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Editor-in-Chief’s Introduction

Disseminating Indigenous Computing and ICT Development in Africa

Computing and ICT no doubt form important pillars in the present day global modern technological processes and development. Although Africa can be said to have improved substantially in the quest for knowledge in this age, much structural advancement and progress in the larger part of the continent have not been noticed. This can be partly ascribed to the relatively meager investment and financial commitment to providing infrastructure for sustainable research. The effect of this is that the technological state and needs of the general African continent are not the same as those of the developed world. As such, research output which may be important for the present socio-econo-technological state of the continent may not quite appear useful in the developed world, and are thus usually not considered fit for their journals. Apart from this, there are relatively few journals based in the African continent that are devoted exclusively to papers on computing and ICT.

It is in the light of the above that the *African Journal of Computing & ICT* is born for the purpose of publishing nontrivial relevant research results in the fields of computer science/engineering, information technology(IT) and allied fields. Every submitted paper is multiple blind-reviewed for quality, relevance, depth and accuracy. We are committed to excellence in publishing and desire that the Afr, J of Computing and ICT will be a prime avenue for the dissemination of cutting edge research report by Africans, for Africa and all lovers of research and development all around the world.

Dr. Longe Olumide has joined the Editorial Board of the African Journal of Computing and ICT as the Managing Editor to further push our desire for consistent and quality publications. His medas touch is brought to bear on this particular volume. We warmly welcome him and look forward to a continuous stream of quality and excellent publications from our stables as he functions as the production and managing editor.

We intend to promote indigenous Computing and ICT development through the dissemination of cutting edge research and development report with a view of reducing the heavy dependence on importation of ICT-related products. The journal welcomes papers from African scholars and also from non-Africans whose papers address important issues that are relevant to Africa.

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Preface to Vol. 4, Issue No. 1

There are a total of eight papers in this volume of the African Journal of Computing & ICT. These papers provide insights into frameworks, cases and innovations that have bearing on research and developments in Computing and ICTs in Africa and beyond.

The opening paper by Onifade and Adebayo presents a novel framework for face recognition where real-time recognition is required on a large scale; the approach adopted is multi-component autonomic grid-based computing which gives a scalable system. The framework introduces separation of the system into different functional component such as the main recognition engine, live-scene capture engine, distributed data repository and the notifying subsystem which all works together to achieve a common goal.

Olawuyi et al’s paper examined the performance of four wavelet family—haar, DB4, Dmey, Coif3, Sym4, in denoising a cardiac Magnetic Resonance Image(MRI), using the Mean Square Error (MSE) value and the Peak Signal to Noise Ratio(PSNR) evaluation factors. The Haar wavelet produced the lowest MSE of 9.7013e-028 and the highest PSNR of 318.26 decibel.

Akinola and Ososifan’s paper evaluated the effectiveness of Ad hoc and Checklist-based software inspection reading techniques in a paper- based environment. Code inspection artifacts seeded with a number of bugs were inspected for bugs by volunteer reviewers. Findings for the repeated experiments were presented.

Richard Boateng reviewed e-commerce and strategy management literature to develop a resource-based model for e-commerce benefits was undertaken. The process-based model provides an understanding of how to identify, integrate, and reconfigure resources to achieve electronic commerce benefits and provides propositions that serves as theoretical platforms for future empirically grounded research on electronic commerce in developing country contexts.

Longe et al employed port knocking sequence, steganography and cryptography as techniques of choice for the development and implementation of a scalable port knock system(SKAM) that protects knock sequence transmission as well as services running on the network server. System performance was evaluated using standard probe tools and obtained very promising results.

Kufre et al examined the circles of network abuse outlined in Network Service Organization’s computer use policies using Airtel Nigeria Plc as a case study. Using questionnaire and other statistical tools analysis of user responses showed that although some actions are prohibited, employees circumvent the security measures put in place in connivance with some IT department staff.

Onuigbo investigated the extent to which students with visual impairment access and uses the internet for knowledge generation and dissemination in Nigerian universities. Descriptive survey design was adopted with findings indicating that students with visual impairment can only access the internet to a low extent due to unavailability of some assistive technology devices.

Finally, Omowunmi Longe’s paper analysed the growth of spectrum utilization by Nigeria television stations in the past ten (10) years and attempt to give a forecast of what it will look like in ten (10) years time. The availability of spectrum and the generosity that follows its’ allocation to broadcasting stations were evaluated in the light of maximizing spectrum allocated to TV stations for use for their maximum use and profit.

Have an insightful and rewarding reading.
The African Journal of Computing and ICT (AJCIICT) was established by the Nigeria Computer section of the Institute of Electrical and Electronics Engineers (IEEE) Inc, New York, USA. Afr. J of Comp and ICT publishes both online and print editions in April, August, December. The Journal solicits original research articles from interested authors for her upcoming editions. The goal of the journal is to contribute to rapid IT developments in Nigeria, Africa and the world through the publication of topical and relevant papers from theoretic/academic and practical / industrial points of view. Submitted papers should contain substantial ideas which have the potential of aiding an invention or a technological breakthrough for general and specialized use.

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Papers are welcome from pure/applied computing and ICT, and allied areas including but not limited to software engineering, computer communication/networks, human computer interaction, data mining, discrete/data structures, design & analysis of algorithms, web security, systems architecture, ubiquitous computing, systems design, information systems, bioinformatics, information management, information science and e-systems (e-health, e-learning, e-government).

The journal considers original research papers, case reports and review papers. Authors must clearly justify the importance of their submission to the readership of the journal. Prospective authors need not be a member of the (Computer Chapter) IEEE Nigeria Section before his/her paper is published. All papers are peer refereed and authors of accepted paper(s) will be required to sign copyright forms before papers are published. The AJCIICT Publication guideline is on the next page(s).

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The block structure is adopted for this journal.

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Table headings/titles should be written above the tables. Figure headings should be written below the tables. These titles should proceed sequentially within the body of the text. Fig. 1 for the first figure, the next Fig 2 etc. Figures should not be numbered based on subsections of the manuscripts. Tables should also be labeled in the same sequence. Centralize Figures. Align Tables to the LEFT.

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ACKNOWLEDGEMENT

A section on acknowledgement for sponsored research, collaborations, funds, grants/other research material sources

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List and number all bibliographical references in 10 point Times, single-spaced, at the end of your paper. When referenced in the text, enclose the citation number in square brackets, for example [1]. Where appropriate, include the name(s) of editors of referenced books.

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Framework for a Dynamic Grid-Based Surveillance Face Recognition System

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Abstract

Face recognition has in recent times achieved an onward approval from people compared to other biometric systems, this is because of its many application areas such as authentication systems, security systems, surveillance systems etc among others. More so, recognizing faces poses as a major form of daily human social intercourse. However, existing face recognition systems are computationally intensive such that their performance under heavy load as applicable under systems like large scale surveillance systems where real-time operation is required is questionable. This work presents a novel framework for face recognition where real-time recognition is required on a large scale; the approach adopted is multi-component autonomic grid-based computing which gives a scalable system. The framework introduces separation of the system into different functional component such as the main recognition engine, live-scene capture engine, distributed data repository and the notifying subsystem which all works together to achieve a common goal. For the face recognition engine, principal component analysis is combined with a feature based technique. This paper describes the proposed architecture in detail.

Keywords - Component analysis, Authentication, Face Recognition, Grid Computing, Biometrics

1. INTRODUCTION

The human face is generally considered to be a universal signifier for peoples unique identity, thus a major goal of human-computer interaction has been the tasks of making computers recognize people from their faces, the reason being that the human face is the main focus of attention in social intercourse and thus plays a major role in conveying identity and emotion. Humans learn faces after a very brief exposure to them, in fact, we can recognize thousands of faces learned throughout our lifetime and identify familiar faces at a glance even after years of separation irrespective of the mood, facial expression, age and general beauty make-ups.

Interestingly, this skill is quite robust, despite large changes in the visual stimulus due to viewing conditions, expression, aging, and distractions such as glasses, beards or changes in hair style. In order to really understand how the brain works and apply the model to the field of computer vision, researchers in face recognition have over time looked at cognitive science with the hope that some mechanism of the brain will be uncovered that would lend itself to be modelled in a computer algorithm, and thus eventually leading to better face recognition systems [5].

However, even though the computer has not been able to truly model the human recognition capabilities in terms of accuracy, it is still useful to have a machine perform pattern recognition. For instance, a machine that reads passenger passports at the border and compare the passport to the facial picture of the owner can process many more passports than a human being in the same time.
This kind of application saves time and money, and eliminates the requirement that a human perform such a repetitive task when they are even prone to making some errors as the computer can easily overcome. In fact, a key potential advantage of a machine system is its memory capacity [5], whereas for a human face recognition system the important feature is its parallel processing capacity where collective usage of auditory, tactile, visual and some other senses are in use [7].

Face recognition is a sub-area of the general pattern recognition problem. Identifying an individual from his or her face is one of the most non-intrusive modalities in biometrics. Biometric is an automated method of identity verification or identification based on the principle of measurable physiological or behavioural characteristics such as finger-print, iris pattern, facial characteristics or a voice sample [2]. Face recognition is of particular interest here because of its wide variety of applications in fields such as law enforcement for mug-shot identification, verification for personal identification such as driver’s licenses and credit cards, gateways to limited access areas, and surveillance systems generally. Due to these, face recognition has continuously gained approval over time.

A Grid is considered to be a decentralized system spanning multiple administrative domains, encompassing multiple platforms and systems, that provides a nontrivial quality of service to a broad audience of clients, where both the set of users and the total set of resources can (and do) vary dynamically and continuously [24]. It handles a large number of hardware and software systems in order to perform functions and computations on high volumes of data. Uniform and transparent access to heterogeneous systems is provided to both the end user and the users’ applications. It is a flexible mechanism through which one can locate and manipulate resources based on a user’s needs combined with a set of rules and permissions. In fact, grid helps enable more effective and nearly seamless collaboration of widely dispersed subsystems as required in the proposed framework.

The adoption of grid computing in this framework is obvious, grid can enable large-scale applications, and the combining of thousands of computers to perform single or many hundreds of tasks.

It provides transparent access to high-end resources and power as found in supercomputing environments from different clients in each sub-system as being proposed in this framework. It further can provide a uniform look and feel to a wide range of resources. This uniform interface will allow clients systems to access files and other resources from the server while also maintaining load balancing. It finally allows for visualization location independence. Computational resources can be separated from data and data can be widely separated (in geography as well as in disparate operating systems) from other pieces of data. Several approaches to modelling facial images exists, these includes Principal Component Analysis, Local Feature Analysis, Linear discriminant analysis and Fisher face which are all based on dimensionality reduction.

Also neural networks, elastic bunch graph theory, 3D morphable models and multi-resolution analysis are some other techniques usually used. Our work focuses on a framework for a scalable grid-based face recognition system. For the face recognition engine subsystem, our preferred technique is the principal component analysis; a holistic approach, among the various techniques available in combination with a feature based approach. Principal component analysis is based on Karhunen-Loeve transform and is our choice because of its simplicity, learning capability, robustness to small changes in the face image, speed and lesser computational overhead when compared to other techniques.

This work presents a general framework for an autonomous grid-based face recognition system that can function efficiently on a real-time scenario. Our work is different from the existing works because of the decentralization of the face recognition system into different functioning components and application of several pre-processing algorithms to serve as multiple filters for the image in order to reduce the false acceptance rate (FAR) and false rejection rate (FRR) in the face recognition engine sub-system. It should be noted that from the list of literatures we’ve come across on face recognition till date, there isn’t anyone that apply the concept of grid computing to recognition, thus making this work unique and novel. The remaining part of this work is divided into four parts. The following section is the literature review on face recognition system, followed by the detailed analysis of the methodology of framework being proposed and then the section showing the results obtained when the face recognition engine is singly tested. The last section contains our conclusion and future works.
2. RELATED WORKS

Reference [4] have a comprehensive survey of different face recognition techniques which include detailed description and classification of the algorithms both for still and video based recognition and should be consulted for further review. Most works in computer recognition of faces has focused on detecting individual features such as the eyes, nose, mouth, and head outline, and defining a face model by the position, size, and relationships among these features. Such approaches have proven difficult to extend to multiple views and have often been quite fragile, requiring a good initial guess to guide them. Research in human strategies of face recognition, moreover, has shown that individual features and their immediate relationships comprise an insufficient representation to account for the performance of adult human face identification.

Nonetheless, this approach to face recognition remains the most popular one in the computer vision literature. One of the first works in face recognition was in [5], where a face recognition technique which focuses on detecting important facial features or key-points such as the eye corners, nose tips, mouth corners and chin edge was implemented. Relative distances between facial key-points were measured and a feature vector constructed to describe each face. These feature vectors were then used in comparing known faces in the database to unknown probe faces.

In reference [6], semi-automated face recognition with a hybrid human-computer system that classified faces on the basis of fiducially marks entered on photographs by hand was implemented. Parameters for the classification were normalized distances and ratios among points such as eye corners, mouth corners, nose tip, and chin point. Also [7], attempted to measure similar features automatically. They described a linear embedding algorithm that used local feature template matching and a global measure of fit to find and measure facial features. In [8] the system was later improved on, based on deformable templates, which are parameterized models of the face and its features in which the parameter values are determined by interactions with the face image. In [9] and [10], an associative network with a simple learning algorithm that can recognize face images and recall a face image from an incomplete or noisy version input to the network was described and was later extended in [11] by using nonlinear units and training the system by back propagation. In [12], all steps of the recognition process were automated, using a top-down control strategy directed by a generic model of expected feature characteristics.

The holistic approach makes use of template matching and identifies faces using global representations i.e. the whole face is seen as one object [13], then extract features from the whole face region. In this approach, as in the previous approach, the pattern classifiers are applied to classify the image after extracting the features. A method of extracting features in a holistic system is by applying statistical methods such as Principal Component Analysis (PCA) to the whole image.

PCA can also be applied to a face image locally; in that case the approach is not holistic. Irrespective of the methods being used, the main idea is the dimensionality reduction. A method usually used is the Eigenface Method by Turk and Pentland [14] which is based on the Karhunen-Loeve expansion. Their work is motivated by the ground breaking work of Sirovich and Kirby [15], [16] and is based on the application of Principal Component Analysis to the human faces.

The main idea here is the dimensionality reduction based on extracting the desired number of principal components of the multi-dimensional data where the first principal component is the linear combination of the original dimensions that has the maximum variance; the n-th principal component is the linear combination with the highest variance, subject to being orthogonal to the n-1 first principal components. The sole aim here is to extract the relevant information of a face and also capture the variation in a collection of face images and encode it efficiently in order for us to be able to compare it with other similarly encoded faces.

Reference [17] proposed a method using PCA which detects the head of an individual in a complex background and then recognizes the person by comparing the characteristics of the face to those of known individuals. Also, in [18], PCA was used for coding and compression for video streams of talking heads. They suggest that a typical video sequence of a talking head can often be coded in less than 16 dimensions. Also in [19], a similarity measure for direct image matching based on a Bayesian analysis of image deformations was proposed. They modeled two classes of variation in object appearance: intra-object and extra-object. The probability density functions for each class are then estimated from training data and used to compute a similarity measure based on the posteriori probabilities. They further present a novel representation for characterizing image differences using a deformable technique for obtaining pixel-wise correspondences. This representation, which is based on a deformable 3D mesh in X-Y-Z-space, is then experimentally compared with two simpler representation i.e. intensity differences and optical flow.
In [20] the use of PCA and Gabor Filters was suggested. Firstly, Gabor Filters, Log Gabor filters and Discrete wavelet transform were used to extract facial features from the original image on predefined fiducial points. PCA was then used to classify the facial features optimally and reduce the dimension. The approximation coefficients in discrete wavelet transform was extracted and was then used to compute the face recognition accuracy instead of using all the coefficients. They suggest the use of combining these methods in order to overcome the shortcomings of PCA. Also, [21] argued that, when raw images are used as a matrix of PCA, the eigenspace cannot reflect the correlation of facial feature well, as original face images have deformation due to in-plane, in-depth rotation, illumination and contrast variation. Also they argue that, they have overcome these problems using Gabor Filters in extracting facial features.

Reference [22] implemented a feature based system; they used a fairly simple fingerprint which includes eye and skin colour, ratios of distances between prominent facial features such as eyes, mouth, nose and chin, and absolute and relative values of width and height of the face and the eyes. The system described the overall geometrical configuration of face features by a vector of numerical data representing position and size of main facial features. First, they extracted eyes coordinates. The interocular distance and eyes position was used to determine size and position of the areas of search for face features. They claimed that their experimental results showed that their method is robust, valid for numerous kinds of facial image in real scene, works in real time with low hardware requirements and the whole process is conducted automatically as applicable for an amber alert system they implemented.

A feature-based technique for face recognition in which eigenface was applied to sub-images (eye, nose, and mouth) was implemented in [23]. In it, they applied a rotation correction to the faces in order to obtain better results.

3. DESIGN FRAMEWORK

Advancement in face recognition systems and evolving algorithms implies development of systems that are highly capable most especially for the surveillance system we have in mind in this work, the high capabilities does not however translate to efficiency when fast and accurate recognition is required under a real-time scenario in a large environment encompassing territories. For instance, a surveillance system that is capable of monitoring and relaying real-time video-feeds across various mounted cameras on the streets of a city as big as Lagos (Nigeria) and probably monitoring and tracking movements of people in case of any social unrest or robbery and performing live-matching of the faces captured from the live feeds to the face of some criminals already in the database at real-time will obviously do well under a grid based system.

This is so because such a task is computationally intensive and requires the use of extremely expensive high performance systems to perform optimally at real-time, this work proposes clustering of inexpensive systems under a grid setting to give such a high performance as may be required at a lesser cost. The framework offers a system that is reliable and dynamic because it can easily swap between working environment in the grid network based on load available on different clients, while also affording availability based on its clustered back-ups of camera feeds across multiple clients in the storage sub-system.

The framework is scalable, robust and offers live support for addition or replacement of different components such as client systems across multiple geographical sites as need arises.

3.1 System Description

In this section, we describe the various components in the proposed framework. The main functional components in the framework architecture are the request server/scheduler, data-capture engine, video processor, clustered live video-feeds databank, core face recognition engine and finally the feedback/alert system. In all, we have six independent functional components all working together real-time to achieve a common purpose.

It should be noted that the main benefit of grid computing adopted in this work is seamless collaboration of different sub-systems, as such under each subsystem, i.e. those mentioned above, we have different systems (clients) that are working independently as a single subsystem e.g. the data-capture engine may have several cameras spread over a large geographical area tracking suspects, each of the camera is a single system but the whole of the camera works as a single system with a super camera with broad geographical coverage, it should also be noted that the architecture supports real-time addition or removal of any clients as need may arise e.g. many cameras may be added or removed to the data-capture engine at any time to capture more areas. The main framework architecture and how the components interrelate are shown in the figure below.
The components and their respective functions are described below in detail.

3.1.1 Data-Capture Engine

The data capture engine is responsible for capturing live data feed from several cameras mounted at different places. After getting the frame from the camera, it contacts the scheduler to confirm the loads weights on the video processor and request for the address of the clients on the video processor that is free and that it can deliver the video frame to, the video processor also has many clients under it spread across some geographical space, the scheduler checks the weight on each of these clients and then decide the one with no load (or the lowest load) at that particular time, the scheduler then automatically copy the name and address of this client to the requesting client from the data-capture engine, the client then register with the video processor which then processes the incoming video feeds.

3.1.2 The Video Processor Engine

The video processor does no work than the work of a validation and pre-processing of the data from the data-capture engine. Upon receiving the video frame, it makes the video frame to pass through a motion detection engine which in itself is a component of the video processor. The motion detector serves the purpose of validating the frame, if motion is not detected from the frame i.e. if there is no movement from the frame, the frame is automatically dropped.

This is because the camera input should be a video stream and detecting no motion means the frame is either corrupt or improperly sent. If motion is detected, the video processor invokes its face detector which detects and localizes the faces in the frame. Thus here, we have the face or list of faces in the video stream and the whole video stream.

The video processor then generates a movie from the video stream and timestamp it with an identity number and its location code. The next thing is for the scheduler to be contacted for the most available client on the live-video stream databank in order to save the face image(s) and the movie for use by the face recognition engine. However, before a stream is transported to the databank for storage, the video processor compresses it to save bandwidth and for faster sending across the grid network. Finally, the video processor makes a copy of the face image(s) detected from the video frame and localized by the face detector invoked as described above and sends it to the face recognition engine. However, it also contacts the scheduler for the address of the most available client under the face recognition engine before sending the face images.

3.1.3 The Video Stream Databank

This does no job than acting as a data repository. Because of the huge amount of space video stream takes up, many clients are involved as data repository system; however, they are all synchronized for easy access and data sharing across the network. The storage is divided into two such that one is for the faces localized from the video stream and the other if for movies generated from the video stream.
When any movie is requested from the databank at a later date, the scheduler checks for the timestamp and then locates the exact system on which the movie is residing. It then retrieves the movie and passes it to the feedback system from which the request is being made. This also makes replaying of the original camera feed possible when a face is recognized from a centralized location.

3.1.4 The Scheduler / Request server

This acts as the central server on which other system depends on for information. It manages the traffic and balances load from clients to clients under various subsystems such that no deadlock is experienced at any point in time. In fact, it acts as dynamic centralized information portal. The request server also have many clients under it which does a synchronize job to service various claims and requests at real-time. This allows for near real-time acquisition of load information, number of clients using the component, the maximum number of connections allowed and of course the address of different clients under each of the components.

3.1.5 The Face Recognition Engine

This is the heart of the system; it contains the face-recognition engine. It receives the copy of face image(s) from the video-processor, performs online training and compares the image(s) to the images in the face database.

The face recognition task on a large scale of images is quite computationally intensive; this component requires a hefty pool of high-performance machines in order to achieve real-time performance. If the number of face images delivered to the face recognition engine at any particular time is more than the number of face recognition clients available to process the images, then the images not processed at that time are buffered by the scheduler and then later resubmitted to any available clients for later matching of the faces. When a match occurs, an event is sent to the feedback system (with the image from the camera feed, the matching image from the database, date, and location of match) which distributes the events (i.e. the image that is recognized and the movie generated and stored from the video stream) to all the clients under it.

It should be noted that the feedback system also have many clients under it which constantly listen to an alert of any match by the face recognition of a face to any of the face in the face database. The retrieval of the movie of the live scene from the live video-stream databank is made possible because the faces localized from any stream is given the same identity with the video stream from which it is detected before being stored in the live-video stream databank.

