide a new approach to discovery of services WSDL by applying distance measures to tags other than the entire document. This approach allows combining distance measures for optimal results.

Our study further embraces the hybrid scheme by attempting multiple combinations of techniques in a bid to improve recall and precision. In conclusion, despite the known limitations of syntactic matching, we believe it offers an effective benchmark to gauge the relevance of platform independent service brokerage. Initial results with proposed approach showed that it is an effective mechanism to obtain a reduced set of syntactically relevant services with pre-defined importance and that are trustworthy.

References


Improving Learning objects reusability through automatic generation web services

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Abstract
To support current needs of flexible e-learning environments, there is need for improved techniques to create, mix and find and compose user e-learning resources. These techniques need to take advantage of the existing web infrastructure and tools to further provide seamless integration with the Internet where most learning objects live. The main enabler has been standardization efforts built around the notion of metadata. However, this standardization effort is not naturally supported by the web infrastructure where e-learning operates. In this paper, we take advantage of the widespread adaptability of web services to provide flexible and composable learning objects as services. We automatically transform learning objects and expose them as services, thereby allowing Learning Management Systems (LMS) to take advantage of the inherent flexibility, agility and mature tools within the domain of web services.

Keywords: web services, learning objects, re-use, e-learning

Introduction
The flexibility, self-learning and non-linear nature of electronic media has made e-learning a viable means to provide learning content. E-learning offers several benefits as opposed to traditional learning including location and time independence, and availability of content even in remote places(Gottfried Vossen 2008). Moreover, with the continuing
unprecedented rate of mobile phone penetration, e-learning is yet to reach its peak. Key to e-learning systems is the need to re-use existing learning resources to build larger and improved learning resources. To support this need, researchers in e-learning technologies have focused on interoperability, transportability and re-use improvement powered by the evolution of metadata standards such as IEEE LOM and ADL SCORM. However, a number of critical issues still remain open that require further attention and in-depth research. First, is that the domain of e-learning has far too many standards creating a new interoperability challenge. Secondly, all these have not kept pace with developments in web infrastructure – the natural home and platform for e-learning. For instance, they do not incorporate modern Web 2.0 techniques where the web is seen as an interactive environment rather than a repository of static documents.

Currently, the re-use, growth and interoperability of e-learning is premised on the use of Learning Objects (LO) (Wiley 2000; Downes 2003; Elliott 2004). LOs have been defined by Wiley (Wiley 2000) as “any digital resource that can be re-used to support learning.” The essence of LOs is to have foundational building blocks for e-learning content that can be re-used in different contexts. Consequently, an LO is neither built for a specific context nor for a specific pedagogical design. This definition further indicates that anything done in learning such as content delivery, learner assessment, interactivity between learner and instructor, among others, can be supported by a learning object. The standard for Learning Object Metadata (IEEE 2002) developed by the IEEE’s Learning Technology Standards Committee (LTSC) defines a learning object as “any entity - digital or non- digital - that may be used for learning, education or training.

A common challenge with learning objects is that the cost of producing effective teaching and learning materials is time consuming (V. Ahmed 2007). There is therefore need to support maximum reusability to allow for the remixing of LOs. A common characteristic of learning platforms is that it is difficult for learners to find appropriate educational services such as courses, seminars, and web-based training applications. Corporate and independent learners aim to choose educational services from heterogeneous sources and of heterogeneous quality. However, since an electronic, world wide infrastructure for the mediation of educational service offerings is missing, learners’ choices of educational services are limited towards pre-selected catalogues. It is still very difficult to orchestrate a combination of learning objectives to deliver a bigger learning goal.

Web services provide a means of organizing services to utilize distributed capabilities. They support means to publish, discover and bind applications through well-defined interfaces. The set of standards include a standard specification for public registries known as Universal Description Discovery and Integration (UDDI 2004), a description language namely Web Services Description Language (WSDL 2007), a distributed object communication protocol called Simple Object Access Protocol (SOAP 2007) and a dynamic, self-defining information specification Language with semantic support known as eXtended Markup Language (XML). With this set of technologies, web
services provide an essential deployment environment to realize dynamic e-learning/e-
busy systems by facilitating application-to-application interaction. Web services can
play a crucial role when it comes to the management of educational services. They can
be used to announce and contract educational services, register learners, and feedback
learning results. In order to combine educational services of different granularity
levels, a workflow model is needed. For example, you may need to enroll into a specific
assessment session before registering a course.

In learning objects repositories, online databases have been constructed by learning
object developers that contain learning objects and their corresponding metadata or
sometimes metadata only. Other online databases offer a centralized database containing
metadata of the available learning objects on a single server and the learning objects
are located elsewhere. Examples of such learning object repositories include Merlot,
CAREO, POOL and NSDC (Downes 2003). In learning content management systems,
a set of learning objects are integrated into one single package in such a way that other
learning object developers are able to locate them and the learning content management
systems are able to assemble the objects into standard compliant learning (Downes
2003).