All these happen at real-time and is possible because of the processing power generated from having pools of many systems synchronized together as obtained under a grid environment.

For the face recognition engine Principal Component Analysis is adopted and then combine with a feature based technique; principal component analysis is performed on the image set in order to calculate the eigenfaces which are then stored for later use, keeping only the M images that correspond to the highest eigenvalues. These M eigenfaces define the M-dimensional “face space". As new faces are experienced, the eigenfaces can be updated or recalculated. The corresponding distribution in the M-dimensional weight space is calculated for each face database member, by projecting its face image onto the “face space” spanned by the eigenfaces. The corresponding weight vector of each image in the database is then updated and recognition can be performed after we might have added the weights computed from the feature based. The algorithm below depicts the steps taken when computing the eigenface and weights using the PCA.

1. Let’s assume the face images in our database is \( x_1, x_2, x_3, x_4, \ldots, x_M \) then we find the mean image which is \( \Psi = \frac{1}{M} \sum_{i=1}^{M} x_i \).

2. Next, we have to know how each face differs from the mean image above like this \( \phi_i = x_i - \Psi \).

This set of very large vectors is then subject to principal component analysis, which seeks a set of M orthogonal vectors, \( U_k \), which best describes the distribution of the data. The kth vector, \( U_k \), is chosen such that the eigenvalues \( \lambda_k = \sum_{i=1}^{N} (U_k^T x_i)^2 \) which is also subject to eigenvector \( \lambda_k \) of \( U_k \), where the vectors \( U_k \) and scalars \( \lambda_k \) are the eigenvectors and eigenvalues, respectively of the covariance matrix \( C \) of the training images depicted as \( C = \frac{1}{M} \sum_{i=1}^{M} x_i x_i^T = \lambda_k \phi_k \phi_k^T \). In essence we are calculating the covariance matrix \( C \).

3. The matrix \( A = [\phi_1, \phi_2, \phi_3, \ldots, \phi_M] \). The covariance matrix \( C \), however is \( N \times N \) real symmetric matrix, and determining the \( N \) eigenvectors and eigenvalues is an intractable task for typical image sizes. We need a computationally feasible method to find these eigenvectors.

Following these analyses, we construct the \( M \times M \) matrix \( L = A^TA \) where \( L = \phi_i^T \phi_j \) and then find the M eigenvectors, \( V \), of \( L \). These vectors determine linear combinations of the M training set of face images to form the eigenfaces \( U_i \). Which we represent as \( U_i = \sum_{k=1}^{M} V_i \phi_k \) where \( i = 1, \ldots, M \).
The associated eigenvalues allow us to rank the eigenvectors based on how useful they are in characterizing the variation among the images. It should be noted that the eigenvalues is an integer value associated with the eigenfaces/eigenvector U.

These eigenvalues are used to construct weights which are kept in the database with the label of that image i.e. the name of the person. Recognition is delayed till after extracting the important features and computing weight for the image with our feature based technique.

3.1.6 Feature Extraction and Ranking
Humans have always identify faces perfectly despite the marked similarity of faces as spatial patterns, this is possible because of our ability to extract invariant structural information from the transient situation of faces such as changing hairstyles, emotional expression, and facial motion effect. In fact, features are the basic elements for object recognition. Therefore, identifying and extracting effectively used features in human face recognition may be very useful. In this work, in addition to the eigenface method apply above, we carefully choose some features that we found to be very important and that mostly differs from person to person e.g. we found that the distances between the eyes, nose, and mouth were not useful as they vary little between people and thus we do not consider them for usage, likewise we found the eye and skin colour, ratios of distances between prominent facial features, and absolute and relative values of width and height of the face and the eyes to be useful. For each facial image, we create fingerprint of some features, these fingerprints were determined based on our analysis of facial images and the variations between them. The list of our finally chosen features includes:

- red, green, and blue values of the eye colour
- ratios between the red and the green values of the eye colour denoted as RG
- ratios between the green and the blue values of the eye colour denoted as GB
- ratios between the red and the blue values of the eye colour denoted as RB
- the width and height of the eye
- the ratio between the width and height of the eye
- the ratio between the distance between the two eyes and the distance between the eye-line and the nose-tip
- the width and height of the face
- the ratio between the width and height of the face
- the RGB values of the skin colour
- The number of lines passing around the chin. Here, we use Hough transform to determine this.

All these are extracted as shown in the diagrams below and a weight computed from them as documented in [25].

Fig 3.0. Eye and head midpoint localization and Left and right eye measurement.

Average eye height (H) = (a1 + a2) / 2
Average eye width (W) = (b1 + b2) / 2
Ratio between the width and height of the eye = H/W
Ratio between the left and right eye’s height = a1 / a2.
Ratio between the left and right eye’s width = b1 / b2.

Fig 3. Average Eye Used.

Fig 4.0. The Face Measurement.
The eye midpoint = d / 2.
Finally, we look at the weight computed by the eigenface technique above for each of the image labelled identically and add the value to the corresponding weight aggregate from the features extracted. This we use as our final weight ranking of each image. The face recognition engine can be represented diagrammatically as below.

**Fig 5.0 The Face Recognition engine**

**3.1.7 The Feedback System**

This is the user interaction subsystem of the framework. It receives the face recognition events and it’s responsible for showing the various operators (the user) that a face recognition match between an image in the face database and the live-camera-feed from the video processor occurred. The location of the camera along with date, the camera image as localized by the video processor and the matched image from the face database is submitted to the feedback system.

It provides a centralized pool where events are recorded. Having a single point (or many single points) where events are stored facilitates the instant comparison of the matches with the camera’s feed. This allows for humans to verify the result and act accordingly if there is a need. The diagram below shows the operation of feedback systems. It should be noted that the feedback system also has many client systems that may be spread across a large geographical space for onward monitoring of any recognition being made.

The framework should be dynamic enough to support continuous addition of hardware equipments. It also should be robust, able to recover from errors and must be flexible and capable of addressing challenges that will constantly arise such as network loss of connectivity, power outage, demand for more components, notification of new services and switching new load onto them etc. The scheduler should constantly listen to the system and be able to easily detect any new components added in form of clients in any of the sub-systems.

**Fig 6.0 The Processes involved in the video-processor subsystem**

The systems being added should also give notification for proper registration by the scheduler so that it can be added to list of available resources to be managed. The scheduler should also constantly poll all the client systems for their load level and availability at a specified frequency (this must not however be too frequent to avoid creating overhead to client systems), addresses and location information while also being able to decide real-time within a relatively small time-space, the requested client with the least load and closest to the requesting client. As a dynamic system, components that are removed or faulty should be detected easily and subsequently removed from the list of available resources.

It is assumed that the components can and will stop working at some point, therefore the connection between the components can break at anytime and should therefore be re-established. If there are no desired components at the current time then the service should continue asking the scheduler for that component repeatedly until it’s found. When the required component is found, its address is cached and periodically checked.
This makes it possible to discover dead services and request new ones from the Scheduler. Likewise, if the connection is good, then, there is no need to query the scheduler for a least loaded service in the pool.

The next section contains the results obtained when the face recognition engine was tested.

4. RESULTS

We present the results obtained for the recognition rate on the face recognition engine when tested separately. The system was trained with our constructed face database of young people containing 15 subjects of 4 images each. The total image trained is 60 which are under different lightning intensity, scale and head pose. The testing was carried out using a total of 45 images, 3 images each of a subject from the people in the training database. We also tested the system with 15 images of unknown people, i.e. people that are not in the training database at all. The training of the system was carried out. Fuzzy-histogram equalization was applied for light variation. We also applied a rescaling algorithm for all the images to be of the same scale, background removal was not done to mimic a real scene experience but manual cropping was made where needed. The algorithms were implemented successfully using JAVA and trained and simulated on a Pentium-IV (2.0 GHz), 2GB RAM to provide valuable results.

In this discourse, we term the false acceptance to be the number of mistaken identity when any of the 15 unknown people as described above are used as probe and the system accept them as identified. Likewise, the false rejection is the number of mistaken identity when any of the real probe sets (45 images) is used and the system is not able to identify the person. The true acceptance depicts the recognition rate, i.e. the correct number of people the system is able to truly identify when the real probe set (45 images) is used and finally, the true rejection rate in this work is the number of people the system rejected as not identified when any of the 15 unknown images is used.

The table below shows the false acceptance and false rejection rate of the system.

<table>
<thead>
<tr>
<th>False accp</th>
<th>False rejtn</th>
<th>True accp</th>
<th>True rejtn</th>
<th>Total Images trained</th>
<th>Test data</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1</td>
<td>43</td>
<td>14</td>
<td>60</td>
<td>45</td>
</tr>
</tbody>
</table>

% of true acceptance/correct acceptance = 5.6%.
% of false acceptance/mistaken acceptance = 4.4%.
% of true rejection/correct rejection = 93.3%.
% of false rejection/mistaken rejection = 6.6%.

The experiment conducted was done real-time but not in a grid setting, we have however given the general framework for the real-time surveillance system we have in mind. The framework should work fine and at a real-time, the fast performance the face recognition engine has shown shows the system should achieve a real-time performance when coupled to the grid environment. The accuracy of the recognition engine in particular can be increased when many face recognition algorithms are combined to get a better hybridized system. The different hardware equipments to be used should also support concurrency, be fast and robust to physical and software errors.

5. CONCLUSION

We have proposed a framework for a grid-based face recognition system in this work. While not yet fully implemented, we expect a successful system in due course of time. The framework presents a dynamic, reliable, and scalable system. The pride of the framework, we believe is in the application of grid computing approach to the face recognition subsystem.

The system fully detail a novel surveillance system that has several components spread across a wide geographical space while working synchronously to achieve accurate recognition at real-time. At any rate, the framework should be easy to implement.

6. DIRECTION FOR FUTURE WORKS

Future works can extend this work to include mobile device like handheld camera device to be able to seamlessly connect directly to the grid easily and being able to feed the system with video inputs for on-the-scene criminal tracking. This particularly can be of great help to policemen that parade crime scenes. Improvements can also be made on the recognition engine for increased accuracy.
REFERENCES

Comparative Analysis Of Wavelet-Based Denoising Algorithms On Cardiac Magnetic Resonance Images (MRIs)

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ABSTRACT

Biomedical images are very much susceptible to noise, which has adverse effect on interpretation and analysis. The presence of noise in biomedical images is a major challenge in image processing and analysis. This is marked by the much attention given to denoising mechanisms in literature. Denoising techniques are aimed at removing noise or distortion from images while retaining the original quality of the image. This paper examines the performance of four wavelet family- haar, DB4, Dmey, Coif3, Sym4, in denoising a cardiac Magnetic Resonance Image (MRI), using the Mean Square Error (MSE) value and the Peak Signal to Noise Ratio (PSNR) evaluation factors. The Haar wavelet produced the lowest MSE of 9.7013e-028 and the highest PSNR of 318.26 decibel.

Keywords - Noise, De-Noise, Biomedical, Peak Signal To Noise Ratio, Mean Square Error, Wavelet

1. INTRODUCTION

The field of image proceeding is faced with the challenge of enhancing image for proper interpretation and analysis. Its development has been triggered by technological advances in digital imaging, computer processors and the need for storing massive data and information. The primary rationale of image processing is to translate images (visual objects) to information. To achieve this, however, image quality must be improved by filtering noise from images, highlighting regions of interest, and separating the object of interest from the background.

There three basic categories of algorithms for image processing in literature [1,3,4,11]. These groups include the middle level algorithms, the highest level algorithms and the lowest level algorithms. According to him, the middle level algorithms utilize low level results for further process, tasks such as segmentation and edge linking are achieved via middle level algorithm, while the highest level are those methods which attempt to extract semantic from the information provided by the lower levels, for example, handwriting recognition. The lowest level algorithm deal directly with the unprocessed and noisy pixel values of the images. They are characterized by the fact that both its inputs and outputs are images [3]. Examples of low level algorithms include edge detection and denoising.

De-noising can be defined as removing unwanted signal or distortion from an image. Noise in biomedical images poses a lot of problem to medical personnel by interfering with the interpretation of medical images for diagnosis and treatment of human. Image noise in a large measure contributes to health hazard faced by human. It affects the...
brightness and quality of an image, which are desirable composition needed for interpretation, classification, understanding and other image processing tasks. Image noise can be defined as the random variation of brightness or color information in images produced by the sensor and circuitry of a scanner or digital camera. Image noise can also originate in film grain and in the unavoidable shot noise of an ideal photon detector [8]. Noise is dependent on certain factors, including environmental and technical, noise in medical image has varying intensity.

The goal of de-noising is to produce the best possible estimate \( q(m, n) \) of the original image \( p(m, n) \). Image denoising is a common procedure in digital image processing aiming at the elimination of noise, which may distort an image during its acquirement or transmission, and at the same time retains its quality and important features.

The measure of success in de-noising is usually an error measure \( E(\hat{y}(m, n), y(m, n)) \) between the original \( y(m, n) \) and the estimate \( \hat{y}(m, n) \) [4]. The performance of the de-noising algorithms is quantitatively assessed using different criteria namely the mean square error (MSE), peak signal-to-noise ratio (PSNR) and the visual appearance [4]. However the visual appearance is predisposed to human error. Different wavelets denoising such as (haar) are usually employed in the denoising process because they have a good time and frequency localization which make them ideal for the processing of non-stationary signals like the biomedical signals, Electrocardiogram images (ECG) and Magnetic Resonance Images (MRI) [7,8]

Another important technique used in image denoising is thresholding. The purpose of thresholding is to convert a coloured image to a gray scale image based on a specified threshold value. There are different approaches to thresholding. These include hard and soft thresholding. Hard thresholding deletes all coefficients that are smaller than the threshold and keeps the others unchanged while the soft threshold deletes the coefficients under the threshold, but scales the ones that are left [4, 6].

2. IMAGE CORRUPTION & DE-NOISING

Each step in an image acquisition process may introduce unsystematic changes and variations into the pixels values of an image. These changes (or distortions) are called noise. This distortion or corruption can be classified into noise or blur (Divya, 2008). A noisy image can be represented by the equation below:

\[
I(t) = S(t) + N(t) \text{ wrt time } t
\]

Where,

- \( I \) is the noisy image
- \( S \) is the original signal/image
- \( N \) is the noise or distortion as a result of some interference (electrical, environmental et cetera.)

There are two different types of noise that can affect a biomedical image:

a. Additive noise: If \( I'(x,y) \) is the noisy digitized version of the ideal image \( I(x,y) \) and \( N(x,y) \) the noise function, then the additive noise can be defined as

\[
I'(x,y) = I(x,y) + N(x,y)
\]

Additive noise is independent of the pixel values in the original image and \( N(x,y) \) is usually 0, hence it does not affect the average brightness value of the image.
b. Impulse noise: also known as salt and pepper or poison or multiplicative noise. The source of impulse noise is usually the result of an error in transmission or an atmospheric or man-made disturbance. This noise model follows a Poisson distribution, that is:

\[ I(t) = (1 - e)S(t) + eN(t) \]  

Where \( e \) is a probabilistic value between 0 and 1.

Noise reduction is a required step for any sophisticated algorithms in computer vision and image processing [5]. De-noising is the techniques employed in removing noise from images. The goal of de-noising is to produce the best possible estimate \( X \) (best) of the original image \( I \). The measure of success in de-noising is usually an error measure \( E \) between the original \( I \) and the estimate \( X \) [4, 11].

3. WAVELET & WAVELET TRANSFORMS

Wavelets are small waves that oscillate with varying amplitude. When they combine with other techniques or parameters can be useful for extraction of information from unknown signal. Wavelet methods or algorithms for image de-noising are the most effective because of their ability to capture the energy of a signal in little energy transform values [6]. There are two types of wavelet transforms – discrete and continuous. The Discrete Wavelet Transform (DWT) is the best for computer programs as their work align with the discrete nature of computers. Here, the wavelet transforms signals into set of coefficients (high and low) with the aim of separating the low and the high signal into noise and quality information. Small coefficients are dominated by noise and hence have to be removed while large coefficients carry more information than noise and are retained for further analysis. In order to remove this noise the small coefficients are reduced to zero. To determine which coefficient is small and which is large, a particular threshold is set, such that coefficients below the threshold is considered small while the ones above the threshold is large.

From the foregoing the following steps are clear for implementing de-noising algorithms that use the wavelet transform.

(i) Compute the wavelet transform of the noisy signal.
(ii) Transform the noisy wavelet coefficients according to specified rule.
(iii) Find the inverse of the transformed coefficients.

3.1 Mean Squared Error (MSE)

This is one of the error criterion used in this work. MSE is a risk function, corresponding to the expected value of the squared error loss. Mean Square Error (MSE) function is commonly used because it has a simple mathematical structure that is easy to compute and it is differentiable implying that a minimum can be sought [4]. It is the squared difference between the original and the denoised image. The MSE is the difference between the original image and the denoised image. Given by:

\[ MSE = \frac{1}{MN} \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} (y(m,n) - \hat{y}(m,n))^2 \]  

Where, \( y(m,n) \) is the original image and \( \hat{y}(m,n) \) is the denoised image wrt image dimension \((m,n)\). A good denoising algorithm reduces MSE.

3.2 Peak signal to Noise Ratio (PSNR)

Another error criterion, PSNR measures the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the quality and reliability of its representation. It defines the purity of the output signal. PSNR is calculated as follows:

\[ PSNR = 10 \cdot \log_{10} \left( \frac{MAX^2_I}{MSE} \right) = 20 \cdot \log_{10} \left( \frac{MAX_I}{\sqrt{MSE}} \right) \]  

Where, \( MSE = \text{Mean Squared Error}, \)
\( MAX_I \) is the maximum possible pixel value of the image.

4. METHODOLOGY

Gaussian additive noise \( G(0, 1) \) was added to the Cardiac MRI in order to access the performance of the various noise filters (algorithms). The performance of the wavelet denoising were evaluated on Cardiac MRI using parameters (error criterion) such as Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE) and Mean absolute error (MAE). The MRI image was obtained from the MRI Center at http://www.mricenter.com/physicians/mri.htm. The cardiac MRI shown below was used for this experiment. The procedures taken for the performance evaluation include:
A. Add additive noise to the image  
B. De-noise the image  
C. Compute the Mean Square Error (MSE) of the different wavelet  
D. Compute the Mean absolute Error (MAE) of the different wavelet  
E. Compute Peak Signal to Noise-Ratio (PSNR) of the different wavelet

The classification into low and high frequency is depend on the threshold value that is set, decomposition result from one level is further restructures to get more details of the image. Therefore the higher the decomposition levels the better, although this also has a disadvantage, as excess decomposition may abstract details. Here the cardiac MRI was decomposed using the 2-level decomposition as shown below.

**Figure 3:** (a) CARDIAC MRI  
(b) Noisy Cardiac MRI  
(c) reconstructed Cardiac MRI

**Table 1: Level-dependent threshold wavelet denoising: Level 1**

<table>
<thead>
<tr>
<th>Wavelet type</th>
<th>PSNR (in decibel) value</th>
<th>MSE value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haar (db1)</td>
<td>317.9299</td>
<td>1.0474e-027</td>
</tr>
<tr>
<td>Db4</td>
<td>264.6464</td>
<td>2.2307e-022</td>
</tr>
<tr>
<td>Dmey</td>
<td>127.2909</td>
<td>1.2134e-008</td>
</tr>
<tr>
<td>Coif3</td>
<td>277.1063</td>
<td>1.2661e-023</td>
</tr>
<tr>
<td>Sym4</td>
<td>285.1621</td>
<td>1.9809e-024</td>
</tr>
</tbody>
</table>

**Table 2: Level-dependent threshold wavelet denoising: Level 2**

<table>
<thead>
<tr>
<th>Wavelet type</th>
<th>PSNR (in decibel) value</th>
<th>MSE value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haar (db1)</td>
<td>318.2625</td>
<td>9.7013e-028</td>
</tr>
<tr>
<td>Db4</td>
<td>255.4901</td>
<td>1.8369e-021</td>
</tr>
<tr>
<td>Dmey</td>
<td>122.3718</td>
<td>3.7661e-008</td>
</tr>
<tr>
<td>Coif3</td>
<td>267.9650</td>
<td>1.0389e-022</td>
</tr>
<tr>
<td>Sym4</td>
<td>272.6831</td>
<td>3.507e-023</td>
</tr>
</tbody>
</table>

5. EXPERIMENTAL RESULT & DISCUSSION

Images are collection of energies, decomposing them generates signals or energies of varying frequency, low frequency signals carries more noise than the ideal image quality.
The denoising algorithms were evaluated based on some error criteria. Efficient denoising algorithm maximizes the Peak Signal to Noise Ratio (PSNR) and minimizes the Mean Squared Error. From the table above, the haar (db1) has the least value for MSE and largest value for PSNR for both level of decomposition.

**6. CONCLUSION & RECOMMENDATION**

Biomedical images especially MRI is susceptible to noise, which has effect on its interpretation and understanding. Wavelet denoising has been adopted severally for biomedical image processing. Two error criteria have been evaluated severally for biomedical image processing. Two error criteria have been evaluated- the Mean Square Error (MSE) and the Peak Signal to Noise Ratio (PSNR), to evaluate the performance of the wavelet algorithms explored in this research. The wavelet that minimizes the Mean Square Error and maximizes the PSNR is considered the best for image denoising. The db4 wavelet has the maximum PSNR [4,10] and thus considered the best (Musoko, 2005). In this research however, the haar (db1) wavelet has the highest Peak Signal to Noise Ratio (PSNR) of 318.2625 and the minimum MSE (9.7013e-028). The dmey wavelet has the poorest performance with the least PSNR and the highest MSE. The Daubechies wavelets discovered by Ingrid Daubechies in 1992, is therefore proposed to be the best wavelet denoising algorithm, since the DB4 and haar (DB1) are from the Daubechies family.

**REFERENCES**


Evaluating Defect Detection Techniques in a Paper-Based Environment - A multi-Trial Experiment Report

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ABSTRACT

Software inspection is normally employed to detect bugs early in software artifacts when they are cheaper to fix. There are controversies on which is the most effective method that should be adopted in carrying out the inspection exercise. Ad hoc (AH) and checklist-based (CB) are the two most used software inspection reading techniques. Therefore, this work is aimed at evaluating the effectiveness of Ad hoc and Checklist-based software inspection reading techniques in a paper-based environment. Code inspection artifacts seeded with a number of bugs were inspected for bugs by volunteer reviewers. The experiment was repeated three times. The experimental design adopted for this research is an independent, two-group between-subjects. The experiments manipulated one independent variable: the review method (AH or CB). Five dependent variables were measured in the experiments: inspection effort, reviewers’ defect detection effectiveness, false positives, meeting gains and meeting losses. Reviewers were randomly assigned to the two levels of the independent variables. Analyses of data were done using independent t-test statistics at 0.05 significance level. Briefly results from the experiments show that the two defect detection techniques perform at the same level of effectiveness in the paper-based code inspection environment.