The focus of this paper is to define transformation rules and develop a platform
that can be used to transform LOs into web services. Given that web services are
typically represented by WSDL files, we shall show how a LO object described in the
LOM standard can be mapped into a WSDL element. We also describe how the new
LO expressed as a service can take advantage of BPEL, an execution language for web
services to create larger combinations of LOs.

**Related Work**

Existing literature (Simon 2003; Devedzic 2004; Jose-Manuel et al., 2006) indicates that
there is a concerted effort to support reusability and easy construction of learning
objects. Beyond efforts in standards, (IEEE 2002; Downes 2003), there is general trend
that sees web services to be the ultimate solution for the current incompatible standards
in the e-learning domain.

In (Saddik et al., 2003), they propose a Web services oriented framework for
e-learning systems aimed at providing a flexible integration model in which all the
learning components and applications are well defined, effectively discovered and
loosely connected. In (Gonzalo et al., 2006), BPEL is proposed to bring orchestration
and collaboration of services.

Despite several efforts, we are not aware of attempts to auto-generate web services
from learning objects. In our work, we introduce the notion of generic operators and
also extend to composition of learning objects based on web service standards.

**Re-use in Learning Management Systems**

Much as a number of such learning objects standards exist, for example, IMS content
packaging standard, IEEE LOM standard, Dublin Core standard, among others, these
standards provide a common data structure for defining the metadata of the learning object (Downes 2003). According to (Downes 2003) and (Cebeci and Kara, 2008), this common data structure includes the following:

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifecycle</td>
<td>the history and current state of this learning object</td>
</tr>
<tr>
<td>General</td>
<td>description of the learning object as a whole</td>
</tr>
<tr>
<td>Meta-Metadata</td>
<td>information about the metadata instance</td>
</tr>
<tr>
<td>Technical</td>
<td>technical requirements and technical characteristics</td>
</tr>
<tr>
<td>Educational</td>
<td>educational and pedagogic characteristics</td>
</tr>
<tr>
<td>Rights</td>
<td>intellectual property rights and conditions of use</td>
</tr>
<tr>
<td>Relation</td>
<td>the relationship with other learning objects</td>
</tr>
<tr>
<td>Annotation</td>
<td>comments on the educational use of the learning object</td>
</tr>
<tr>
<td>Classification</td>
<td>relation to a particular classification system</td>
</tr>
</tbody>
</table>

The IEEE LOM standard requires that the learning object’s metadata be stored in a single XML file and then be made available for the purpose of easy discovery and retrieval of learning objects from the repositories (Downes 2003). Due to this requirement, this standard is divided into two parts; the first part, called IEEE LOM Data Model standard (1484.12.1) specifies a conceptual data schema that defines the structure of a metadata instance for a learning object. The second part called IEEE LOM XML Binding standard (1484.12.3) describes an XML binding to enable the exchange of LOM instances between conforming systems that implement the 1484.12.1 data model.

**Learning objects as Web Services**

In this section we show how learning objects can be automatically transformed into services. Consider the example in Listings 1, below of typical LO expressed in LOM.
Listings 1: Extract of LOM representation

```xml
<lom xmlns="http://ltsc.ieee.org/xsd/LOM"
     xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    <general>
        <identifier>
            <entry>lo_repo/content/1296294053.xml</entry>
        </identifier>
        <title>
            <string language="en">photosynthesis</string>
        </title>
        <language>en</language>
        <description>
            <string language="en">description of photosynthesis</string>
        </description>
        <keyword>
            <string language="en">plants</string>
        </keyword>
    </general>
    <educational>
        <description>
            <string language="en">1</string>
        </description>
        <language>
            <source>LOMv1.0</source>
            <value>final</value>
        </language>
    </educational>
    <technical>
        <format>web page</format>
        <location>http://www.wiki.com/plants</location>
    </technical>
</lom>
```

It can be observed that description at the basic level, a learning object should have three major parts summarized in the table below:

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Introduction
Which introduces the learner to the content presented in the LO. This could be a simple page that gives a summary about the LO.

## Body
Which is the actual content of the LO for the learning process. Here the content presented in the body of the LO largely depends on the pedagogical method used by the designer. For example, the designer might choose to divide it into three parts namely; Engagement, Apprehension and Comprehension.

## Application
which is where the learner applies the knowledge gained from the LO, say, through a quiz.

Similar to learning objects, a key component of web services is how they are described. Web services are generally described by an XML description document, expressed in the Web Service Description Language (WSDL). Given then that both LOM and WSDL are XML documents, the transformation process reduces to definition of mapping between the elements in the different documents.

### Transformation rules
The transformation of LOM to WSDL is supported by the commonality of tags. The table below shows the LOM elements (also known as tags), and their corresponding WSDL component transformations. To enable quick searching, some of the description elements are mapped onto operations. For instance, the General.Language tag can be mapped to both the Definition.Documentation tag as well as new operation called `getLanguage()` that can be called on the service. As a convention, the dot notation is used to denote nested tag elements.