Keywords - Code Inspection, Defect Detection Technique, Ad hoc, Checklist, Defect Detection Effectiveness

1. RESEARCH BACKGROUND

Software inspection is one of the industry best practices for delivering high-quality software [11]. The main benefit of software inspections derives from applying inspections early during software development and then preventing the exponential growth of defect repair cost [10]. Formal software inspection process has increased in popularity continuously over thirty years in the western part of the world.

There hardly exists a software company that dares to confess publicly that it does not use any inspections at all [5]. Chatzigeorgiou and Antoniadis [1] in their article reports that “The number of software organizations that have incorporated formal reviews in their development process is constantly increasing and the belief that efficient inspections cannot only detect defects but also reduce cycle time, increases process visibility, improves programmers’ capability and lower costs is spreading”. Tyran [3] and Harjumaa et al., [2] also report that inspections have gained wide acceptance as a development tactic and can take up to 15 percent of the time allotted to a software project.

A critical observation of the counterpart software organizations in developing countries especially Africa shows that this software quality assurance is highly compromised in their software development process [4].
Empirical software inspection researches are also well-established among researchers in developed nations of the world. Results from these studies have had very great impacts on the quality of software being produced into the global market. Comparatively, little or nothing has been contributed from the African environment along this line of research. Nevertheless, it has been hypothesized that for empirical inspection experiments to gain credibility, it is necessary to conduct them in different environments, using different people, language, culture and documents [6, 7].

Considering the increasing importance attached to inspection on software in today's global environment, and couple with the fact that African nations especially Nigeria are waking up to the challenge of producing quality software into the global market, an initial survey of some software development houses in Lagos, Nigeria, on their perception and level of incorporating software inspection into their software process was carried out. 90% of the Nigeria software houses are situated in Lagos due to a high level of commerce activities in the area [8]. Results from the survey suggest that the software practitioners covered in the survey needs to be sensitized on the need to incorporate inspection into their software development process [25].

In order to achieve the sensitization objective, a multi-trial code inspection experiment was conducted with thirty professionals and 'para-professionals' with a view to evaluate the defect detection techniques (precisely ad hoc and checklist-based reading techniques) on some code artifacts. Twenty (20) of the reviewers were among those in the earlier surveyed practitioners. The experiments were carefully conducted in a well-coordinated experimental paper-based environment. Specifically, this work is done to actually revalidate the results obtained by researchers in developed economies in Nigeria (Africa) environment with the following main objectives:

(i) To determine if every software inspection really need formal meetings.
(ii) To determine if checklist method of inspection could have any significant improvement on the effectiveness of software inspection.

1.1 Inspection Reading Techniques in Brief

Software inspection process is normally done with 3 to 8 people including a moderator, reader and a recorder to take notes. The subject of inspection is typically a document such as a requirements specification, design document, code or a test plan and the purpose is to find problems technically referred to as bugs and see what is missing, not to fix anything [12, 17, 18].

Beginning from old landmark work of Fagan [9], several approaches have been proposed for carrying out the inspection exercise. For instance, meeting versus “meetingless” method [12, 13], N-fold [15], Active Design Review [16], phased inspection [17], tool support [18] and numerous others. The state-of-the-art approach is to conduct the inspection in a distributed collaborative environment [2, 14].

Ad hoc and checklist-based have been the major reading techniques used in software inspections. In practice, most industrial inspection implementations use Ad hoc or checklist-based reading (CBR) during defect detection [9, 19, 20]. Ad-hoc reading, as its name implies, provides no explicit advice for inspectors on how to proceed, or what specifically to look for during the reading activity. Hence, inspectors must resort to their own intuition and experience to determine how to go about finding defects in a software document. Checklists offer stronger support mainly in the form of yes/no-questions that inspectors have to answer while reading a software document, although it lacks concrete guidance for answering the questions [14].

Scenario-based reading techniques have been proposed to support the inspectors throughout the reading process in the form of operational scenarios [21]. A scenario consists of a set of activities aimed to build a model plus a set of questions tied to that model. While building the model and answering the questions, the reader should write down the defects he finds within the document. Each reader in the inspection team gets a different and specific scenario in order to minimize the overlapping of discovered defects among team members and then increasing the inspection effectiveness after defect collection at the meeting.

The first family of scenario-based reading techniques, Defect-Based Reading (DBR), was defined for detecting defects in requirements documents written in a state machine notation for event driven-process control systems [22]. Each DBR scenario is based on a different class of requirements defects and requires a different model to be built before answering to specific questions.

Perspective-Based Reading (PBR) is another family of scenario-based reading techniques which have been proposed to improve the inspection effectiveness for requirements documents expressed in natural language [23].
The idea behind PBR is that various customers of a product should read the document from a particular point of view. For PBR, the different roles are those within the software development process, for example, analyst, tester, user. [24]. In this work, we evaluate the effectiveness of ad hoc checklist-based reading techniques on code inspections.

1.2 Research Hypotheses

The following hypotheses were tested within the span of this empirical research study:

- \( H_{01} \): There is no significant difference between the effectiveness of ad hoc and that of checklist reading techniques in code inspection.

- \( H_{02} \): There is no significant difference between the effectiveness of preparations and that of real inspection meetings in code inspection process.

- \( H_{03} \): Inspections with large team size have longer inspection effort (time), but find no more defects than smaller teams.

1.3 Paper Outline

The rest of this paper is organized as follows. In Section 2, the design of, as well as threats to the validity of the experiments are explained. The results obtained from the experiments and their discussions are presented in Section 3. Summary and conclusions are presented in Section 4.

2. THE EXPERIMENTS

2.1 Subjects

Thirty (30) professional software practitioners were involved throughout the experiments out of which ten (10) industrial trainees from some universities in the country (University of Ibadan, Obafemi Awolowo University, Ile Ife and Lagos State University) were involved. The trainees were carefully selected so as to minimize validity threats to the experiments. Only trainees who had spent up to 5 months out of the required 6 months in their places of industrial attachments and who had done serious programming with java both at school and in the industry were recruited as part of the inspection teams. In addition, the trainees had completed the 3rd year (300 Level) at school. These trainees are tagged ‘para-professionals’ in this report. The reviewers were invited to the Computer laboratory in the Department of Computer Science, University of Ibadan, Nigeria on four week-ends between March to July 2009. The first weekend was used for introducing the participants to inspection techniques. Participants were randomly reassigned to teams for each experiment.

2.2 Experimental Artifacts

Three java codes were invented and seeded with some number of errors by the researcher for the experiment. The first artifact used was a 212-line Java code that accepts a one line mathematical expression, scans the expression for different brackets/braces in it and finally checks if the mathematical expression is well formed with respect to bracket usage and compatibility. For example, \((x - b(c + d))/(r + y)\) is well-formed while \((x-b(c + d)/(r + y))\) is not well formed due to incompatibility of the brackets. The program uses all the functionalities of stack data structure: push, pop, overflow, underflow, top and initialize. The code was seeded with 18 errors – 10 logical and 8 syntactic/ semantic.

Experiment 2 was performed using a 168-line java code that implements two popular algorithms: Bubble sorting and Recursive Binary search algorithms. The program accepts data into a one-dimensional array of variable size. Variable in the sense that java has the capability to dynamically set the size of an array. The program firstly sorts the array in ascending order using the bubble sorting technique. If a particular data is needed to be searched for in the array, the program employs the recursive binary search technique on the array to do this. If the data exists in the array, the program reports the data as well as the index of the array from which it was found; else it reports ‘data not found’. The program was seeded with 7 logical errors and 5 syntax/semantic errors, making a total of 12 seeded errors.

Experiment 3 was also performed using a 156-line java code that accepts data into two 2-dimensional arrays. These arrays were used as matrices. Major operations on matrices were implemented in the program such as sum, difference, product, determinant and transpose of matrices. All conditions for these operations are tested in the program. The code was developed, compiled successfully and implemented okay by the researcher before it was finally seeded with 18 errors: 12 logical and 6 syntax/semantic. The program accepts data into the two arrays, then performs all the operations on them and reports the output results of computation if there were no errors. If there were errors in form of operational condition not being fulfilled for any of the operations, the program reports appropriate error log for that operation.
2.3 Experimental Design

The experimental design adopted for this research is an independent, two-group between-subjects design. It is one in which participants were randomly assigned to the two levels of the independent variable (in this case, the review methods: Checklist or Ad Hoc). In this design, each participant is assigned to only one group (Ad Hoc or Checklist), and consequently, the two groups are independent of one another.

2.4 Variables

The experiments manipulated three independent variables: the number of reviewers per team (1, 2, 3, 4, or 5 reviewers, excluding the code author), the review method – ad hoc (AH) and checklist (CBR) and the phases of inspection – preparation and collection meeting.

Five 5 dependent variables were measured in the experiments: inspection effort in terms of time spent (in minutes) on inspecting the code artifacts, estimated defect detection ratio measured as a ratio of total true defects detected by the reviewers to the total seeded defects in the inspection artifacts, the number of defects first identified at the defects collection meeting (Meeting Gains), the number of defects found at preparation but never reported at meeting (Meeting losses) and the percentage of defects reported by an individual or group that were determined not to be defects during the collection meeting (false positives).

2.5 Experimental Instrumentation

The designed instruments for the experiments are three Experimental Codes, Preparation Forms and Defects Collection Meeting Forms. The Experimental Codes served as the artifacts reviewed by the reviewers in the inspection processes. Preparation Forms were filled in during preparation phases by the reviewers. The Experimental Codes and the Preparation Forms were both given to the reviewers to inspect individually as preparations for a maximum of two hours on each experimental occasion. The reviewers recorded the times during which the artifact was reviewed, and the line number of each issue ("suspected defect") as well as the description of the defects suspected. Most importantly, the reviewers recorded their Identity Numbers and their names on the forms.

An hour after the preparation phases were completed, the review collection meetings were held. The Meeting Forms were filled in at the Defects Collection Meeting. When completed, they gave the time during which the meetings were held, line number and a description of the defect. The team’s identity numbers were recorded on the defect collection meeting form to identify which team has which form.

2.6 Conducting the Experiments

The reviewers were broadly grouped into two. Each group was then distributed into teams of varying sizes from 1 to 5. The first group was not given any aid such as checklist for the inspection while the second group was given. The reviewers, not minding their initial experiences, were given proper trainings on some specific issues of software inspection and about some trivial aspects of the experimental artifacts, such as the algorithms for the codes during the first weekend meeting. These were done to ensure they understand the inspection artifacts very well. The experiments were closely monitored and organized by the researcher.

During preparations, reviewers analyze the codes in order to find defects. All suspected defects were recorded on the Preparation Forms given to them. The experiments placed no time limit on preparations but an average of 60 minutes (1.0 hour) was generally observed by the reviewers for the inspections. During the defect collection meetings, one of the reviewers in each team was selected as the reader as well as the recorder and the moderator. This reviewer paraphrases the code. During this activity, reviewers may bring up any issues found during preparation or discuss new ones. All issues raised were thus recorded in the defects collection meeting forms by the recorder. Before the commencement of the defect collection meetings, the preparation forms were collected by the researcher in order that the reviewers do not mistakenly add to their preparation forms any issues that were not found until collection. Also, there was no time limit placed on defect collection meetings but an average of 47 minutes (0.78 hours) was generally observed by the reviewers.

2.7 Threats to Validity of the Experiments

The question of validity draws attention to how far a measure really measures the concept that it purports to measure [26]. Therefore, in this experiment, we considered two important threats that may affect the validity of the research in the domain of software inspection.
2.7.1 Threats to Internal Validity

Threats to internal validity are influences that can affect the dependent variables without the researcher's knowledge [12]. We considered three such influences: (1) selection effects, (2) maturation effects, and (3) instrumentation effects. Selection effects are due to natural variation in human performance [22]. For example, if one-person inspections are done only by highly experienced people, then their greater than average skill can be mistaken for a difference in the effectiveness of the treatments. We limited this effect by randomly assigning team members for each inspection. This way, individual differences were spread across all treatments.

Maturation effects result from the participants' skills improving with experience. If the same set of participants were used in all three experiments, there may be maturation effect also as the participants' inspection ability may get better over time. Randomly assigning the reviewers and doing the review within the same period of time checked these effects.

Instrumentation effects are caused by the artifacts to be inspected, by differences in the data collection forms, or by other experimental materials. In this study, this was negligible or did not take place at all since all the groups inspected the artifacts within the same period of time. Again, one set of data collection forms was used for all the groups (the treatments).

2.7.2 Threats to External Validity

Threats to external validity are conditions that can limit our ability to generalize the results of experiments to industrial practice [22]. We considered two sources of such threats: (1) experimental scale and (2) subject generalizability. Experimental scale is a threat when the experimental setting or the materials are not representative of industrial practice. One of the major problems with industry-academic collaborative software engineering research in Nigeria is that the software houses do not want to expose their software projects to ‘external intruders’ for security reasons, as they asserted [4]. This study made use of the researcher’s personal invented codes and so, this poses a great limitation on generalizing the results from the experiments to industrial scale.

3. RESULTS

The average results obtained from the series code inspection experiments are reported in the Tables 3.1 to 3.7 and Figures 3.1 to 3.4. Table 3.1 gives the average true defects reported by code reviewers at preparation in the multi-trial experiments.
Figure 3.1 shows that the aggregate average number of true defects by the checklist defect detection method is better than the Ad hoc method across the team sizes. However, further statistical test is needed to clarify this.

The common measure of inspection cost is total effort – the number of hours spent in preparation and meeting by each reviewer and code author. Effort in this work means the total time spent, in minutes, either by individual or collectively as a team in one session of the inspection. Table 3.2 gives the average effort (time) expended for inspection at preparation by the reviewers.

### Table 3.2: Teams’ Average Preparation Effort (Average Time Taken) for codes inspection

<table>
<thead>
<tr>
<th>Team Size</th>
<th>Experiment 1 (Time in Minutes)</th>
<th>Experiment 2 (Time in Minutes)</th>
<th>Experiment 3 (Time in Minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AH</td>
<td>CB</td>
<td>R</td>
</tr>
<tr>
<td>1</td>
<td>54</td>
<td>64</td>
<td>69</td>
</tr>
<tr>
<td>2</td>
<td>65</td>
<td>62</td>
<td>60</td>
</tr>
<tr>
<td>3</td>
<td>75</td>
<td>56</td>
<td>45</td>
</tr>
<tr>
<td>4</td>
<td>63</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>62</td>
<td>68</td>
<td>70</td>
</tr>
</tbody>
</table>

The Aggregate Average effort expended (that is, time taken) at preparation by the reviewers was $63.47 \pm 2.57$ SEM and $56.33 \pm 2.64$ SEM minutes for Ad hoc and Checklist methods of code review respectively. Approximately 1.06 and 0.94 hours respectively. This result also shows that the aggregate average effort expended by reviewers using checklist defect detection technique is lower than that of the Ad hoc technique at preparation.

Table 3.3 gives the average number of true defects detected by teams at collection meeting during the code inspection experiments.

### Table 3.3 Average Number of True Defects Detected by Teams at Collection Meeting for Codes inspections

<table>
<thead>
<tr>
<th>Team Size</th>
<th>Experiment 1 (out of 18 seeded errors)</th>
<th>Experiment 2 (out of 12 seeded errors)</th>
<th>Experiment 3 (out of 18 seeded errors)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AH</td>
<td>CB</td>
<td>R</td>
</tr>
<tr>
<td>1</td>
<td>8</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>14</td>
<td>9</td>
</tr>
</tbody>
</table>

Across all the code inspections, the aggregate average number of true defects detected at collection meeting was $9.6 \pm 0.49$ SEM and $10.8 \pm 0.79$ SEM respectively for Ad hoc and Checklist code review techniques.

This means that on the average $[(18 + 12 + 18) / 3 = 16$ seeded errors], 63.06% and 67.94% of the total issues raised at defect Collection Meetings turn out to be True defects for Ad Hoc and Checklist defect detection methods respectively. The results show that Checklist defect detection technique is better than the Ad hoc technique at Collection Meeting for the code inspections. However, further statistical analysis (to be discussed soon) is needed to buttress this point. Figure 3.2 shows the chart of Aggregate Average True defects reported at the Defect Collection Meetings by the teams during the code inspections experiments, with their Y-error bars.

Figure 3.2 Aggregate Average Numbers of True Defects Reported by the Teams at the Collection Meeting during Code Inspections.

Across all the code inspections, Figure 3.2 shows that checklist defect detection technique was better than Ad hoc for team sizes 1, 2 and 4; while they perform the same for team size 3. However, Ad hoc outperform to a little extent than Checklist for team size 5. Further statistical analyses (also to be discussed soon) are needed to determine which would be better off in defect collection meeting during code inspection.

Table 3.4 shows the average effort expended by teams during collection meeting.
The Aggregate Average effort expended (that is, time taken) at Defect Collection Meeting by the reviewers was \(48.73 \pm 4.53\) SEM and \(46.00 \pm 3.60\) SEM minutes for Ad hoc and Checklist methods of code review respectively. Approximately 0.89 and 0.83 hours respectively. This result shows that the aggregate average effort expended by reviewers for Defect Collection Meetings are roughly the same for both Checklist and Ad hoc methods of code reviews.

**False Positives**

False positives are the issues raised by the reviewers to be defects at meeting but are not truly defects. Table 3.5 shows the values of the false positives obtained for the code inspection experiments.

**Table 3.5 Number of False-Positives Reported at Defects Collection Meeting**

<table>
<thead>
<tr>
<th>Team Size</th>
<th>Experiment 1 (Time in Minutes)</th>
<th>Experiment 2 (Time in Minutes)</th>
<th>Experiment 3 (Time in Minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AH CB R</td>
<td>AH CB R</td>
<td>AH CB R</td>
</tr>
<tr>
<td>1</td>
<td>54 64</td>
<td>67 69</td>
<td>90 61</td>
</tr>
<tr>
<td>2</td>
<td>67 45</td>
<td>35 33</td>
<td>39 30</td>
</tr>
<tr>
<td>3</td>
<td>60 35</td>
<td>38 40</td>
<td>35 35</td>
</tr>
<tr>
<td>4</td>
<td>66 60</td>
<td>32 43</td>
<td>40 32</td>
</tr>
<tr>
<td>5</td>
<td>40 65</td>
<td>38 45</td>
<td>30 33</td>
</tr>
</tbody>
</table>

Meeting gains were not recorded for team size 1 because only one reviewer was involved. The only reviewer did not need to hold any inspection meeting again after the preparation phase. He would still raise the same issue if he works on the code for a number of times.

Across all the code inspection experiments, the aggregate mean gains by the teams at collection meeting was \(1.92 \pm 0.43\) SEM and \(0.67 \pm 0.23\) SEM respectively for Ad hoc and Checklist defect detection techniques. Further computations shows that 14.69% and 5.63% of the total issues raised at collection meeting turn out to be Meeting Gains for the Ad hoc and Checklist techniques respectively.

**Meeting Losses**

Meeting losses give the number of defects that were found during the preparation phase but were never detected and reported during the meeting phase of an inspection. Table 3.7 shows the values obtained in the code inspection experiments.

**Table 3.6: Meeting Gain Values during the Code Inspections**

<table>
<thead>
<tr>
<th>Team Size</th>
<th>Experiment 1 (out of 18 seeded errors)</th>
<th>Experiment 2 (out of 12 seeded errors)</th>
<th>Experiment 3 (out of 18 seeded errors)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AH CB R</td>
<td>AH CB R</td>
<td>AH CB R</td>
</tr>
<tr>
<td>1</td>
<td>1 2 1</td>
<td>1 1 1</td>
<td>1 1</td>
</tr>
<tr>
<td>2</td>
<td>2 2 3</td>
<td>3 0 4</td>
<td>4 0</td>
</tr>
<tr>
<td>3</td>
<td>0 0 0</td>
<td>1 5 0</td>
<td>5 0</td>
</tr>
<tr>
<td>4</td>
<td>1 2 1</td>
<td>2 0 2</td>
<td>2 0</td>
</tr>
<tr>
<td>5</td>
<td>1 2 1</td>
<td>1 0 2</td>
<td>2 1</td>
</tr>
</tbody>
</table>

Meeting losses were not recorded for the team size 1 for the same reason highlighted under Meeting Gains earlier. Across all the code inspection experiments, the aggregate mean meeting losses by the teams at collection meeting was \(1.42 \pm 0.31\) SEM and \(1.33 \pm 0.19\) SEM respectively for Ad hoc and Checklist defect detection techniques. Further computations shows that 11.81% and 9.88% of the total issues raised at collection meeting turn out to be Meeting Losses for the Ad hoc and Checklist techniques respectively.
3.1 Further Statistical Data Analyses

The hypotheses formulated for this study were tested using Statistical Package for Social Sciences (SPSS) version 10 for Windows. The results presented here were obtained from the computer aided data analyses.

The purpose of carrying out further statistical test on the data obtained in these experiments is to test the various hypotheses formulated in this research.

\[ H_0: \text{There is no significant difference between the effectiveness of ad hoc and that of checklist reading techniques in code inspection.} \]

3.11 Analysis of the Teams’ Preparation Data

The preparation data obtained from the experiment is further reduced to Table 3.8 by computing the mean values of the true defects reported by the reviewers across the three code inspection experiments.

Table 3.8: Mean Aggregate True Defects Reported by Reviewers at Preparation

<table>
<thead>
<tr>
<th>Team Size</th>
<th>ad hoc</th>
<th>checklist</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.67</td>
<td>11.67</td>
</tr>
<tr>
<td>2</td>
<td>7.67</td>
<td>9.67</td>
</tr>
<tr>
<td>3</td>
<td>8.00</td>
<td>9.33</td>
</tr>
<tr>
<td>4</td>
<td>7.67</td>
<td>10.33</td>
</tr>
<tr>
<td>5</td>
<td>9.67</td>
<td>10.33</td>
</tr>
</tbody>
</table>

Table 3.8 is used to test if there is any significance difference in the effectiveness of reviewers at preparation for the two inspection methods used – Ad hoc and checklist. Independent samples t-test was used to test this hypothesis at 0.05 error probability level. This statistical test is adopted since the experiments were run independently by two different groups. This test is used to determine if the means of two unrelated samples differ [26].

Independent t-test analysis shows that there is a high significant difference in the effectiveness of reviewers at preparations using ad hoc and checklist reading techniques (\( p = 0.005 \)).

3.12 Analysis of Teams’ Collection Meeting Defects

Table 3.9 shows the aggregate average true defects reported by the groups during the collection meetings.

Table 3.9: Defects Collection Meetings’ Aggregate Average True Defects

<table>
<thead>
<tr>
<th>Team Size</th>
<th>Ad hoc</th>
<th>Checklist</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.67</td>
<td>11.67</td>
</tr>
<tr>
<td>2</td>
<td>8.67</td>
<td>11.00</td>
</tr>
<tr>
<td>3</td>
<td>10.33</td>
<td>10.33</td>
</tr>
<tr>
<td>4</td>
<td>11.00</td>
<td>11.33</td>
</tr>
<tr>
<td>5</td>
<td>10.33</td>
<td>9.67</td>
</tr>
</tbody>
</table>

Table 3.9 is used to test if there is a significance difference in the effectiveness of reviewers at defects collection meeting. Result of the independent t-test analysis shows that there is no significant difference in the effectiveness of reviewers at Defects Collection Meetings using ad hoc and checklist methods of code inspection (\( p = 0.132 \)).

3.13 Interpretation and Discussion of the hypothesis:

Ad hoc and checklist have been the major inspection techniques used in software inspections. The hypothesis states that there is no significant difference between the effectiveness of ad hoc and that of checklist reading techniques in software inspection. This null hypothesis holds for the defect collection meeting. The alternative hypothesis holds for the preparation data. Report on comparing these reading techniques in software inspection preparations is rare to the best of our knowledge. Therefore we base our arguments on the defect collection meetings.

Previous results earlier gotten in this work show that on the average, Ad hoc method uncovers 63.06% of the average total seeded bugs in the codes while Checklist uncovers 67.94%. These results are actually of small marginal differences and this accounts for the acceptance of the null hypothesis.

The average percentage relative improvement (\( R \)) of Checklist Effectiveness (CE) over Ad hoc Effectiveness (AE) is calculated to be small. This is shown below:

\[
R = \frac{CE - AE}{AE} \times 100 \quad \text{[1]}
\]

\[
= \frac{(67.94 - 63.06)/63.06}{67.94} = 0.077 = 7.7\%
\]

The Relative improvement of a method over another is a measure of how that method outperforms the other [20]. This result shows that Checklist (CBR) exhibits a 7.7% percentage effectiveness improvement over Ad hoc. This is a weak result, which makes us to accept the null hypothesis.
However, this result may be attributed to the small size of the code artifacts being used for the experiments. Effort in terms of time taken for the inspections in hours could be a considerable factor to the effectiveness and / or efficiency of reading techniques. One would expect that checklist reviewers would take more time and thus find more defects than the Ad hoc reviewers who do not have any aid for the inspection (since they will have to read both the codes and the checklists). Results from the experiments indicate that approximately 0.89 and 0.83 hours are used by the inspectors using Ad hoc and Checklist respectively. Again, the marginal difference in time is very small. Statistical independent t-test results also reveals that there is no significant difference in the effort taken by the reviewers using Ad hoc and Checklist (p = 0.132). This result is also attributed to the small sized codes used in the experiments.

Our results are in consonance with some related works in the literatures. To mention a few, Giedre et al., [7] results from their experiment to compare checklist based reading and perspective-based reading for UML design documents inspection shows that Checklist-based reading (CBR) uncovers 70% in defect detection while Perspective–based reading (PBR) uncovers 69% and that checklist takes more time (effort) than PBR. Porter and Votta [22] on their experiment for comparing defect detection methods for software requirements inspections show that checklist reviewers were no more effective than Ad hoc reviewers. Lanubile and Visaggio [24] on their work on evaluating defect detection techniques for software requirements inspections, also show that no difference was found between inspection teams applying Ad hoc or Checklist reading with respect to the percentage of discovered defects.

Nagappan, et al. [27], on their work on preliminary results on using static analysis tools for software inspection made reference to the fact that inspections can detect as little as 20% to as much as 93% of the total number of defects in an artifact. Briand, et al., [28], reports that on the average, software inspections find 57% of the defects in code and design documents. Les [29] in his work on “Testing the value of checklists in code inspections” shows there is no evidence that checklists significantly improve inspections.

Therefore we conclude that Ad hoc and Checklist-based reading techniques are not different in terms of effectiveness, when reviewers use them in code inspections within the constraints of our paper-based code inspections. These results suggest that any of the defect detection reading techniques, Ad hoc or Checklist, could be conveniently employed in software inspection depending on choice; since they have roughly the same level of performance stemming from the acceptance of the null hypothesis; but Checklist may actually enhance performance.

### 3.14 Comparing Preparation with Defect Collection Meeting

The hypothesis stated for ascertaining whether meeting is needed for an inspection or not is stated below:

\[ H_{02} : \text{There is no significant difference between the effectiveness of preparations and that of real inspection meetings in code inspection process.} \]

In normal software inspection exercise proposed by the pioneer of software inspection, Michael Fagan [9], preparation as a stage in the process is meant for the reviewers to comprehend the artifact over some period of time before a defect collection meeting is held. One input to the collection meeting is the list of defects found by each reviewer during his or her preparation. In defect collection meetings, members of an inspection team meet to find as many faults as possible and discuss the issues found by each reviewer during the preparation stage. Therefore defects collection meetings have two main purposes;

- Consolidating the defects found by the inspectors/reviewers into one list.
- Looking for more defects during the meeting, called the meeting gain.

Synergy (process gains) has been attributed to inspection meeting [12, 30]; in which reviewers find more defects due to their different viewpoints, skills and knowledge, which are always pooled together in a meeting.

Researchers like Porter, et al., [22] and Votta, [13] have found some empirical findings that contradict this suggestion. Coupled with other problems associated with holding inspection meetings such as cost, time schedule and getting all team members present, a critical question yet unresolved is whether a meeting is actually needed for software inspection exercise or not. Our hypothesis is based on this question. The two defect detection groups (Ad hoc and Checklist) are compared individually using paired samples t-test. Paired sample t-test analysis shows that the null hypotheses hold for the two techniques with \( p = 0.071 \) for Ad hoc and 0.227 for Checklist, with correlations of 0.4 and 0.5 respectively. This means that there were no significant differences between the effectiveness of reviewers at preparation and collection meeting for the two inspection techniques examined in this work.
Although small sized code artifacts were used in the experiments, the result is actually in line with some industrial related works such as Siy [31] and Porter et al., [12]. In their works, Porter et al., [12] got a correlation of 0.4 between preparation defects and meeting defects. Johnson and Tjahjono [32] found that although meeting based reviews are more costly than non-meeting based reviews, there was no significant difference between them in terms of number of faults found. This result is also in line with what we obtained in our previous pilot study for this work using medium size code with students [33].

Many people consider the meeting to be the central step of the inspection process because they believe that several people working together will find defects that none of them would find while working separately. This is known as "synergy". Meetings also serve as a way to spread domain knowledge since unfamiliar inspectors interact with more experienced developers. Finally, meetings provide a natural milestone for the project under development. It does however take time and effort to schedule a meeting and recent studies have shown that meetings do not create as much synergy as previously believed [13]. In addition, the problems of improperly held meetings are well-documented [34, 35]. These include free-riding (one person depending on others to do the work), conformance pressure (the tendency to follow the majority opinion), evaluation apprehension (failure to raise a seemingly "stupid" issue for fear of embarrassment), attention blocking (failure to comprehend someone else’s contribution and to build on it), dominance (a single person dominating the meeting), and others. Individual-centered inspections avoid these problems by eliminating the inspection meeting or de-emphasizing it (for example, making it optional, making attendance optional, and so on.). However, they risk losing the meeting synergy.

### 3.15 Comparing Large and Small Inspection Teams

The idea behind comparing large and small inspection teams is to find out if there is need for large inspection teams or not. This analysis was done to see whether there is any significant difference between the effectiveness of the smaller size teams (1, 2 and 3) and larger size teams (4 and 5). According to related works such as Siy [31] and Porter et al., [12], as long as additional reviewers find some new defects and don’t negatively affect collection meeting performance, it is expected that larger teams would find more defects than smaller teams. The following hypothesis, following Porter et al., [12], is therefore set.

\[ H_{03}: \text{Inspections with large team size have longer inspection effort (time), but find no more defects than smaller teams.} \]

In order to verify the hypothesis, we consider the team sizes’ defects detection effectiveness and the effort taken by the teams in the three code inspection experiments, reproduced in Table 3.10.

#### Table 3.10: Defects Collection Meeting Aggregate Average True Defects and Efforts

<table>
<thead>
<tr>
<th></th>
<th>Ad hoc Defects (Teams 1 to 3)</th>
<th>Ad Hoc Defects (Teams 4 to 5)</th>
<th>Ad Hoc Effort (Teams 1 to 3)</th>
<th>Ad Hoc Efforts (Teams 4 to 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ad hoc</td>
<td>7.67</td>
<td>11.00</td>
<td>70.33</td>
<td>46.00</td>
</tr>
<tr>
<td>Checklist</td>
<td>8.67</td>
<td>10.33</td>
<td>47.00</td>
<td>36.00</td>
</tr>
<tr>
<td>Checklist</td>
<td>10.33</td>
<td>44.33</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Paired samples t-test analyses show that there was no significant difference in both defects detected and effort taken by the small size teams and that of the large size teams for the two inspection reading techniques used in the three code inspections. For Ad hoc, \( p_{\text{defect}} = 0.205 \) and \( p_{\text{effort}} = 0.230 \), and for Checklist, \( p_{\text{defect}} = 0.344 \) and \( p_{\text{effort}} = 0.841 \). The ps are not significant. Pearson correlation coefficients for the defects are -1.0 for Ad hoc and 1.0 for Checklist.

![Figure 3.3: Graph of Teams’ defect detection effectiveness against the Team Size](image-url)
Figure 3.3 shows the graphs of teams’ defects detection effectiveness against team sizes at defect collection meeting for the three code inspection series. From the graphs, it can be seen that checklist based reading technique has a high effectiveness with team size of 1, reducing in value to team size 3 before picking to a maxima on team size 4. On the other hand, Ad Hoc effectiveness grows steadily, following a normal curve, from team size 1 to maxima of 4 before coming down. The two methods overlap at team size 3. The fact that the two methods have their maxima at team size 4 is in consonance with the suggestion of the software inspection originator, Michael Fagan [9], who suggested that the team size for a software inspection should be a maximum of four for better results. At team size 3 where the curves coincide, the two techniques produced equal effectiveness in defect detection in the inspection experiments.

Votta [13] notes that determining the optimal team size for inspections is an important contemporary research issue. Previous work in this area produced inconsistent results with recommended team sizes ranging from 2 to 12 [9, 13, 19, 22, 36, 37, 39, 40]. Shaheen et al., [41] results on inspection with Object Oriented UML design indicate that there is no single optimal team size. Our statistical tests earlier reported in this section indicate that there are no statistical significant differences between large and small teams in terms of defect detection effectiveness and effort.

Their research was actually carried out in an industrial-based large-scale life software development. Porter, et al.’s, experimental results suggest that reducing the number of inspectors from 4 to 2 may significantly reduce effort without increasing inspection interval or reducing effectiveness. Figure 3.4 show the graph of effort (Mins) expended by reviewers against the team sizes. The graph reveals that effort increases steadily with team size for checklist-based inspection and decreases with team size for teams using Ad Hoc. The Checklist curve is expected since effort is bound to increase with team size and because the teams will have to examine on the checklist before they will finally agree on an issue. On the other hand, the reason why the Ad Hoc curve is decreasing with team sizes may be attributed to the fact that the time taken by higher teams for deliberations on issues may be short. The fact is that smaller size teams usually take less time (effort) for inspection exercises.

Therefore, we submit, within some experimental errors in our experiment that team size of 4, which exhibited maximum defect detection effectiveness is better employed in software inspection tasks although at higher cost (time) than the smaller team sizes.

3.16 Statistical Analyses of False Positives, Meeting Gains and Losses

Table 3.11 shows the mean aggregate false positives reported by individual teams in the three code inspection series.

<table>
<thead>
<tr>
<th>Team Size</th>
<th>Ad Hoc</th>
<th>Checklist</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0</td>
<td>1.3</td>
</tr>
<tr>
<td>2</td>
<td>1.7</td>
<td>2.3</td>
</tr>
<tr>
<td>3</td>
<td>1.3</td>
<td>1.0</td>
</tr>
<tr>
<td>4</td>
<td>0.7</td>
<td>1.7</td>
</tr>
<tr>
<td>5</td>
<td>1.3</td>
<td>2.3</td>
</tr>
</tbody>
</table>

The mean aggregate number of false positives reported by the Ad Hoc reviewers is 1.0 while that of Checklist is 1.72. Further independent t-test statistics results show that there is no significant difference between the false positives reported for both Ad Hoc and Checklist inspection techniques (p = 0.106).
Table 3.12 shows the mean meeting gains obtained from defect collection meetings from the three code inspection series.

**Table 3.12: Mean Meeting Gains for the three code inspection series**

<table>
<thead>
<tr>
<th>Team size</th>
<th>Ad hoc</th>
<th>Checklist</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.00</td>
<td>1.33</td>
</tr>
<tr>
<td>2</td>
<td>3.00</td>
<td>0.67</td>
</tr>
<tr>
<td>3</td>
<td>1.67</td>
<td>0.33</td>
</tr>
<tr>
<td>4</td>
<td>3.00</td>
<td>0.33</td>
</tr>
</tbody>
</table>

The mean aggregate meeting gains are 2.00 and 0.44 for Ad Hoc and Checklist based inspections respectively. Further independent t-test statistic results shows that there is a high significant difference between the meeting gains of Ad Hoc and Checklist based inspection reviewers ($p = 0.02$). Table 3.13 shows the Mean meeting losses for the three code inspection series.

**Table 3.13: Mean Meeting Losses for the Three Code Inspection series**

<table>
<thead>
<tr>
<th>Team size</th>
<th>Ad hoc</th>
<th>Checklist</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.00</td>
<td>1.67</td>
</tr>
<tr>
<td>2</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>3</td>
<td>2.00</td>
<td>1.00</td>
</tr>
<tr>
<td>4</td>
<td>1.67</td>
<td>1.67</td>
</tr>
</tbody>
</table>

The mean aggregate meeting losses are 1.47 and 1.22 for Ad Hoc and Checklist based inspections respectively. Further T-test statistical results shows that there is no statistical significant difference between the meeting losses of Ad Hoc and Checklist based inspection reviewers ($p = 0.464$). Software inspection defect collection meetings are held with a view to detect as many defects as possible; more than the individual preparation phase and minimize losses. Across all inspections, 14.69% and 5.63% of all defects discovered are meeting gains for Ad hoc and Checklist based inspection reviewers ($p = 0.034$). Table 3.14 gives the major results from the statistical analyses of false positives, meeting gains and losses for the three paper-based code inspections.

**Table 3.14: Summary results of analyses of false positives, meeting gains and losses from the three code inspection paper-based series**

<table>
<thead>
<tr>
<th></th>
<th>Ad hoc (Aggregate mean)</th>
<th>Checklist (Aggregate mean)</th>
<th>p-value</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>False Positives</td>
<td>1.00 (8.06%)</td>
<td>1.73 (13.31%)</td>
<td>0.106</td>
<td>$H_0$ accepted</td>
</tr>
<tr>
<td>Meeting gain</td>
<td>2.00 (14.69%)</td>
<td>0.44 (5.63%)</td>
<td>0.034</td>
<td>$H_0$ rejected</td>
</tr>
<tr>
<td>Meeting loss</td>
<td>1.47 (11.81%)</td>
<td>1.22 (9.88%)</td>
<td>0.464</td>
<td>$H_0$ accepted</td>
</tr>
</tbody>
</table>

These results show that the defect collection meeting has only improved the effectiveness of Ad Hoc reviewers by only 2.88% while that of checklist reviewers is even in reverse negative trend. There have been a number of studies during the last few years which show little or virtually no meeting gain with respect to the number of faults in inspections where fault discovery is held in the preparation phase [30]. For instances, Votta [13] found in his experiment that the meeting on average found only additional 4% of faults. Johnson and Tjahjono [32] found that although meeting based reviews are more costly than non-meeting based reviews, there was no significant difference between them in terms of number of faults found. The advantage of having a meeting is that it significantly reduces the number of false positives. Porter et al., [22] even found a negative meeting gain averaging around 1% [30].

These results have implications on our analysis of the effectiveness of the reviewers. Since the percentage of new defects first discovered (meeting gains) at meeting is very low, it then means that holding meeting for software inspection may not be necessary as suggested by Porter et al., [12, 22] and Votta [13] suggests replacing inspection meetings with depositions, where the author and, optionally, the moderator meet separately with each of the reviewers to get their inspection results. According to Porter et al., [12], one thing the meeting does is to remove false positives. What is being considered here is to find out if either the preparation stage or the collection meeting stage could help in reducing the time it takes to ‘weed’ incorrect issues that were specified to be true issues.
(false positives). This is necessary because the author of the work product will have to deliberate on the false positives to really ascertain that they were not defects. Since the meeting involves a situation where the participants work collectively to detect defects, it would have been expected that the meeting stage would have less false positives than the preparation stage.

The results show that there is no statistical difference between the two reading techniques in terms of number of false positives incurred during the meeting (p = 0.106), and that checklist incurred slightly more false positives than the Ad Hoc method.

4. SUMMARY & CONCLUSIONS

A multi trial experiment on code inspection was carried out. Inspection methods (Ad Hoc and Checklist based reading techniques) on some small-sized Java code units (180 Lines of Code LOC, on the average), seeded with some syntax and logical errors were applied. The methods were assessed by assigning different team sizes working in parallel to the code units. Specific results and discussion of their implications from points of view of both practitioners and researchers are summarized below.

- **Individual Preparations for Code Inspection**

  Results from this study indicates that there is a high significant difference in the reading techniques (Ad Hoc vs Checklist) in terms of defect detection effectiveness of reviewers at preparation (p = 0.005). About 53% of the total issues reported during preparation turn out to be true defects for Ad Hoc reviewers (47% are false positives). While about 69% turn out to be true defects for Checklist-based reviewers (31% are false positives). The average effort expended at preparation is roughly 63 minutes per individual reviewer for Ad Hoc reviewers while 56 minutes were spent on the average by Checklist–based reviewers.

  For practitioners, the results suggest that Checklist-based reading technique would be better employed by reviewers at preparation since more defects are located with little time. However, the results also suggest that a good deal of effort is currently being expended on issues that might better be handled by automated tools or standards, especially when using Ad- Hoc reading technique since few defects are located by reviewers more time. For researchers, these suggest that developing better defect detection techniques may be much more important than any of the organisational issues discussed in this experiment as suggested by Porter et al., [22].

- **Meeting Gains**

  Results from this study indicate that there is a high significant difference in meeting gains of reviewers with respect to the two reading techniques adopted (p = 0.034). The mean meeting gain for the Ad Hoc reviewers is 2.0 and that of Checklist-based reviewers is 0.44. These meeting gains are very low compared to the functional requirements of an inspection meeting, which is to detect as much defects as possible. - The small number of seeded errors meant that most errors were already found in preparation, thus making it likely that there is little meeting gain.

  When we compare the defect detection effectiveness of reviewers at both preparations and meetings, the results show that there are no significant difference in the results (p for Ad Hoc = 0.071, p for Checklist = 0.227). Net meeting improvements are very low in Ad Hoc Based reading and even worst for Checklist Based reading technique. One implication of this result is that it may be worthwhile to explore meeting-less inspections.

- **Team Size**

  No difference was found in the defect detection effectiveness and efforts taken for inspections by smaller (1, 2 and 3) or larger (4 and 5) teams for both Ad Hoc and Checklist based reviewers on the small-sized codes. Argument on what may constitute the optimum size for software inspection abounds. For practitioners, these results suggest that reducing the default number of reviewers 5 or 4 to about 2, even 1 may significantly reduce effort without reducing effectiveness.

  The implication of this result for researchers is unclear for now. And as suggested by Porter et al., [12], there is need to develop a better understanding of why higher team such as 4 and 5 were not more effective than lower teams, preferably team size 2. The analysis shows further that higher teams may suppress a large number of possible true defects such as teams 4 and 5 having higher meeting losses in the results obtained from the experiments.
REFERENCES


A Resource-Based Model For E-Commerce In Developing Countries

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ABSTRACT

Previous efforts in electronic commerce (e-commerce) research in developing countries shows that there is an acute lack of theoretical frameworks and empirical evidence to understand how developing country firms realize electronic commerce benefits amidst their national constraints. This paper sets out to develop a theoretically abstracted but contextually grounded model of how developing country firms can orient their resources and realize these benefits amidst their national constraints. A review of e-commerce and strategy management literature to develop a resource – based model for e-commerce benefits was undertaken. The process-based model provides an understanding of how to identify, integrate, and reconfigure resources to achieve electronic commerce benefits; provides propositions that serves as theoretical platforms for future empirically grounded research on electronic commerce in developing country contexts and brings organizations closer to identifying and categorizing the strategic value of resources and the role managerial capabilities and intangible resources play in sustaining e-commerce benefits. Finally, our findings provides organizations the strategic options to address resources which have lost their value or have become less valuable to their strategic orientation in e-commerce adoption thereby serving as a starting point of examining e-commerce in developing countries through the theoretical lens of information systems and strategic management.

Keywords - Electronic Commerce Strategy, Developing Countries, Resource-based Theory, Dynamic Capabilities, Resources

1. INTRODUCTION

Electronic commerce (e-commerce) presents a lot of opportunities and benefits to firms in developing countries (DCs). There is some evidence of developing country firms achieving strategic, informational and operational benefits from e-commerce adoption [34] [32] [31]. The promise of these benefits and the related broader impacts has led to questions about how firms can achieve and sustain these benefits.

On the theoretical front, developing country e-commerce research has focused more on the potential benefits to be achieved and pre-conditions to e-commerce adoption [6]. Current research on e-commerce in DCs has been rather elusive of a strategic understanding of how firms achieve and sustain these benefits amidst their multi-prong contextual challenges. A number of authors have therefore called for the need for such knowledge [7][8][33].