<table>
<thead>
<tr>
<th>LOM</th>
<th>WSDL</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td></td>
</tr>
<tr>
<td>General.Definitions</td>
<td>Definitions</td>
</tr>
<tr>
<td>General.Identifier</td>
<td>-Targetnamespace = uri</td>
</tr>
<tr>
<td>General.Language</td>
<td>-Definition.Documentation</td>
</tr>
<tr>
<td>General.Description</td>
<td>-portType.Operation= getLanguage()</td>
</tr>
<tr>
<td>Metadata</td>
<td>-Message (an abstract, typed definition of the data being communicated.)</td>
</tr>
<tr>
<td>Technical</td>
<td>Binding (a concrete protocol and data format specification for a particular port type.)</td>
</tr>
<tr>
<td>Technical.Format</td>
<td>Types (a container for data type definitions using some type system (such as XSD).)</td>
</tr>
</tbody>
</table>
**Generic operations**

To address the different types of learning objects, we introduce the notion of generic operations during the transformation process. For instance, an LO whose content is a video clip needs to be supported by operations such as play, pause, preview, resume, view and so on. Below is a table of the operations supported.

<table>
<thead>
<tr>
<th>Content Type</th>
<th>Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Video</td>
<td>Play, Preview, Resume, Pause</td>
</tr>
<tr>
<td>Audio</td>
<td>Play, Resume, Pause</td>
</tr>
<tr>
<td>Text</td>
<td>Read, View, Bookmark</td>
</tr>
</tbody>
</table>

**Flexible Composition of Learning Objects**

BPEL is focused on the orchestration of SOAP web services and based on XML, so it facilitates the interchange formats and brings interoperability. It provides a relatively easy and straightforward way to compose several web services into new composite services called business processes. BPEL, therefore, extends the Web Services Interaction model, enabling support for business transactions. Business processes can be described either as executable, whereby the actual behavior of a participant in a business interaction is modeled, or as abstract, whereby descriptions specify the mutual message exchange behavior between parties without revealing their internal behavior (BPEL 2007). LOs can be exposed as web services, and described in an abstract manner, allowing for them to be easily integrateable, and reusable (as Figure 1 below illustrates) (BPEL 2007).
One of BPEL’s design goals is to define processes that interact with external entities through webservice operations defined using WSDL. This fits the use for LOM element transformation to web services. Each LO is exposed as a webservice, and the BPEL process specifies the exact order in which the services should be invoked.

The process receives a request, say for a specified education service, invokes the involved services, and responds to the request. For example, to compose a LO combining video and audio content types (services) together, the learner invokes the process by specifying the name of the content they wish to study. The BPEL process will then invoke the respective services for the audio and video content asynchronously and return the results to the learner, who will then choose the operation to be undertaken next. This defines a new composite/larger service built from existing services. It also gives the learner an opportunity to choose educational services that are from heterogeneous sources, and therefore quality.

**Implementation**

The implementation allows for automatic conversion of LOs to services and auto-generation of the WSDL document that describes the service. Figure 2, shows the user interface where the user can browse and load XML representations of the LOs. Once the XML is loaded, the middle button is then pressed to show the corresponding service on the right.
During conversion, it is very easy to check the original XML against the new WSDL document, given that both are displayed side-by-side as indicated in Figure 3. Once the web services are generated, they are stored in a repository, where they can be searched for for re-use using web service standards.

**Figure 3: LOM to WSDL transformation**

![LOM to WSDL Transformation](image)

**Improvements**

The LO to WSDL transformation brings with it all the advantages that web services offer, which can therefore be extended to the LOs, including, among others:

- The ability to engage and integrate other learning objects, also presented as web services and of different granularity levels, in order to compose larger objects and consequently achieve more comprehensive learning objectives.
- The learning objects, stored as web services, are able to inter-operate with other applications that are also based on open standards.
- The learning objects are then rendered more scalable, making it easier and cheaper to add features and other learning components, facilitating easy customization and enhancing reuse.
- Also, since the transformed webservies are stored in an online repository, they can be accessed at any time, from any location and provide an electronic infrastructure for mediation of education services.

**Conclusion**

In this paper, we defined transformation rules and developed a platform that can be used to transform LOs into web services. Further, we have described how flexible composition is achieved when LOs are expressed as services. The use of BPEL allows for innovative orchestration of learning resources with interoperability that is inbuilt into service-oriented architecture. As part of future work, we shall extend automated conversion of services to cover other LOs standards other than LOM.
We conclude by mentioning that a service-oriented approach to developing e-learning objects opposed to the conflicting and incompatible standards that has been the case in the past, is inline with general developments in web infrastructure, specifically web 2.0 that focuses on easy re-use, growth and interoperability of e-learning components.

References