This emphasis on the strategic guidance to creation of firm-level benefits is opportune given the potential contribution of firms in DCs to addressing the resource-poverty in their context and the broader impacts on socio-economic development. In a review of e-commerce literature in DCs [8] Boateng et al. evaluated three theories and conceptual frameworks which have gained some mileage in attempting to develop a strategic perspective of e-commerce in DCs.
The frameworks are Porter’s five competitive forces model used in a case study of a Chinese company [12]; a conceptual framework for electronic business (e-business) strategy used in a case study of a Chinese company [29]; and the resource-based frameworks used in both qualitative and quantitative-based studies [33][19][52][15]. Though the first two studies generated some critical lessons applicable to the generic paradigm of e-commerce in DCs and to market chain management models, only the studies using the resource-based theories offered a path to understanding the strategic options firms take to circumvent or address their contextual challenges to achieve and sustain e-commerce benefits. The resource-based theory studies examined e-commerce adoption and assimilation across a number of developing regions including Mexico, Ecuador, China, Taiwan, and Brazil. These studies highlighted a number of research gaps:

- García-Murillo [19] study pointed out that there exists a mismatch between the realities for DC firms and assumptions of Western models of enterprise (such as Porter’s [41] recommendations), thus proposing that as organizational business practices evolve with their changing business environments, more research is needed to redefine existing knowledge to be consistent and applicable with the dynamic nature of the environment.
- Montealegre [33] also emphasized the need for a process-based model of dynamic capability development as compared to the present existence of factor-oriented models which fail to offer understanding of how these capabilities are developed, deployed and managed in alignment with a firm’s overall strategy. Future research could offer such understanding by developing a process-based model of resource or dynamic capability development.
- Zhu and Kraemer [52] argued that the integration of two models, Technology-Organization and Environment and the resource-based theory, is an initial step towards understanding the complex relationships among technology, environments and organizational performance and thus necessitates further research to refine application of both theories in this interrelationship.
- Cui et al. [15] suggested that IT management, compared with IT infrastructure, plays a more important role in foreign invested firms than in local and joint-invested firms. This tends to stem from the mature usage and experience of IT by foreign firms. Future research should consider how local firms can put more focus on a good fit between IT physical assets and management resources.

These gaps outline future research directions on the use of the resource-based theories to investigate the strategic perspective of e-commerce in DCs. This paper, in response to the above research calls, seeks not to identify the precise resources for e-commerce, but provide a theoretically-oriented understanding of how DC firms can develop, deploy and manage these resources. This theoretically-oriented understanding can then guide the empirical research to be executed via future research in order to add on a practice or managerially-oriented perspective. The paper is thus organized as follows; first, an overview of e-commerce is presented; second, an overview of the RBT is given; third, a model for conceptualizing the link between resources and e-commerce benefits is developed and propositions for future research are outlined; fourth, the managerial implications are discussed; and fifth, the conclusion is presented.

### 1.1 E-commerce in Developing countries: Seeking Strategic Options

In this paper e-commerce is defined, from a broader perspective, as the use of information and communication technologies (ICTs), particularly telecommunication networks, to share business information, to maintain business relationships and to conduct business transactions involving both businesses and individuals [43].

Firms in DCs which use ICTs to share business information, maintain business relationships and conduct business and commercial transactions may achieve three interrelated types of benefits, namely, operational, informational and strategic benefits [18] [7]. Strategic benefits are associated with benefits which improve the market performance of the firm – extending its reach, product differentiation, improving revenue and the loyalty of trading partners and customers. Informational benefits are associated with benefits which improve communication, relationships and enhance access to information about the firm and its products. Operational benefits are associated with reducing the costs of transactions and achieving efficiency of operations through e-commerce.

The type of technology and the extent of integration of the technology into the business processes determine the ability of firms to achieve benefits of higher value. However, DCs differ in the readiness of their institutional infrastructure – economic, cultural, legal and technological framework to support the uptake of e-commerce at the firm-level and national-level and achieve these benefits.
A review of e-commerce-in-DCs research published between 1993 and 2005 suggests the preponderance of Asian studies; which is, perhaps, reflective of the relative maturity of ICT infrastructure in terms of roll-out and usage in Asian DCs as compared to that of African DCs [7] [8]. Thus, contextual challenges may influence the ability of firms to achieve e-commerce benefits. Firms making efforts in achieving some benefits demonstrate a set of resources which are deployed and managed in manner to circumvent or address the challenges [51].

In discussing the use of global resources, argued that the initial e-commerce efforts of firms in Ghana, Tanzania, and Kenya were characterized by their use of web hosting services abroad to bypass local web service weaknesses. Other reported accounts of websites like Ethiogift.com (Ethiopia) and Munshigi.com (Bangladesh) detail the marketing of ‘cultural capital’ products – national cultural resources – like art, flowers and sheep online to non-resident inhabitants who purchase them to be delivered to relatives or friends living at home [45]. A survey in South Africa investigating factors which characterize firms that have been successful in e-commerce adoption and institutionalization suggested that, the combination of dynamic capabilities, top management commitment and business resources enable successful firms to develop e-commerce models which work within the constraints of their environment [31].

Similar findings suggesting the complex interaction of global, national and firm level resources to address the resource poverty in DC have been discussed by Montalegre [33] and Garcia-Murillo [19]. This presupposes that research focusing on the strategic options these firms take to develop and deploy resources which address the contextual challenges and help achieve e-commerce benefits may offer strategic guidance to other DC firms. The resource-based theory and its extension, the dynamic capabilities framework, hold the promise of this resource perspective of e-commerce in DCs. The following sections of this paper will examine RBT and e-commerce so as to develop a strategic approach for e-commerce adoption.

2. RESOURCE-BASED THEORY – AN OVERVIEW

RBT tends to be the prevailing paradigm that explains or helps to understand how and why firms develop the capability to gain and sustain competitive advantage [37][48][3]. Its later extension, the dynamic capabilities approach examines how these firms adapt and even capitalize on rapidly changing technological or volatile environments as in DCs [44]. Within these theoretical frameworks, rival firms are viewed to compete on the basis of their internal characteristics, resources, through which they build competitive advantage and a superior long-term performance [48][3][46].

Traditional strategic analysis considers a firm’s resources as strengths that a firm uses to conceive and implement their strategies [27][40]. These strengths include ‘all assets, capabilities, organizational processes, firm attributes, information, knowledge, et cetera controlled by a firm that enable the firm to conceive of and implement strategies which improve its efficiency and effectiveness’ [6] as [2]. This seemingly broader perspective of firm resources has been recently narrowed as ‘assets and capabilities that are available and useful in detecting and responding to market opportunities’ [42][13] as cited in [46].

Assets are considered as anything tangible or intangible which a firm uses in its processes for creating, producing, and/or offering its products (goods or services) to a market, whereas capabilities are repeatable patterns of actions in the use of assets to create, produce, and/or offer products to a market’ [42] cited in [46]. Other authors who tend to differentiate resources from capabilities; define resources as tangible or intangible assets or inputs to production, and capabilities as a coordinated set of tasks which utilize these assets for the purpose of achieving a particular end result. Both conceptualizations, however, agree that capabilities utilize assets to achieve a defined organizational objective. This paper adopts the former concept – resources consisting of assets and capabilities.

Assets can be classified as tangible, intangible and personnel-based resources [21]. Tangible assets include ‘the financial capital and the physical assets of the firm such as plant, equipment, and stocks of raw materials’; intangible assets comprise ‘assets such as reputation, brand image and product quality’; and personnel-based (or organizational) assets include technical know-how, managerial commitment, knowledge and skills, organizational culture, employee training and loyalty [5]. Assets are assembled, integrated and deployed within business processes to form the capabilities which an organization uses to improve its efficiency and effectiveness [21].

In a broader conceptualization, an organizational capability is ‘a high-level routine (or collection of routines) that together with its implementing input flows, confer upon the organization’s management a set of decision options for producing significant outputs of particular type’ [9] as cited in [50].
This collection of routines can also be considered as being operational or dynamic depending on their ability to cause change (rates of change) or impact through their output in the organization. Operational or ordinary capabilities, also known as ordinary or ‘zero-level’ capabilities are ‘those that permit a firm to ‘make a living’ in the short-term’, while dynamic capabilities, are those that ‘operate to extend, modify or create ordinary capabilities’ [50]. Dynamic capabilities, from the dynamic capabilities approach [44] is ‘an extension of the resource-based view of the firm that was introduced to explain how firms can develop their capability to adapt and even capitalize on rapidly changing technological environments’ [33]. They are developed through the appropriate adaptation, integration, and reconfiguration of internal and external organizational assets, capabilities and business processes to respond to the dynamic business environment [44].

On the other hand, recent work by [47], in building on this conceptualization of capabilities, further explains that ‘dynamic capabilities are the ‘ultimate’ organizational capabilities that are conducive to long-term performance, rather than simply a ‘subset’ of the capabilities, as [44] suggest’ (p. 36). The authors conceptualize capabilities in three classifications: capabilities (first order), core capabilities (second-order), and dynamic capabilities (third order). In their argument, firms deploy operational or ordinary capabilities to attain a desired goal which ensures their economic survival. Core capabilities are deployed when a bundle of resources are deployed in the strategic direction of the firm. Dynamic capabilities become the overarching capabilities which go beyond achieving economic survival and strategic objectives to ensure that a firm’s performance is sustained in response to the threats and opportunities in its business environment.

They enable a firm to develop core capabilities among other resources and deploy them to create and sustain a strategic advantage in its business environment. This makes them critical to a firm’s performance in rapidly changing technological environments [44] and the volatile environments in DCS [35]. This transformation of resources occurs in a ‘swift, precise and creative manner’ in line with the threats and changes to its strategic orientation [47].

A capability may therefore exist as an ordinary capability until it is deployed alongside other resources in the strategic orientation of the firm to become a core capability or address an environmental change and/or to sustain firm performance to become a dynamic capability. This also presupposes that the creative potential of these capabilities, or in broader perspective, resources, differs. One may then ask what makes these resources differ in their ability to enable a firm to create and sustain its performance in the marketplace. This leads us to consider the attributes of resources.

2.1 Resource Attributes

RBT posits that to create and sustain a competitive advantage or achieve a performance beyond that of its competitors in the marketplace, a firm’s resources must be heterogeneous and immobile, and to have that potential, the resources must simultaneously have attributes of being valuable, rare, imperfectly imitable and not strategically substitutable or non-substitutable by other resources [3] – the VRIN conditions [9]. The attributes are briefly explained as follows:

- **Valuable**: For a firm’s resource to be valuable, it must be able to help the organization conceive and implement strategies capable of exploiting opportunities and neutralizing threats in its environment and thereby improve its efficiency and effectiveness [3]. It must be able to generate rents - lower costs in delivering products than that of competitors or revenue fromdifferentiating its products (goods or services) - to be captured by the firm [3]. The resource remains appropriate for the rent generating activity when the costs of exploiting the resource do not offset the rents generated [38]. For example, in the development of a new product in a manufacturing firm, the cost of exploiting a resource should not be more than the profits made from the new product; otherwise the value creation process becomes relatively unsustainable with time.

- **Rare**: To create an organizational performance beyond economic survival, a resource has to be rare, uncommon or scarce in its distribution across the competitors in the market [1]. It should be rare in its functionality and not just its type – functionality lies in capabilities generated from a combination of resources such as tangible, intangible and organizational assets [5]. The lack of rare resources creates competitive parity, where no firm obtains a clear competitive advantage, but ‘firms do increase their ability of economic survival’ [39][40][41] as cited in Barney [3]. Some types of resources like IT infrastructure are easily available on the market, however, when combined with other organizational resources like managerial skills and knowledge, organizations can create a functionality - market responsiveness or customer support capability - which may be rare across the competitors in the market [43].

- **Imperfect Imitability**: Resources become imperfectly imitable when it is more difficult for
competing firms to replicate them [9]. These occur in the presence of isolating mechanisms [42]; when, firstly, its occurrence or availability to the organization is due to its unique historical conditions; secondly, the link between resources and the firm’s sustained competitive advantage is causally ambiguous, and lastly, resources themselves are socially complex in nature [17] [3]. These isolating mechanisms increase the costs of competing firms in imitating a successful firm’s resources. When other competitors imitate a functionality or are able to obtain other resources capable of substituting that resource, the resource loses its ability to create a sustained competitive advantage or organizational performance, though it may be valuable to the organization and rare among rival firms. It thus becomes important for resources to be also imperfectly imitable, and beyond that, become not strategically substitutable by other resources.

- **Non-Substitutability:** Substitutes can be in the form of imitating resources exactly or using different resources to create the effect of a resource as used in the successful firms. Competing firms are able to develop substitutes when they are able to discern the value-creation process and understand the value contributed by the resource possessed by the successful firm [3]. These substitutes are only valuable when competing firms are able to achieve a low-cost strategy for developing and exploiting the resource to achieve a value same as or superior to that of the successful firm. However, in the presence of the isolating mechanisms discussed earlier, discerning or understanding the value creation process of resources becomes difficult. This increases the costs of imitation and substitution, reducing the value or rents generated by the substitutes [10].

In effect, RBT states that creating competitive advantage lies in the heterogeneity of valuable resources or in possessing resources that are valuable, appropriate and rare or uncommon across firms, and sustaining that advantage depends on them being imperfectly mobile; inimitable and non-substitutable [3][46]. So then how does the concept of ordinary, core and dynamic capabilities fit in? As earlier explained, dynamic capabilities go beyond ensuring the company’s economic survival to enabling it to sustain and achieve new benefits thereby sustaining and improving its performance.

The firm may therefore need to develop higher order capabilities – core and dynamic – which extend the functionalities of existing and new assets and capabilities (largely ordinary), make them more rare, inimitable and not strategically substitutable and therefore increase their potential value contribution to a sustained organizational performance. Core capabilities are deployed when resources are oriented within the strategic orientation of the firm. Then in order to sustain the benefits achieved or respond to the threats (and/or opportunities) on core capabilities and performance of the firm, dynamic capabilities become necessary.

Economic survival occurs when a company tends to have just valuable resources that enable it to obtain competitive parity. At this stage the resources may consist of largely ordinary capabilities, and perhaps a few core capabilities. However, the need to go beyond economic survival is arguably typical of the idiosyncratic institutional uncertainties in DCs [35]. Any change necessitating the detailed customization of the product, integration with other products, or extension of its functionalities to serve a specific or different target market requires the combination and reconfiguration of organizational assets and capabilities in order to achieve and sustain new benefits thereby sustaining and improving its performance [50]. In other scenarios such as the case of merger or acquisition at the firm-level or new developments in the national ICT infrastructure, a firm may expand its resource portfolio. However, without deploying the new resources in, perhaps, the ‘redefined’ strategic direction of the firm, the rent generating ability of the new resources acquired may not be fully exploited.
These higher order capabilities therefore form part of a strategic process through which the firm develops, deploys and manages resources to sustain its performance in its rapidly changing or volatile business environment. Mata et al [30] capture the tenets of the RBV/RBT in a RBV model of competitive advantage, which examines conditions under which a firm’s resources create and sustain competitive advantage [[3]]. This paper relates the model (Figure 1) to achieving and sustaining organizational performance.

The model is based on a set of three questions about a firm’s resources; assets and capabilities:

- The first question is: Is the resource valuable – thus, does the resource add any value, such as lowering costs and generating revenue, to the firm? If it does not, then the resource leads to no organizational performance, and if it does, a potential value exists and the next question is asked.

- The second question is: Is the resource heterogeneously distributed across competing firms – thus, is the resource rare or uncommon to competing firms? If it is not, then the resource leads to competitive parity; and if it is, a potential for an organizational performance beyond economic survival exists and the next question is asked.

- The final question in the model is: Is the resource imperfectly mobile – thus, do competing firms have a disadvantage or cost in acquiring, developing and using this resource as compared to the successful firm which already possess this resource? Being imperfectly mobile captures both being imperfectly imitable and non-substitutable. If it is not, the resource leads to temporary organizational performance beyond economic survival, and if it is, a potential for sustained organizational performance exists and the resource would lead to that. Immobility of resources is based on isolating mechanisms as discussed earlier.

It is important to note that through building and rebuilding – coordination (integration), learning and reconfiguration of resources – the firm creates core and dynamic capabilities which make resources more valuable, rare and immobile, thereby increasing their potential value contribution to sustained organizational performance [44]. With this overview of RBT, the next objective is to conceptualize the link with e-commerce in DCs.
3. RESOURCES AND E-COMMERCE BENEFITS – THE CONCEPTUAL LINK

In order to identify resources that can create e-commerce benefits, the framework proposed by Mata el al. [30] can be adopted as a resource-based model of e-commerce benefits in DCs, Figure 2.

Fig 2: A Resource-Based View Model of E-commerce Benefits
The three questions of the framework can also be applied as follows:

- **First, is the resource valuable and appropriate to achieving any benefit?** – If it is not then no e-commerce benefit can be achieved, and if it is, then a potential resource may have been identified.
- **For this potential resource, the second question to ask is, is this resource heterogeneously distributed across competing firms?** – If it is not then the resource may generate e-commerce benefits which may largely be operational and informational.
- **Then, since the resource may be imitable or substitutable in the marketplace, the third step is to ask, is the resource imperfectly mobile?** – If it is not, the resource may create e-commerce benefits of which strategic benefits may be temporal or unsustainable, and if it is, the resource may create e-commerce benefits which are strategic and sustainable.

Two key implications emerge from the preceding discussion. First, it is important to identify resources which create e-commerce benefits and those that help sustain benefits, and second, to recognize that resource development depicts a complex and dynamic interaction of resources which differentiate their initial and long-term impact. Each of these implications is examined in turn below.

### 4. RESOURCE IDENTIFICATION

We begin by asking, what resources do DC firms need to create e-commerce benefits? E-commerce capabilities are a **coordinated set of tasks**, which utilize e-commerce technologies and other firm resources for the purpose of achieving e-commerce benefits. They consist of a combination of internal and external (accessible to the organization) resources which enable the organization to develop e-commerce capabilities that create and sustain e-commerce benefits at a certain point of their strategic orientation.

These resources may exist as ordinary, core and dynamic capabilities and assets depending on a firm’s strategic orientation, nature of operations and the extent of integration of e-commerce into its core activities. Among these resources, valuable resources enable a DC firm to achieve firm-level benefits that are largely operational and informational, and resources that are imperfectly mobile (inimitable and non-substitutable) enables a DC firm to achieve and sustain strategic benefits. Valuable resources may consist of ordinary (and some core) assets and capabilities.

For example, extant research [51] has indicated that due to weak infrastructure, most DC firms end up using web hosting services in developed countries like the USA. While this means of overcoming their constraints may be valuable, it is also relatively available for all firms in the marketplace; hence, it is not heterogeneously distributed across the firms. Depending on the organizational objectives, financial capital, managerial and technical skills available, a DC firm can combine these resources to manage this external relationship in a unique and coherent manner, and thus create a capability relatively heterogeneously distributed across the firms in its business environment. These resources can be rebuilt or combined with other resources to create new resources of more potential strategic value to the DC firm. The new resources may be unique in their functionality or embedded in intangible resources (like social capital) to become firm-specific in their nature.

Hence, DC firms can create a strategic fit or resource complementarities between IS resources and core firm activities to develop firm-specific IS resources which are imperfectly mobile. Though IS resources can provide the technical online functionality, it is through their interaction with intangible resources such as reputation, social capital, trust, goodwill, and managerial knowledge, that more strategic e-commerce benefits can be obtained.

When IS resources are integrated with other resources their value is reinforced in the firm. Lake [26] study on e-commerce activity in Ethiopia suggested that, the success of firms in selling the work of Ethiopian artists online was based on the existing international reputations of the artists. Brunton *et al.* [11] also argue that, in the context of DCs, because regulatory and normative institutions are relatively weak, there is an increased reliance on cognitive institutions and hence, social capital and social networks between parties – firms and their customers – become the means by which trust is developed and maintained.

Complementing IS resources with intangible resources (reputation and social capital) makes the benefits creation process become complex in nature. The frequent interaction of IS resources and these intangible resources makes the functionality provided by the IS resources become embedded in the invisible actions, social relationships and image and symbols [4]. They therefore become socially complex and relatively embedded in the tacit firm knowledge through frequent application.
Hence, the output of this complex interaction such as customer responsiveness, product development or service differentiation is firm-specific and imperfectly mobile. This largely generates strategic benefits including an enhanced social capital and reputation. Thus, these intangible resources form part of the medium and outcome of developing and deploying resources which are imperfectly mobile. This discussion is predictive of the following:

Proposition 1: Firms that develop valuable resources will develop e-commerce capabilities that create (largely) operational and informational benefits.

Proposition 2: Firms that develop imperfectly mobile (imitable and non-substitutable) dynamic resources will develop e-commerce capabilities that create and sustain strategic benefits.

5. RESOURCE DEVELOPMENT

Firms develop resources through a consistent search and examination of viable alternatives. This search does not necessarily occur in a linear process. It is more about a complex interaction which can occur between internal resources at the firm-level and external resources at the industry and national level. Teece et al. [44] conceptualized this complex interaction as firm specific processes – coordinating, learning and reconfiguration – through which organizational resources or embedded capabilities are developed. Coordination stems from recognizing and examining the congruencies and complementarities among existing resources or current processes, and between them and assets positions.

By identifying distinct ways of combining or coordinating resources, firms can create unique or firm-specific resources which may be imperfectly mobile and rare among competing firms. Then again, learning through repetition and experimentation enables the firm to acquire the tacit knowledge to perform its processes better and quicker, for existing processes to be innovated and for new processes to be identified [28]. Reconfiguration, involves the examination of the rapidly changing environment of the firm to transform or reconfigure a firm's assets structure and processes to sustain their strategic value to the firm.

The works of Jarvenpaa and Leidner [24][19] demonstrate several examples of the complex interaction of resources where IS resources (like IS infrastructure and technical skills which have gained much focus in IS literature) interact with other constructs – non-IS resources (like firm reputation, brand, socio-cultural capital and networks) – to create e-commerce benefits.

As earlier explained, the integration of e-commerce capabilities with these intangible resources increases their firm-specificity and reduces their mobility, and hence, increases their potential contribution to e-commerce benefit creation and impact on development. This discussion is suggestive that:

Proposition 3: Intangible resources (reputation, social capital and status) have a strong impact in complementing efforts of developing country firms in using tangible resources (technology, skills and physical capital) to create and sustain e-commerce benefits.

Proposition 4: IS resources influence the creation of e-commerce benefits both directly and indirectly through interaction with other resources.

Beyond the creation of a resource, is the maintenance of the resource. Maintaining resource is a capability which involves a lot of exercising or usage of the capability for it to become more habitual and embedded in organizational memory and culture. As the resource becomes more tacit in nature, the development process may fade away in the organization and conditions of causal ambiguity and social complexity are created around the resource, making it imperfectly mobile [3]. However, due to threats to the resource or to the firm's competitive position, the resource may branch into at least one of following six paths – retirement, retrenchment, renewal, redeployment, replication and recombination [23].

Retirement occurs when threats or extreme conditions force the firm to retire the resource entirely; like prohibition of the sale of a specific product may retire the resource – such as manufacturing plants – that were used in producing and delivering that product [23]. Where the threats are less severe and do not suddenly retire the resource, it may initiate a gradual reduced utilization of the resource like falling demand for product, and thus lead to retrenchment.

On the other hand, certain threats or crises can rather give the firm the motivation to seek to improve a resource through renewal, redeployment and recombination, instead of retiring it. Alternatively, the firm might even seek to enter a new product or geographic market which may redevelop the retired or retrenched resource.
For example, the introduction of email reservations into King Hotel in Egypt was met with the lack of requisite human resource competencies in English, in understanding of the reservation system, and in basic computer literacy [25]. In addressing the employee resistance from potential job losses and reduction in commissions, the top management had to resort to implementing the online reservation system alongside the manual reservation system, the assistant manager taking charge of online reservations, and paying commissions to employees, even for online reservations, while training employees over time.

This is an example of a complex interaction – coordination, learning and reconfiguration – of resources in change management and strategic thinking (see Table 1) to avoid the retiring or retrenching of resources. Renewal of a resource requires the firm to enter a new development stage and search, examine and develop new alternatives. As in King Hotel, renewal may lead to modification of a resource as new alternatives may define changes in processes and functionalities. Redeployment occurs when the resource is redeployed into a market for a different but closely related product. Such transfers would require an alteration of the resource to enable it serve a different product market. The resource would thus have to enter a new development stage for it to be redeployed.

The firm may also reproduce the same resource in a different geographic market, thus replicating the resource. Since barriers to replication exist, the firm may experience an initial drop in the level of the resource (capability), and then redevelop it back to its pre-replication level. Recombination occurs when original resources are combined with other resources to form new resources. This can occur during the renewal of resources in a current product market or in transferring the resource to a different but related market. Ideally, renewal, redeployment and recombination may lead to substantial alteration of the original resource, and on further development create a new resource relatively distinct from the old one [23].

In effect, through distinct processes of resource coordination, learning and reconfiguration firms orient resources within their strategic orientation to develop the desired e-commerce capabilities.

These resource development processes explain the paths through which resources are developed, deployed and managed to create and sustain significant outputs or e-commerce benefits. E-commerce capabilities as outputs of resource development have to further interact with other resources such as social capital, reputation, and image, to become firm-specific resources which have more strategic value to the firms. At this stage of achieving strategic benefits, e-commerce capabilities, among other output resources, become more causally ambiguous, socially complex or defined by unique historical conditions. These attributes increase their potential strategic value, making them more valuable, rare, imperfectly imitable and non-substitutable. The ability of the firm to carry out these resource development processes depends on the higher order – core and dynamic – capabilities in the firm. As such, the model suggests that:

**Proposition 5:** Firms with resource development processes - coordination, learning and reconfiguration - develop higher order resources that create and sustain e-commerce benefits.

This said, we note that the constraints in the context of DC firms also have an attendant effect on the resource development process in the firms. Firms, through dynamic managerial capabilities, can examine and identify threats and opportunities in the market, and integrate the strategic measures to respond to them with respect to resources accessible to them [31]. Then again, being able to institute measures to respond to these threats is not enough, these firms have to devise a relatively low-cost manner of accessing IS resources and integrating them with other resources in order to sustain the rent generating ability of their e-commerce capabilities [2] [3]. As firms engage in the frequent application of e-commerce capabilities, the capabilities become more tacit in nature and imperfectly mobile and hence, largely contribute to creating and sustaining strategic benefits [23].

Consequently, the RBV model of e-commerce benefits, Figure 2, can be used to identify and evaluate which resources can be used by DC firms to create and sustain e-commerce benefits amidst the constraints of their context, and through the resource development processes – coordination, learning and reconfiguration – can be used to build and rebuild resources to circumvent the constraints, be congruent to the rapidly changing business environment, and ensure the sustainability of e-commerce benefits for the long-term. The ability to manage the resource identification and development processes effectively within the strategic orientation of DC firms depends on the managerial capabilities accessible to them.

The next question we ask is, what are the implications of the RBV model of e-commerce benefits and the propositions outlined to managers or to e-commerce strategy at the firm-level.
6. MANAGERIAL IMPLICATIONS

As discussed, extant literature posits three types of e-commerce benefits – strategic, informational and operational. The achievement of these benefits depends on the extent of integration of e-commerce capabilities in the firm. Firms that have their core business operations largely enabled by e-commerce capabilities are more likely to obtain benefits which directly impact on their revenue or which are more strategic. However, creating these benefits is not enough. It is also important firms institute actions to sustain the benefits.

The ability to sustain the benefits in the light of changes in the business environment of the firm also depends on the existence of dynamic capabilities in the firm. These dynamic capabilities lie in managerial capabilities of DC firms [31].

Hence, to the managers of DC firms, the first objective is to identify which core activities can be enabled by e-commerce; and second, develop the necessary integration of resources identified with these core activities. Our RBV model of e-commerce benefits offers DC managers the path of resource identification and processes to develop resources. In terms of resource identification, first, we identify that firms should develop a low-cost strategy of accessing and developing resources necessary to capability development.

This may require substitution of global resources for local IS resources [51] and/or the use of intangible resources to access and effectively exploit the few IS resources (Lake, 2000). Second, for DC contexts where rich interpersonal communication is emphasized (like Ghana and India), firms should consider intangible resources – social capital and perceived reputation – as critical resources which can facilitate the development of socially complex or embedded e-commerce capabilities. These intangible resources form part of the medium and outcome of developing and deploying e-commerce capabilities. Creating complementarities between these sets of resources increases the potential value of the capabilities to the benefits creation process, as they tend to reinforce the intangible resources and generate interrelated strategic benefits. This leads us to consider resource development.

Resource development stems from the ability to create strategic fit between e-commerce capabilities, as IS resources, with other resources including the intangible resources earlier outlined. This strategic fit occurs through three processes – learning, coordination and reconfiguration – which enables firms to develop capabilities that created and sustained e-commerce benefits.

This ability for firms to create strategic fit largely depends on the managerial capabilities present in the firm. As seen in the case of King Hotel, managerial capabilities enabled the firms to create strategic ties between resources in a manner that increased their value as compared to their individual value [25], 2004). Hence, to DC managers we note that managerial capabilities are the key set of capabilities which enable firms to be adaptive and responsive to the uncertainty and the lack of consistent availability of resources.

The firms that are successful at e-commerce – achieve largely strategic benefits – are those who internalize this set of capabilities and create an intimate interaction between the managerial capabilities and e-commerce capability development processes (see Montealegre [33], Cloete et al’s study [14], notes that most SMEs are extremely cautious and hesitant in adopting e-commerce since they perceive benefits to be irrelevant or not appropriate to their organization and, moreover, because of the pressure to show the return on investment.

A manager’s intention to adopt e-commerce would therefore be stronger if there was a more favourable attitude - perceived strategic value and insight. Thus, the direct engagement of managerial capabilities in e-commerce capability development processes facilitates the strategic visibility of e-commerce in core firm activities and thereby influences usage. The onus is therefore on the firm to be able to attract, acquire or develop and internalize such capabilities to make them relatively immobile in its business environment. Our RBV model of e-commerce benefits offers DC managers offers the starting point to achieve this.

7. CONCLUSION

This paper began with an objective of determining how firms in developing countries develop, deploy and manage resources to implement and realize e-commerce benefits amidst their national constraints. For this objective, RBV has offered the understanding that DC firms can orient their resources to circumvent their constraints and create and sustain e-commerce benefits. The conceptual framework, Figure 2, proposed emphasizes the need for DC firms to focus on or seek to develop distinct resources that are valuable, rare, imperfectly imitable and non-substitutable. However, the development process of these resources is a cumulative, expansive and a highly path-dependent process which thus requires the commitment of the organization and a defined focus to achieve it.
Identifying the resources is not enough. Knowing how to dynamically integrate organizational processes and assets to be congruent with the changing business environment is what is critical.

Arguably, the model developed in this paper may be applicable to developed countries or more institutionally e-commerce ready contexts. However, the fact that the model moves away from the current research focus on institutional readiness and adoption factors to a more strategic perspective of reinforcing or developing resources to navigate institutional constraints and achieve and sustain e-commerce benefits, makes it more applicable to DCs or resource-poor contexts. Current success stories suggest the need to develop complementarities or a strategic fit between IS resources and intangible resources like social capital and reputation. For DCs this may be considered a necessary recourse to the weaknesses of regulatory and normative institutions which may affect e-commerce adoption. Furthermore, this is an opportunity to also develop more imperfectly mobile resources which sustain benefits. As there are no universal sources for achieving e-commerce success (Barney 1997), future research may begin from the outlined research propositions and conduct an empirical study that will make the model more theoretically-grounded and practically-orientated to the context of developing countries.

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Richard Boateng – A Resource-Based Model for E-Commerce in Developing Countries


Scalable Knock Authentication Mechanism (SKAM) for Addressing TCP and UDP Probe Vulnerabilities in Open Network Ports.

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ABSTRACT
Scanning TCP and UDP connections for finding susceptible hosts is one of the most popular techniques used by malicious cyber criminals and hackers to discover and map services that are listening on a specified port. Using this method an attacker can create a list of potential weaknesses and vulnerabilities in open ports leading to exploitation and compromise of a remote host. We employed port knocking sequence, steganography and cryptography as techniques of choice for the development and implementation of a scalable port knock system (SKAM) that protects knock sequence transmission as well as services running on the network server. System performance was evaluated using standard probe tools and very promising results were obtained.

Keywords- Port scanning, knocking, sequence, security and network

1. INTRODUCTION
One of the popular methods for finding susceptible hosts is Port scanning. Port scanning is the process of connecting to TCP and UDP ports for the purpose of finding what services and applications are running on the target device. After running applications, open ports and services are discovered; the hacker can then determine the best way to attack the system. This technique consists of sending a message to a port and listening for an answer. The received response indicates the port status and can be helpful in determining a host’s operating system and other information relevant to launching a future attack.

Probe is the first step that an attacker will take before breaking into a system. Port scan, OS fingerprint, application vulnerability scan and network mapping are all very common on the Internet nowadays. Smart [1] designed a fingerprint scrubber aimed at operating system probe (TCP/IP stack fingerprinting). In order to collect the system information, the attacker will send carefully crafted packets to the remote target and watch their responses. These packets make use of the ambiguity of network protocol, and cause the different OS give responses differently because of lack of standard. The attacker, then, matches the returned responses with the signature database to identify the remote system type.

An important problem in the domain of network security is the plethora of services running on networked machines, and more specifically, the open ports which allow any user to connect to those services and attempt to attack them in any one of countless ways. In the early years of its inception, around the 1980s, the Internet was designed purely with interoperability in mind.
The engineers involved wanted machines to communicate easily, unhindered by the obstacles brought upon by ‘unnecessary’ security features such as authentication and access control. In fact, security features were, for the most part, unheard of, and programming flaws in network-enabled software coupled with weaknesses in early networks brought about many opportunities for attacks [2].

2. PORT KNOCKING

Port knocking is a technique first introduced in the blackhat and trade literature to prevent attackers from discovering and exploiting potentially vulnerable services on a network host, while allowing authenticated users to access these services [3]. However, the first published description of a port knocking scheme can be traced to the work of Barham[4], who describe a scheme whereby a passphrase is transmitted in clear text to a firewall either through a series of SYN packets, in a single “knock” packet, or as an option in the SYN packet. Subsequently, Port-knocking is introduced by Martin Krzywinski [5] as a method of connection through a closed port. It is mostly focused on the server’s personal firewall and protecting UNIX-based services with iptables. Since using this method protects important administrative services like SSH, SNMP, and etc, from denial of service and/or any possible attacks, and moreover it is flexible for developers to have their own implementation, it is widely embraced by the industry and academic communities and several open source implementations have been released.

At first, closing off ports may seem undesirable, but every program listening on an open port can potentially pose a security threat to the system [6]. Most of the time, the vulnerabilities that hackers exploit are due to programs running on open ports. Port knocking provides a simple yet effective solution to this problem. It enables the computer to pass traffic to these ports when needed and deny it the rest of the time, all while keeping the entire process secure against those who might be watching.

Many existing port knocking applications suffer from serious flaws in how cryptography is applied to provide authentication. For instance, in Doyle’s system [7], the IP address of the client, the requested TCP port, and an open/close flag are concatenated and padded into a 64-bit message, which is encrypted using the Blowfish algorithm and a shared secret key, and encoded into port numbers. The server decrypts the message and opens or closes the requested port to the client host, depending on the flag value.

The claim is that this construction prevents successful replay attacks by preventing attackers from knowing what action was taken; however, an attacker capable of intercepting the authentication sequence would also be able to infer the contents of the message by analyzing network traffic for connections opened immediately after an authentication exchange, or closed immediately before. Thus, the attacker could authenticate and gain access by assuming the valid client’s IP address and replaying the authentication sequence.

Another system, Cryptknock, uses an unauthenticated Diffie-Hellman exchange to generate a session key, which is then used to encrypt a shared secret. The standard man-in-the-middle attack against Diffie-Hellman would allow an attacker to recover the shared secret and authenticate at will. Krzywinski’s system [8] allows a wide variety of possible configurations, most of them insecure, due to plain-text password transmission, inappropriate application of encryption (in the same manner as Doyle), and insecure checksum algorithms. Also, many existing systems (especially ones employing encryption) make no attempt to determine if messages that they receive are authentic. For instance, when Doyle’s system receives a message, it will decrypt it and execute its contents. No attempt is made to ensure that the message was valid in the first place, so a denial-of-service attack could be launched by sending random data to it, with the result of polluting firewall tables with random rules.

In some cases, the authentication token sent is not bound to the client or the server. This could permit a variety of masquerading, reflection, or man-in-the-middle attacks under certain circumstances. Another common _aw is the use of global shared secrets for authentication, known by all users of a port knocking server. This leads to administrative difficulty in changing keys. In conjunction with systems that allow clients to request the opening of arbitrary ports, a key compromise would allow an attacker to open any port on the system. Some systems, such as [4], use time-based pseudorandom key streams in which keys must be valid during a time window corresponding to the maximum acceptable clock drift and the maximum transmission time between client and server. This allows a window of opportunity for attackers to replay captured authentication tokens. A window size of a few tenths of seconds should be adequate for good security, but this is only practical on low-delay networks with time synchronization mechanisms in place.
Between distant hosts on the Internet under different administrative domains, transmission delay alone may be up to half a second, while poor deployment of time synchronization systems makes clock drifts of several minutes common. This leaves ample time for attackers to replay captured authentication sequences. For a graphical representation of port knocking in action see, fig. 1 below [9].

![Fig 1. Port knocking in action. Source [9].](image)

### 3. THE SKAM SYSTEM ARCHITECTURE

SKAM employ Steganographic dynamic knock sequence for port Authentication across closed port. The intention is to achieve the following:

- Develop a system that prevents the malicious users from monitoring network traffics even when they recognise the existence of such traffic.
- Implement a system that can prevent port scanning and different port attacks.

#### 3.1 Design

The design of SKAM depends on two main components. In what follows, is the description of these two components:-

- Server
- Client

1) Server: The first key component of this system is the server, the program which receives the knocks from the client and interprets them as commands to open ports in the firewall, execute system calls, or take other actions. The goal of the server is for it to successfully perform four primary tasks: log monitoring, retrieval and storage of port knocks, decryption of completed knock sequences, and firewall modification.

![Fig 2. Architecture illustrating the Server](image)

2) Client: The second key component needed for this system is the client program, the part that will do the knocking. The client begins by prompting the user for a source host, a destination host, a port number, an offset, an action value, and an encryption password. Host names can be entered either in the form of a domain name (i.e. www.google.com) or an IP address (i.e. 192.168.03.01), as they will ultimately be resolved to an IP address. The client, upon resolving the source hostname, is left with an IP address which is composed of 4 1-byte values, each with a possible range of 0 – 255. The port number, on the other hand, has a possible range of 0 – 65,535. Finally, the action value tells the server whether the requested port should be opened or closed.

![Fig 3. Architecture illustrating the Client](image)
Launcher is the start-up component which is used to instantiate the inner component, and also starts and checks user-defined XML files and launches the graphic interface.

Packet Listener is the packet filtering component that analyses the incoming packets at the IP level, it receives packets, knock sequence and analyses them based on the information in the inner component.

Actions Manager is used to control the opening and closing of port and also the firewall based on the knock sequences received from the packet listener.

Logger is the component that performs the record keeping of all activities.

Decoder is used to filter incoming packets and decrypting payload using the secret key stored in the inner component.

Packet Injector receives requests for sending packets and sends them over the network.

Encoder is used to encrypt the XML file before sending over the network.

The two main component of the system: Client and the server, have common inner component which is represented in the figure below:

Fig 4. Common Inner component for the client and Server. Adapted from[10].

3.2 Operation
The Operation of the entire System consists of the following main steps:

1) Traffic Monitoring: Communication with the server will be in the form of XML files. A port knocking server will be installed to check all the traffic command arriving at the firewall in order to ensure that the client on the network have the authorized use of the network and computing resources as in figure below.

Fig 5. Traffic monitoring at the Server

2) Knock Sequence Processing: The Knock sequences are defined in XML files. Traffic holding a knock sequence is being captured from the client and the port knocking server extracts the data from the packet received. The knock sequence contains some information that is used to prove the client request and identity. If this information provides the valid authentication parameters, the firewall is being demanded by the server to open the concern port for the client. Otherwise, the port knocking server blocks the client identity from accessing that server.

3) Client and Server Authentication: All messages sent from the client to server (i.e., the request and response) are encoded as sequences of TCP or UDP port numbers. At this stage, the server takes a randomly generated knock sequence and encrypts it using a secret key (symmetric) that only the client can provide and sends it as a knock sequence to the client in order to make sure that it is communicating with the correct client. The client on receiving the packet carrying the encrypted knock sequence, extracts it and decrypts it using a secret key (symmetric) which they share with the server. Then it sends the random number generated as a knock sequence back to the server again. The server then extract the knock sequence and checks if the received message holds the same number as the one it randomly generated before, it then executes the command based on the client's request. Decrypted knock sequence will provide the server with the information it needs to open a specific port in the firewall.
The client and server share a key, as well as a counter which is incremented for every client connection attempt. The counter prevents replay attacks by ensuring that every SYN packet sent by the client is different from any packets sent previously. We use sequence number and timestamp fields of the SYN packet to embed our MAC information.

5. KNOCK SEQUENCE

Every XML file sends contains a list of actions, they correspond to actions that the listener will do after a correctly received knock sequence. These actions include:

1) Types of Action
   - Open port
   - Closed port

The system allows deployment of three types of packages: TCP, UDP and ICMP. For each packet the user can set all the header fields. The XML file is a list of packages that correspond to packets that the server will receive to perform the actions listed above.

4. ALGORITHM

The Port knock algorithm [3][10] is outline below. A Port Knock client initiates a connection which composes of a TCP SYN packet to a Port Knock-enabled server and embeds an authentication token into the packet. The server receives a SYN packet and extracts the authenticator. If verification is successful, the server allows the connection to continue, otherwise the packet is dropped.

4) Port Closing: Leaving a port open to the public means an invitation for the intruder, therefore, if the port is left silent for specific period of time the server will demand firewall to close the open port using a timeout mechanism. So that the next time the client wants to connect again a new generated sequence number will be used for the authentication, this is to prevent replay attack prior port knock sequence. Lastly, the server returns to its task of monitoring the system log.

5) KNOCK SEQUENCE

Client - Server: MAC_{counterClient}(k) encoded in package header of SYN packet

Server: Set counter_{Server} = counter_{Server} + 1 for i = 0 to failureT

If (MAC_{counterServer}(k) == MAC_{counterClient}(k))
  Set counter_{Server} = counter_{Server} + i + 1;
  resynchronize counter if client is ahead
  Server - Client: SYN-ACK
goto e.

Client: if (SYN - ACK received) then
  Set counter_{Client} = counter_{Client} + 1, goto e;
  connection was successful

Client: if (SYN - ACK not received) then
  Set counter_{Client} = counter_{Client} + 1;
  assume server got SYN, but SYN - ACK was lost
goto c.

Server, Client: proceed with package connection
If (FIN or RST received) then
  goto a.

Where:
- Counter_{client/server} is the per-IP-address counter maintained by Client/Server
- i is a value derived from Client’s IP address and a symmetric key shared between Server and Client
- Package can either be TCP, UDP
- k is a Package flow identifier
- failureT is a failure-tolerance parameter

Figure 6. Port knocking server opens firewall to the client

Figure 7. Port closed after communication
5.1 Legal Implication

Whether or not scanning is ethical is a delicate tricky question. While scanning is widely held to be a malicious activity, professionals use the technique regularly to diagnose network problems and to detect vulnerabilities on their own network. The legitimacy of a port scan is often determined by the circumstances surrounding the incident in an attempt to establish intent.

A scan may or may not be an attack. In the vast majority of instances, a scan does not cause any damage to its target system. How can an activity that is so passive and non-harmful be considered malicious? While a scan is not any more destructive than “ringing the doorbell to see whether someone’s at home,” (Smart, 2000) it is a highly invasive activity. The information taken from a scan can often leave the target system violated and therefore vulnerable. A scan is considered malicious when the intent is to reveal vulnerabilities in the target. Establishing guidelines for proper scanning activity and implementing them into policies is an important and difficult task that needs to be performed by the Information Security community.

6. CONCLUSIONS

Port Knocking can be used to construct authentication systems on firewalls with the goal of only allowing authorised users access to open ports on the system. It helps add an extra barrier to your computer and makes it harder for hackers to get a toehold into your system. A number of standard tools such as Nmap, Zenmap GUI, Netcat, free port scanner, TCPReplay, wireshark are used to perform port and packet monitoring and to also evaluate the performance of this system. This system is found to be invulnerable to the following types of attack:

* Dos Attack: Timeout mechanism is used to monitor the server for specific period of time on the server by adding a time stamp to every client and periodically checking the list, deleting the client that were created too long ago and it will be issued a request timeout for further re-authenticated before it is allowed to access the requested port again which will prevent the system from buffer over.

* Replay attack: To prevent replay attack, a dynamic knock sequence is produce to prevent hacker from detecting the next knock sequence and only IP address encrypted in the knock sequence is allowed accessed to the system.

* Spoofing Attack and Man-in-middle attack: A Steganographic technique embedded with cryptographic technique is used to prevent a situation in which one person or program successfully masquerades information transmitted from one system to another by falsifying data and thereby gaining an illegitimate advantage of the system.

* Zero day attack: ensuring that all port remains closed to unauthorised access has prevented unknown exploit to a software developer. Thereby, preventing zero day attack or zero day vulnerabilities.

7. DIRECTION FOR FUTURE RESEARCH

Platform independence is still a challenge to the cross-platform implementation of the SKAM architecture. Some specialized libraries are used for network traffic capture and also for sending network traffic over the network. These libraries are not compatible on some platform. Another interesting possible future work is the extension of the symmetric key used for encryption to asymmetric key.

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Social Engineering and Workplace Productivity - Balancing the Odds

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ABSTRACT
Apart from contending with the problems of intrusion into enterprise information platforms, organizations are also faced with the consequences of unguided access and usage of social engineering website in the workplace. We examined the circles of network abuse outlined in Network Service Organization's computer use policies using Airtel Nigeria Plc as a case study. We designed a questionnaire titled “The Impact of Social engineering websites on organizational productivity” as the research instrument. Using descriptive and inferential statistics, analysis of user responses showed that although some actions are prohibited, employees circumvent the security measures put in place in connivance with some IT department staff. Most employees are also not aware of the far reaching consequences of these seemingly harmless acts on the organization. Recommendations were made based on our findings.

Keywords: Enterprises, Social Engineering, Website, Face book, Productivity, Airtel.

1. INTRODUCTION
Social engineering is a collection of techniques used to manipulate people into performing actions or divulging confidential information. While similar to a confidence trick or simple fraud, the term typically applies to trickery for information for gathering or computer system access. In most of the cases the attacker never comes face to face with the victims and the later seldom realize that they have been manipulated.

Social engineering is a collection of techniques used to manipulate people into performing actions or divulging confidential information. While similar to a confidence trick or simple fraud, the term typically applies to trickery for information for gathering or computer system access. In most of the cases the attacker never comes face to face with the victims and the later seldom realize that they have been manipulated. These techniques of information gathering are often carried out through the use of websites [8]. Social engineering websites sometimes referred to as “friend-of a friend” sites are built upon the concept of traditional social networks where one is connected to new or already known people. The purpose of some networking sites may be purely social, allowing users to establish friendships or romantic relationships, while others may focus on establishing business connections.
Although the features of social networking sites differ, they all allow us to provide information about oneself and offer some type of communication mechanism (forums, chat rooms, e-mail, and instant messenger) that enables you to connect with other users. On some sites, users can now browse for people through shared connections. Many of these sites have communities or subgroups that may be based on a particular interest. However, these sites generate potential benefits for business organizations, but the area of concern is the security implications posed by the sites. Social engineering websites rely on connections and communication so that they encourage one to provide a certain amount of personal information. When deciding how much information to reveal, people may not exercise the same amount of caution as they would when meeting someone in person because the internet provides a sense of anonymity and the absence of physical interaction provides a false sense of security [6].

While the majority of people using these sites do not pose a threat, malicious people may be drawn to them because of accessibility and amount of personal information that is available. As a result, the information could be used to conduct social engineering attack. Social engineering involves luring unsuspected users to take a cyber-bait much the same way a conventional fishing involves luring a fish using the bait. Phishing is a form of social engineering that deceives consumers into disclosing their personal and financial data, such as passwords, ATM pin numbers, credit card numbers and bank account numbers. It is an attempt to elicit a specific response to a social situation the perpetrator has engineered (Tony, 2009). Among other forms of cybercrime, phishing scams are on the increase in Nigeria.

The remaining part of the paper is organized as follows. In the next section we examined some related issues. This is followed by a section highlighting social engineering scenarios in the Nigerian context. We then formulate research questions and elucidate our research methodology. We conclude with recommendations based on the research findings.

2. RELATED ISSUES

Internet social activities have presented marketers with challenges as well as opportunities to reach specific target markets. Facebook emerged on the social network scene over half a decade ago; originally viewed as a networking site limited to college students. In 2006, Facebook was serving as many as 7.5 million registered users and was seventh among the more accessed websites in the U.S. [2]. Recruiters for businesses and colleges are finding the social and professional networks are to perform background checks on potential employees. In the past many companies used Google and Yahoo to perform these background checks but recently Facebook, MySpace, Xanga and Friendster are being utilized in this regard [1]. These organizations are looking for “red flags” which might indicate that the potential student or employee might not fit into organizational cultures as expected. Organizations often gain access to these websites by asking a college student working for the organization to perform the background check. Thus, while some college students think only other students have access to their postings, they are finding that such postings are often times ending up on the desks of potential employers.

Merely trying to prevent infiltration on a technical level and ignoring the physical-social level leaves organizations wide open to attack [4]. While many security systems and technologies have been deployed to prevent intruders from accessing high value systems, an organization simply cannot patch against social engineering [10][3]

3. THE NIGERIAN SCENARIO

One area of concern that seems to elude popular debate about social engineering and cyber crime in Nigeria is the potential danger that social engineering poses to business and other organizations in the country. Highly motivated attackers can have much more success by manipulating people (insiders within an organization) rather than trying to hack the various levels of sophisticated security technologies put in place by organizations to secure their operational network. Primal motivators such as fear, greed and sexuality can be used to manipulate employees into releasing information unwittingly thus providing unauthorized access to organizational information systems [5]

Social engineering therefore constitutes a powerful force that can change the way organizations and the security community perceives insider threats. A casual interrogation of employees in some Nigerian business and financial organizations showed that while on break or when the pressure of work is less, they engage in online chat on social engineering websites using the organization internet facilities (Longe et al, 2010). Generally, these actions do not fall within the circles of network abuse as outlined in major organizational computer use policies.
Most employees are not aware of the far reaching consequences of these seemingly harmless acts on the organization. Social engineering is the human side of breaking into a corporate network. Cyber criminals cannot be lucky in convincing a firewall to give them access to a bank record, nor can they compel anti-spyware to allow them glean through an organizational database but they could find it easier to persuade a person whose confidence they have gained to allow them admittance to secured area of a network or even to disclose confidential information [2][9]. Nowadays, these criminals explore social engineering websites such as yahoo personals, twitter, zoosk, Facebook and many dating websites as springboards for their attack. By luring employees into a facade of relationships, they use phishing, plant spywares, use anonymous proxy servers and other hacking tools to hack into secured organizational information. For our study, we delimited Airtel telecommunications at both Ibadan and Lagos offices as our case studies. We concern ourselves with the use of social engineering websites by the employees of Airtel telecommunications as well as its resulting impact on organizational productivity.

4. RESEARCH QUESTIONS

With this increased dependence on online and internet based business transactions and the migration of former paper-based procedures to electronic platforms, research is warranted into the current trends in the use of social engineering websites by employees in organizations, the level of awareness of these risks involved when using these websites as well as measures (if any) put in place by Nigerian organizations to deal with these problems. The research questions that emanate from the foregoing are as follows:

- What is the level of social engineering websites usage employees in the case study?
- Are employees aware of the threat posed by social engineering websites to their organization?
- What are the mechanisms and policies that are put in place by Airtel telecommunication to check the threat of social engineering website?
- What is the level of compliance to the anti-threat mechanism and policies at Airtel telecommunication?
- What are the impacts of social engineering websites’ use by Airtel employees on organizational productivity?

5. METHODOLOGY

We employed the use of questionnaires as a quantitative research instrument to solicit responses on the level of awareness of risks as well as the level of usage of social engineering websites in the targeted organization. Qualitative interview was carried out among security departments in Airtel telecommunications to ascertain the level of preparedness and readiness to deal with social engineering related risks. Descriptive statistical methods of simple frequency counts and percentages were used to analyse the demography and research questions while inferential statistics of T-test was used to analyse the hypothesis.

Hypothesis

To address the research questions, we formulate and analysed the presented hypothesis:

Hypothesis 1

H$_0$: There is no significant difference in the perceived productivity of employees of Airtel Telecommunication as a result of using Social Engineering Websites.

Hypothesis 2

H$_0$: Airtel’s organizational policies on the use of social engineering websites will not significantly affect employee’s use of social engineering websites at their workplace.

Table 1: T-test on sex of Airtel’s employees and the use of social engineering websites.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex and the use of social</td>
<td>1315</td>
<td>33859</td>
<td>6.152</td>
<td>250</td>
<td>.000</td>
<td>*Sig</td>
</tr>
<tr>
<td>engineering websites</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1 is a t-test on the sex of Airtel’s employees and their use of social engineering websites. The table reveals that the result is less than .05 alpha level of significance (t-cal .000 < 0.05 alpha level). Therefore, the null hypothesis is rejected. This is an indication that male and female use of social engineering websites significantly affects employee productivity. Subtly, there is indication that female employees also use social engineering websites than their male counterparts.

Hypothesis 2

H$_0$: Airtel’s organizational policies on the use of social engineering websites will not significantly affect employee’s use of social engineering websites at their workplace.
Table 2: T–test policy on website use and employees’ compliance

<table>
<thead>
<tr>
<th>Variables</th>
<th>mean</th>
<th>Std</th>
<th>T</th>
<th>df</th>
<th>Sig 2-t</th>
<th>Rem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policy on the use of social engineering websites and compliance by employees</td>
<td>-2072</td>
<td>5.6295</td>
<td>5.83</td>
<td>250</td>
<td>.000</td>
<td>* Sig</td>
</tr>
</tbody>
</table>

Table 2 is a T-test on the use of social engineering websites and the compliance of employees’ policy. The table reveals that the t-test is lower than the alpha level of significance .05 (t-test cal .000 < .05 alpha level). The hypothesis is rejected. This is an indication that there is a significant difference between the variable tested. Therefore, Airtel’s organizational policy on the usage of social engineering websites will not significantly affect employees’ use of the websites at the workplace. The hypothesis is therefore rejected.

6. CONCLUDING REMARKS

Social engineering attacks are one of the hardest threats to defend against because they involve the human element which in itself is quite unpredictable. Nevertheless, there are some measures which can certainly bring the risk associated with social engineering to acceptable levels. While attacks on human judgement are immune to even the best of security defence systems, companies can mitigate the risk of social engineering with an active security culture throughout the organization that keeps on evolving as the threat landscape changes.

Findings from this research indicate deviance to organizational policy on social engineering websites usage. This means that existing policies does not discourage employee use of the website. Based on the foregoing we recommend well documented and accessible security policy, associated standards and guidelines as foundations for acceptable use of web facilities within organizations. These policies should clearly document in simple terms, its scope and content in each area that it applies to. Acceptable usage policies should address business usage of email, computer systems, telephone, network etc.

Prospective employees should be screened to ensure that they do not pose a security threat to the organization if employed. Compliance monitoring should be put in place to continually ensure that the security policy is complied with.

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Knowledge Generation and Dissemination For the Visually Impaired Using Web-Technologies - A Case For Nigerian Universities

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ABSTRACT

The world wide web provides information and knowledge across the globe to as many as are connected to it. This has enhanced knowledge generation and dissemination especially among university students and staff. However, studies suggest that educational institutions have been slow in ensuring accessibility of internet facilities to students with disabilities. This study investigated the extent to which students with visual impairment access and uses the internet for knowledge generation and dissemination in Nigerian universities. Descriptive survey design was adopted and a sample of one hundred and thirty eight university students with visual impairment was used for the study. Four research questions guided the study and mean and standard deviations were used to answer the research questions. Findings indicate that students with visual impairment can only access the internet to a low extent due to unavailability of some assistive technology devices. It was suggested that universities should establish resource centres where students with visual impairment will have computers with adequate assistive ICT facilities.

Keywords: Visually impaired, Internet, Accessibility, Education

1. INTRODUCTION

The internet is the world’s largest and most widely used network which is currently critical for educational advancement. It provides current and speedy information for students especially where most libraries in the developing world stock books with obsolete information that cannot meet the demands of the fast moving world. One feature that makes the internet very important is its constant availability. It gives university students opportunities to access information for research as well as disseminate information.

In order words, the internet is a network of networks which provides an easy access to every information on the latest research reports from anywhere in the world and users exploit it to facilitate knowledge transmission. Knowledge is a mental process of cognition that involves appreciation and understanding of ideas, concepts and theories. As an abstract process, knowledge cannot be physically felt but can be appreciated and applied in problem solving situations for the growth and development of both human and material economy.
In an age where knowledge economy is the pivot on which industrial and technological developments revolve, the world systems seem to be knowledge-driven. And the rapid advances in information and communication technology has given a boost to the knowledge economy. One innovation in knowledge generation and dissemination technique that has become central in the world is ICT [13]. It is a veritable learning tool which gives opportunities to access and disseminate knowledge. Nigerian universities, in order to keep pace with the modern trend in information communication and technology, are making some effort to provide ICT infrastructure through the provision of cyber cafes, introduction of Afrihub and introduction of some computer courses to enhance teaching, learning and research.

Efforts are being made to increase the bandwidth for internet connectivity so that students and lecturers can access the World Wide Web anywhere any time in the school. Students are expected to pay their fees and upload same online, register their courses, check results, check allocation of hostels, and submit some of their assignments online. In spite of these efforts and expectations, some studies have indicated that the visually impaired may not have had full access to the internet facilities and therefore, may not have benefited maximally from the provisions of the internet [22].

Visual impairment generally refers to those who have seeing difficulties which cannot be corrected by eye glasses [8]. It includes those who are blind, those with low vision and those with partial sight. Visual impairment in this context refers to students who cannot functionally and effectively make use of vision and they, therefore, require special education and adapted materials in order to learn effectively. In this study, it includes the blind and those who cannot use their residual vision to access information.

Accessibility refers to full and equal participation in the use of the internet facilities by the students with visual impairment through some assistive technology devices. Access according to Craven (2003) includes both physical access to hard ware and software as well as ensuring that the visually impaired can access what is on the screen and also interact with resources and services. Accessibility to the internet facilities is a right of students with disabilities. This is why Article 9 of the United Nations Convention on the rights of persons with disability (2006) which deals with accessibility states that parties shall ensure to persons with disabilities access on an equal basis with others, to information and communications systems including the internet.

UNESCO in their meeting on Internet accessibility and the Disabled 2009 reiterated their commitment to ensuring that persons with disabilities participate fully in the knowledge economy. In line with the above the National Policy on Education 2004 emphasized that persons with disabilities will have equal access to education as others. The Royal National Institute[15] observed that the internet is one of the most significant developments since the invention of Braille because it has for the first time, given the blind and the partially sighted an access to the same wealth of information as the sighted. The assistive technologies which enable students with severe visual impairment to access the internet include screen reader software applications which convert texts into synthesized speech such as Job Access With Speech (JAWS) and Home Page Reader. Others are refreshable braille display which translates texts to braille and screen enlargement software and braille embosser which converts computer generated texts to embossed Braille output. These software unfortunately cannot convert graphic images and they, therefore pose limitation to the students.

Armstrong [1] opines that educational institutions have been slow in ensuring that the learning materials and environments are accessible to those with a variety of disabilities and as a result, a digital divide which hinders those with disability from having equal access to education unlike their able bodied counterparts still exists. Yu et al [22] noted two major limitations which the visually impaired encounter in the use of the internet as poor accessibility to the web content and limitations of the currently existing assistive technology. Many websites are not accessible to the visually impaired [11][17]. Moreover, most web pages are graphically oriented and contain fonts, colours, frames and tables that put the visually impaired at a disadvantaged position [10].

In [2] and [3] it was noted that found that navigation and accessing the visual cues through the modern graphic representations and interfaces posed problems to the students. Williamson et al [21] in their study, found that the visually impaired experience difficulty using the internet because of cost, lack of computer skills, lack of confidence in being able to use a computer and inability to access information due to poor web design. In line with the above, Gerber [6] and UNESCO [19] noted that the visually impaired lack basic ICT skills, training and training materials.

The visually impaired students experience hard ware, software and web accessibility problems while using the internet [16]. They further noted that they experience difficulty copying text from a web page, searching a subject using the keyboard as well as
registering to a website. Screen readers and screen magnifiers are highly complex and are quite operating system specific. To them operating such complex systems would be difficult for people who are ‘technologically frail’. It becomes more difficult for them because the computing environment is complex and using the software is equally complex [7].

In [9], Jones suggested that web designers should be sensitive to the needs of visually impaired users when preparing their information sites. Simsek et al [16] also suggests that the visually impaired need to develop their ICT skills and there is a need to increase the number of ICT related courses offered in universities. With the increasing use of Internet by university students for generating and disseminating knowledge, it would be pertinent to ascertain the extent to which the students with visual impairment in Nigerian universities have access to the Internet, the challenges they may encounter while using the Internet and also proffer solutions to the problems.

2. RESEARCH QUESTIONS

Based on the above, four research questions were raised to guide the study:

1. To what extent do students with visual impairment have access to internet facilities?
2. To what extent do students with visual impairment use the internet facilities for knowledge generation and dissemination?
3. What are the impediments to the use of the Internet by students with visual impairment?
4. What are the strategies for enhancing the use of Internet by students with visual impairment?

3. RESEARCH METHODOLOGY

The design for this study is a descriptive survey design which is intended to examine the extent to which students with visual impairment have access to Internet services, the problems they may encounter in accessing the Internet and also make suggestions for improvement. The population of this study comprised all the students with visual impairment in the federal universities in Nigeria. In Nigeria there are 27 federal universities but only 6 of the universities have special education departments or units. One of the universities is in north-west geo-political zone, one in north central, one in south west, one in south east and two in south south geo-political zones of Nigeria. The sample for the study consists of all the one hundred and thirty eight (138) visually impaired students in the universities which have special education departments or units. Students with visual impairment in these universities were chosen because it was expected that since they have special education departments or units, they will have computer services that will meet the needs of the special needs students. Purposive sampling technique was used and because the sample size was small, the entire population served as sample.

A researcher generated questionnaire titled Visually Impaired Access and Usage of Internet Questionnaire was used to generate the data. The brailed instrument is a 52 item questionnaire which were generated from the reviewed literature. It consists of four major clusters. The cluster A contains information on accessibility of Internet facilities, cluster B deals with the extent students with visual impairment use the Internet facilities for knowledge generation and dissemination, cluster C deals with problems they encounter in the use of Internet and cluster D deals with solutions to those problems.

The questionnaire was rated on a four point rating scale. The first two clusters adopted a four point rating scale of Very High Extent = 4 points, High Extent = 3 points, Low Extent = 2 points and Very Low Extent = 1 point. The last two clusters used a rating scale of Strongly Agree (4 points), Agree (3 points), Disagree (2 points) and Strongly Disagree (1 Point). The instrument was validated by two experts each in special Education, Computer Education and Measurement and Evaluation. It was trial tested using seven visually impaired students in two state universities. The reliability coefficient was computed using Cronbach alpha and a reliability coefficient of 0.73, 0.69, 0.84 and 0.81 were obtained respectively for section A, B, C, D respectively. Administration of the instruments to the respondents and their retrieval were done using three research assistants and the data generated were analyzed using non-parametric statistics of mean and standard deviation. The following decision rules were adopted. An item with a mean rating of:

(a). 0.50 - 1.49 Interpreted as Very Low Extent or Strongly Agree
(b) 1.50 - 2.49 Interpreted as Low Extent or Agree
(c). 2.50 - 3.49 interpreted as High Extent or Disagree
(d) 3.50 - 4.00 interpreted as Very High Extent or Strongly Disagree
4. RESULTS

Table 1: Mean ratings of the Respondents on the extent students with visual impairment have access to internet facilities

<table>
<thead>
<tr>
<th>S/N</th>
<th>Items</th>
<th>X</th>
<th>SD</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I can access information from the internet any time I want to</td>
<td>2.35</td>
<td>1.13</td>
<td>LE</td>
</tr>
<tr>
<td>2</td>
<td>I can access information from the internet from my hostel</td>
<td>1.99</td>
<td>1.30</td>
<td>LE</td>
</tr>
<tr>
<td>3</td>
<td>I can only access information from the internet when I am in the cyber café</td>
<td>2.63</td>
<td>1.31</td>
<td>HE</td>
</tr>
<tr>
<td>4</td>
<td>I have access to computers with screen readers</td>
<td>2.21</td>
<td>1.40</td>
<td>LE</td>
</tr>
<tr>
<td>5</td>
<td>Braille display is available for me to use</td>
<td>1.47</td>
<td>0.99</td>
<td>VLE</td>
</tr>
<tr>
<td>6</td>
<td>I can access my e-mail</td>
<td>2.25</td>
<td>1.29</td>
<td>LE</td>
</tr>
<tr>
<td>7</td>
<td>I can access information using internet search engines</td>
<td>2.25</td>
<td>1.34</td>
<td>LE</td>
</tr>
</tbody>
</table>

Table 1 showed that items 1, 2, 4, 6 and 7 had mean ratings ranging from 2.21 – 2.35 indicating that the students with visually impairment had access to those items to a low extent. They had access to item 5 to a very low extent since it had a mean rating of 1.47 while they had item 3 to a large extent since the mean rating is 2.63. The items on the Table had standard deviations ranging from 0.99 -1.40 which is an indication that the responses are not far apart from the mean.

Table 2: Mean ratings of the respondents on the extent students with visual impairment use the internet facilities for knowledge generation and dissemination

<table>
<thead>
<tr>
<th>S/N</th>
<th>Students with visual impairment use internet to</th>
<th>X</th>
<th>SD</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Send e-mail</td>
<td>2.67</td>
<td>1.18</td>
<td>HE</td>
</tr>
<tr>
<td>9</td>
<td>Submit assignment</td>
<td>1.67</td>
<td>1.07</td>
<td>LE</td>
</tr>
<tr>
<td>10</td>
<td>Access assignments</td>
<td>2.47</td>
<td>1.19</td>
<td>LE</td>
</tr>
<tr>
<td>11</td>
<td>Read newspapers</td>
<td>1.82</td>
<td>1.13</td>
<td>LE</td>
</tr>
<tr>
<td>12</td>
<td>Surf the website where they can gain more in-depth knowledge about a particular topic</td>
<td>2.35</td>
<td>1.18</td>
<td>LE</td>
</tr>
<tr>
<td>13</td>
<td>Participate in discussion with their colleagues from other universities</td>
<td>1.55</td>
<td>1.03</td>
<td>LE</td>
</tr>
<tr>
<td>14</td>
<td>Communicate important educational information to friend</td>
<td>2.20</td>
<td>1.29</td>
<td>LE</td>
</tr>
<tr>
<td>15</td>
<td>Analyze data</td>
<td>1.77</td>
<td>1.15</td>
<td>LE</td>
</tr>
<tr>
<td>16</td>
<td>Disseminate information on their projects to more viewers</td>
<td>2.19</td>
<td>1.24</td>
<td>LE</td>
</tr>
<tr>
<td>17</td>
<td>Take an internet excursion</td>
<td>1.41</td>
<td>0.88</td>
<td>VLE</td>
</tr>
<tr>
<td>18</td>
<td>Communicate with an expert or a significant person</td>
<td>1.82</td>
<td>1.13</td>
<td>LE</td>
</tr>
<tr>
<td>19</td>
<td>Search for information or services offered in a particular location</td>
<td>2.61</td>
<td>1.30</td>
<td>HE</td>
</tr>
<tr>
<td>20</td>
<td>Download information that is not in the school library</td>
<td>2.72</td>
<td>1.34</td>
<td>HE</td>
</tr>
<tr>
<td>21</td>
<td>Chat with friends</td>
<td>2.19</td>
<td>1.36</td>
<td>LE</td>
</tr>
</tbody>
</table>

Table 2 indicated that items 9, 10,11,12,113,14,15,16,18 and 21 had mean ratings of 1.55-2.47 indicating a low extent. Item 17 had mean rating of 1.41 indicating a very low extent whereas items 8,19 an 20 had mean ratings ranging from 2.61- 2.72 indicating a high extent. The items on the Table had standard deviation range of 0.88- 1.36 indicating that the respondents were close together among themselves and not far from the mean. This suggests that the students with visual impairment use internet for knowledge generation and dissemination to a generally low extent.
Table 3: Mean responses of the respondents on the impediments to the use of internet by students with visual impairment

<table>
<thead>
<tr>
<th>S/N</th>
<th>The problems students with visual impairment have using the internet are</th>
<th>X</th>
<th>SD</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>Unavailability of Braille displays</td>
<td>2.73</td>
<td>1.38</td>
<td>A</td>
</tr>
<tr>
<td>23</td>
<td>Fear of using the internet</td>
<td>2.12</td>
<td>1.34</td>
<td>D</td>
</tr>
<tr>
<td>24</td>
<td>Lack of adequately trained support staff in the cyber cafes</td>
<td>3.52</td>
<td>1.10</td>
<td>SA</td>
</tr>
<tr>
<td>25</td>
<td>Difficulty copying text from a web page</td>
<td>3.21</td>
<td>1.11</td>
<td>A</td>
</tr>
<tr>
<td>26</td>
<td>Difficulty searching for a topic with the keyboard</td>
<td>2.59</td>
<td>1.09</td>
<td>A</td>
</tr>
<tr>
<td>27</td>
<td>Constant power outage</td>
<td>3.58</td>
<td>0.82</td>
<td>SA</td>
</tr>
<tr>
<td>28</td>
<td>High access charges</td>
<td>3.10</td>
<td>1.23</td>
<td>A</td>
</tr>
<tr>
<td>29</td>
<td>Lack of basic word processing skills such as how to save a document</td>
<td>2.38</td>
<td>1.31</td>
<td>D</td>
</tr>
<tr>
<td>30</td>
<td>Lack of specialized instructors who have knowledge of the softwares and who can train the students</td>
<td>3.75</td>
<td>0.62</td>
<td>SA</td>
</tr>
<tr>
<td>31</td>
<td>Students do not have an interest in computers and its uses</td>
<td>1.32</td>
<td>0.74</td>
<td>SD</td>
</tr>
<tr>
<td>32</td>
<td>Inadequacy of the screen readers</td>
<td>3.80</td>
<td>0.51</td>
<td>SA</td>
</tr>
<tr>
<td>33</td>
<td>Difficulty accessing graphically oriented webpages</td>
<td>2.91</td>
<td>1.02</td>
<td>A</td>
</tr>
<tr>
<td>34</td>
<td>Difficulty logging into a website</td>
<td>2.91</td>
<td>1.03</td>
<td>A</td>
</tr>
<tr>
<td>35</td>
<td>Difficulty navigating from one window to another</td>
<td>2.75</td>
<td>1.02</td>
<td>A</td>
</tr>
<tr>
<td>36</td>
<td>Difficulty using link lists</td>
<td>3.18</td>
<td>1.03</td>
<td>A</td>
</tr>
<tr>
<td>37</td>
<td>Inability to store information on flash drives</td>
<td>1.95</td>
<td>0.83</td>
<td>D</td>
</tr>
<tr>
<td>38</td>
<td>Difficulty accessing visual cues on the internet</td>
<td>3.29</td>
<td>0.95</td>
<td>A</td>
</tr>
<tr>
<td>39</td>
<td>Difficulty accessing pdf files</td>
<td>3.28</td>
<td>0.96</td>
<td>A</td>
</tr>
<tr>
<td>40</td>
<td>Lack of skill in the use of the screen reader</td>
<td>3.53</td>
<td>0.67</td>
<td>SA</td>
</tr>
</tbody>
</table>

Table 3 showed that respondents strongly agreed with items 24, 27, 30, 32 and 40 as impediments to the use of internet since they have mean ratings ranging from 3.52 - 3.80. They also agree with items 22, 25, 26, 27, 33, 35, 36, 38 and 39 as impediments since they had mean ratings ranging from 2.59 - 3.29. However, they disagree with items 23, 29 and 37 since they had mean ratings ranging from 1.95 - 2.38 indicating that those items are not impediments. The standard deviation which ranges from 0.51 - 1.38 shows that the respondents were not far apart from the mean in their responses.

Table 4: Mean responses of the students on the strategies for enhancing the use of internet by students with visual impairment

<table>
<thead>
<tr>
<th>S/N</th>
<th>Items</th>
<th>X</th>
<th>SD</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>41</td>
<td>Training the students with visual impairment on basic ICT skills</td>
<td>3.85</td>
<td>0.36</td>
<td>SA</td>
</tr>
<tr>
<td>42</td>
<td>Provision of alternative power generation system</td>
<td>3.74</td>
<td>0.44</td>
<td>SA</td>
</tr>
<tr>
<td>43</td>
<td>Provision of technical support staff that can install and operate the software</td>
<td>3.69</td>
<td>0.57</td>
<td>SA</td>
</tr>
<tr>
<td>44</td>
<td>Provision of computers with adequate internet assistive software</td>
<td>3.74</td>
<td>0.72</td>
<td>SA</td>
</tr>
<tr>
<td>45</td>
<td>Training special educators on the use of computer assistive devices</td>
<td>3.79</td>
<td>0.52</td>
<td>SA</td>
</tr>
<tr>
<td>46</td>
<td>Government reducing the tariffs paid on ICT assistive facilities</td>
<td>3.63</td>
<td>0.94</td>
<td>SA</td>
</tr>
<tr>
<td>47</td>
<td>Importation of computer assistive devices by government and universities so as to make it readily available to the students</td>
<td>3.79</td>
<td>0.53</td>
<td>SA</td>
</tr>
<tr>
<td>48</td>
<td>Integrating internet and computer assistive technology into the school curriculum</td>
<td>3.79</td>
<td>0.53</td>
<td>SA</td>
</tr>
<tr>
<td>49</td>
<td>Reducing the access charge paid by students with visual impairment before they access the internet</td>
<td>3.63</td>
<td>0.67</td>
<td>SA</td>
</tr>
<tr>
<td>50</td>
<td>Increasing the interest of the students toward computers and its use through awareness programmes</td>
<td>3.73</td>
<td>0.44</td>
<td>SA</td>
</tr>
<tr>
<td>51</td>
<td>Building resource rooms/centres where students with visual impairment can access the internet</td>
<td>4.00</td>
<td>0.00</td>
<td>SA</td>
</tr>
<tr>
<td>52</td>
<td>Installing screen readers in some computers in the school library</td>
<td>3.95</td>
<td>0.23</td>
<td>SA</td>
</tr>
</tbody>
</table>
Data on Table 4 indicated that all the items 41-52 had mean ratings ranging from 3.63 - 4.00 which shows that all the respondents strongly agreed with the items as strategies for enhancing the use of internet by students with visual impairment. The standard deviation range of 0.00 – 0.94 indicated that the responses were close to the mean.

5. DISCUSSION

It was found out from the study that students with visual impairment can access the internet from the cybercafé to a high extent while internet assessment from either their hostels or classrooms can only be done to a low extent. The result further revealed that the students have low access to the assistive technology devices such as screen readers software and other refreshable Braille displays which enable those with severe visual impairment to access the internet. This finding confirms the results of previous studies by Yu et al [22] that the visually impaired may not have full access to internet facilities and therefore, may not benefit maximally from internet services.

Lack of access to these software could be as a result of their very high cost which makes it difficult for students to purchase. It could also be that the universities do not pay much attention to the needs of this minority group which confirms what Armstrong [1] asserts that educational institutions have been slow to provide the learning materials needed by students with disabilities.

With regards to the extent students with visual impairment utilize internet facilities for knowledge generation and dissemination, it was revealed from this study that the students used internet to access materials for their assignments, submit their assignments, read newspapers, communicate important educational information, chat with friends, disseminate information on their project and analyze data to a low extent. On the other hand, they use internet to send email, search for information offered in a particular location and access information that is not in the library to a high extent.

These findings indicate that the students with visual impairment can now access information from websites which promotes some level of independence. The Royal National Institute (1998) observed that the internet is one of the most significant developments since the invention of Braille because it has for the first time offered the blind and the partially sighted access to the same wealth of information as the sighted. In line with the above Craven [4] also noted that advances in technology have enabled persons with visual impairment to access a variety of information which suits their needs and requirements.

However, in spite of these assertions, the students with visual impairment in Nigeria seem to concentrate on using the internet to generate information which may not be in the library for their academic work. They also use it in other areas as accessing and submission of assignments, reading newspapers, chatting with friends and for dissemination of information such as circulating information on their projects to wider viewers and communicating important educational information to friends. In these areas, they still use the internet to a low extent.

It was found from this study that students with visual impairment experience some impediments in the use of internet. Some of the impediments include unavailability of some assistive technological devices as Braille displays, and screen readers, and screen magnifier. Other impediments centre around the difficulty in copying information from web page, difficulty searching for a topic with the keyboard, difficulty accessing graphically oriented web pages, logging into a website, using link lists, accessing pdf files and difficulty accessing vital cues from the net. These findings were supported by Bayer & Pappas [2]; Chiang et al [3] and Simsek et al [16] who noted that students with visual impairment experience limitations in the use of internet due to poor accessibility to the web content as well as limitations of the currently existing assistive technology devices.

They also noted that most web pages are graphically oriented and these pose difficulties to the students. This finding did not yield the same result as the studies by Williamson et al [21] who found that students with visual impairment experienced difficulty due to lack of computer skills and lack of confidence in their ability to use the computer. This study revealed that fear of using the internet and lack of basic word processing skills as well as lack of interest in the use of internet were not impediments to the use of internet by students with visual impairment. This implies that they were not afraid to use the internet, they have an interest and they have the basic ICT skills but other external factors as unavailability of Braille displays and difficulties navigating the web pages, inadequacy of screen readers were impediments. Other impediments to the use of internet by students with visual impairment are constant power outage as well as lack of specialized instructors who have knowledge of the software and who can train the students. Also there is inadequately trained support staff in the cyber cafes.
This finding is in line with the opinions of Hersh & Johnson [7] which stated that screen readers and screen magnifiers are highly complex and are quite operating system specific. To them operating such complex systems would be difficult for people who are ‘technologically frail’. It becomes more difficult for them because the computing environment is complex and using the software is equally complex. The problem of power outage has generally hampered knowledge generation and dissemination in the country. Internet usage are generally supported by electricity and Nigeria like many developing countries have problem of poor electricity supply. This serves as an impediment to the use of internet.

It was revealed from the study that the respondents agreed that all the items listed on Table 4 are the strategies for enhancing the use of the internet by students with visual impairment. Some of the strategies were provision of technical support staff that can install and operate the software, provision of computers with adequate internet assistive software, government reducing the tariffs paid on ICT assistive facilities, importation of computer assistive devices by government and universities so as to make it readily available to the students, integrating internet and computer assistive technology into the school curriculum, building resource rooms/centres where students with visual impairment can access the internet, installing screen readers in some computers in the school library and training the students with visual impairment on basic ICT skills.

6. CONCLUSIONS

It is obvious from this study that students with visual impairment have low access to internet facilities in various universities that offer special education in Nigeria. They still struggle to access information from the world wide web relevant for their academic excellence. This is due to the dearth of assistive technology devices that will enable them to have access to the computerized information via the internet. The websites which are not easily accessible to them constitute another barrier. If the students with visual impairment must have equal and quality access to internet facilities just like their counterparts, then the cybercafés must be made visually impaired friendly. Universities should establish resource rooms/centres where students with visual impairment will have computers with adequate assistive ICT facilities. Furthermore, website designers should develop websites that can be accessible to students with visual impairment.

Based on the foregoing, it is recommended that Universities should establish resource rooms/centres where students with visual impairment will have computers with adequate assistive ICT facilities. While Website designers should develop websites that can be accessed by students with visual impairment, laws stipulating accessibility and standardization of internet facilities for students with visual impairment should be promulgated. Government should also allocate more funds to education and part of it should be dedicated to purchase of ICT assistive facilities. Finally special educators should be trained on the use of computer assistive devices so that they can train the students who will be able to queue into the 21st century knowledge economy.

REFERENCES


Spectrum Utilization for Broadcasting Stations in Nigeria - Maximizing Coverage Area and Transmission Time

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ABSTRACT

In as much as Nigeria has known some levels of technological growth and development and this had affected virtually all aspects of the economy, of which the broadcasting industry is not left out at all. This paper analyses the growth of spectrum utilization by Nigeria television stations in the past ten (10) years, the present and attempt to give a forecast of what it will look like ten (10) years time. The availability of spectrum and the generosity that follows its allocation to broadcasting stations necessitates that every television station should maximize the spectrum allocated to them for their maximum use and profit. Five categories of broadcasting stations were considered in this research, percentages of their spectrum utilization were obtained, and the respective growth in spectrum utilization was discussed.

Keywords: Spectrum, Television, Frequency, Spectrum Utilization, Station.

1. INTRODUCTION

Spectrum can be defined as a range of frequencies for electromagnetic waves. In the 17th century, the word spectrum was introduced into optics, referring to the range of colours observed when the white light was dispersed through a prism. The term spectrum was soon applied to other waves such as sound waves and also to any signal that can be decomposed into frequency components. It can also refer to the compound signal itself, such as the spectrum of visible light, a reference to these electromagnetic waves, which are visible to the human eye [8].

Electromagnetic spectrum is the range of all possible frequencies of electromagnetic radiation. It extends from frequencies used for modern radio to gamma radiation at the short-wavelength and covering wavelength from thousands of kilometers down to a fraction of the size of an atom e.g radio, microwave, infrared, visible, ultraviolet ray, x-ray and gamma ray. Radio spectrum is usually taken to comprise that part of electromagnetic spectrum falling between frequencies of 3KHz and 3000GHz though frequency above 100GHz is not yet practicable [5].

The range of frequency for television stations is either in the Very High Frequency (VHF) range (30 – 300MHz) or Ultra High Frequency (UHF) range (300 -3000MHz) having wavelengths of 10m – 1m and 1m - 100m respectively. The range of television channels and their frequencies are shown in the table below.
Table 1: Broadcast Frequencies (NTA, 1989)

<table>
<thead>
<tr>
<th>Band</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>TV Band (Channels 2  - 6)</td>
<td>54MHz – 88MHz (VHF)</td>
</tr>
<tr>
<td>TV Band III</td>
<td>174MHz – 218MHz (VHF)</td>
</tr>
<tr>
<td>TV Bands IV &amp; V</td>
<td>470MHz – 806MHz (UHF)</td>
</tr>
</tbody>
</table>

Three key concepts of spectrum monitoring are (Sihag, 2003):

i. Validating information and legitimate users
ii. Evaluating real levels of usage of the spectrum
iii. Identifying areas of further use, sharing or relocation.

Broadcasting started in Nigeria in 1933 through the Radio Diffusion System (RDS), which relayed radio programme especially news from the British Broadcasting Corporation (BCC) [1]. From the RDS emerged Nigeria Broadcasting Service (NBS) in 1950. The NBS was incorporated in 1957 to become the Nigerian Broadcasting Corporation (NBC). Since the establishment of the National Broadcasting Commission (NBC) in 1957 and the Nigeria Communication Commission (NCC) in 1992, some aspects of spectrum management were ceded to the regulation and liberalization of the new democratic government I 1999 and the enactment of the new Nigeria Communication Act 2003, more power, functions and independence have been given to the regulators. The Technical Services Department (TSD) was left with the management of radio frequency spectrum for government and non-commercial users of radio frequency spectrum for their private networks. TSD had always been responsible for the national monitoring of radio frequency resource, the individual monitoring of radio frequency spectrum for commercial users by both NCC and NBC notwithstanding. The department also represents Nigeria Administration at international bodies that have relevance with the use of radio frequency spectrum and satellite orbital resources e.g International Telecommunications Union (ITU), Commonwealth Telecommunication Organization (CTO) and International Telecommunications Union – Radio [3][4][6].

Before a television broadcast station is established in Nigeria, it needs to provide some information to NBC among which are name and address of applicant, names and nationality of directors, equity structure, type of broadcasting, license required, purpose of license, location of station, coverage area, effective radiating power, type and make of transmitters etc among others. This reveals that every station’s license indicates their coverage area. Also, it is worthy of note here that every station is given a period of 24 hours to broadcast their signals daily.

Different kinds of spectrum monitoring exists and are put under the following classes [2][4][7]

i. Monitoring band occupancy
ii. Monitoring channel occupancy
iii. Interference investigation
iv. Compliance (routine) monitoring
v. International monitoring

2. METHODOLOGY

As stated above, spectrum monitoring here is done by monitoring band occupancy. Government regulators and private entities have been interested in both how spectrum is used in practice and how to measure its’ utilization. In this research, five independent sources were chosen to monitor the usage or utilization of spectrum of five categories of television stations in Nigeria:

1. State-owned state-operated television station (Station 1)
2. Federal-owned state-operated television station (Station 2)
3. Federal-owned federal-operated television station (Station 3)
4. Private-owned non-satellite television station (Station 4)
5. Private-owned satellite television station (Station 5)

This research was carried out for a period of one month in the year while record of data for spectrum utilization in the year 2000 was collected from respective television stations’ studio log books and predictions were estimated for spectrum utilization for the next ten years (that is year 2020) in Nigeria.

3. RESULTS AND CALCULATIONS

Every data necessary for spectrum utilization were collected and mathematical operations were carried out and analyzed. Spectrum Utilization is given by the formula:

\[ U = \frac{BAT}{A} \]  

Where
\[ U = \text{Spectrum Utilization} \]
\[ B = \text{Bandwidth of transmission} \]
\[ A = \text{Area of coverage of signal} \]
\[ T = \text{Period of transmission} \]

Every broadcasting station has a licensed bandwidth or frequency for transmission as allocated to them by NBC as tabulated below.
A visit was carried out to the five chosen television stations as stated above and their respective areas of coverage were obtained. This was further confirmed by the use of a questionnaire to the residents of these areas and available data at the stations using signal strength meter.

Let licensed Area of coverage be \( A \), Actual area of coverage by transmitted signal be \( A_c \).

\[ \frac{A_c}{A} = \Phi \]

Ratio of coverage area, \( \Phi = \frac{A_c}{A} \)

Therefore \( A_c = \Phi A \) ........................... (2)

Let Licensed period of transmission be \( T \) (which is 24 hours),

Let average time used for transmission for the month be \( T_x \)

Ratio of time of spectrum usage \( \varrho = \frac{T_x}{T} \);

Therefore \( T_x = \varrho T \) ........................... (3)

The data obtained were fixed into the equations (2) above and the table 3 results.

**Table 2 : Bandwidth, Coverage Area and Time of Spectrum Usage for the Television Stations**

<table>
<thead>
<tr>
<th>Station</th>
<th>Transmission Bandwidth</th>
<th>Percentage Actual Area of Coverage of Signal in Year 2010, ( A_c )</th>
<th>Percentage Area Actual of Coverage of Signal in Year 2000, ( A_c )</th>
<th>Ratio of Time of Spectrum Usage in Year 2010, ( \varrho )</th>
<th>Ratio of Time of Spectrum Usage in Year 2000, ( \varrho )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>524.98 MHz</td>
<td>94%</td>
<td>0.94</td>
<td>0.74</td>
<td>0.70</td>
</tr>
<tr>
<td>2</td>
<td>217.22 MHz</td>
<td>80%</td>
<td>0.80</td>
<td>0.89</td>
<td>0.80</td>
</tr>
<tr>
<td>3</td>
<td>748.25 MHz</td>
<td>100%</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>4</td>
<td>560.15 MHz</td>
<td>93%</td>
<td>0.93</td>
<td>0.90</td>
<td>0.80</td>
</tr>
<tr>
<td>5</td>
<td>550.50 MHz</td>
<td>100%</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Recall that \( U = BAT \)

In an ideal situation where all spectrum is fully used by a broadcasting station, \( U_i = BAT_i \)

In such cases, all licensed area is covered by the television station and the total time of the day (24 hours) is used for transmission by the broadcasting station.

That is \( A_i = T_i = 1.00 \)

\( U = B \times 1 \times 1 = B \)

But let actual spectrum utilized be \( U_c \). Therefore, spectrum utilization,

\[ U = \frac{Actual \ Spectrum \ Utilization}{Ideal \ Spectrum \ Utilization} = \frac{U}{U_t} \]

% spectrum utilization = \( U \times 100\% \)

For station 1 in 2010, spectrum utilization is calculated thus:

Day 1, \( U_1 = B A_c T_1 \)

\[ = 524.98 \times 10^6 \times 0.94 \times 0.877 / 524.98 \times 10^6 \]

\[ = 0.824 = 82.4\% \]

Day 2, \( U_2 = B A_c T_2 \)

\[ = 524.98 \times 10^6 \times 0.94 \times 0.874 / 524.98 \times 10^6 \]

\[ = 0.822 = 82.2\% \]

Day 3, \( U_3 = B A_c T_3 \)

\[ = 524.98 \times 10^6 \times 0.94 \times 0.866 / 524.98 \times 10^6 \]

\[ = 0.814 = 81.4\% \]

Average spectrum utilization for the month,

\[ U_{av} = \frac{U_1 + U_2 + U_3 + \ldots + U_{30}}{30} = \frac{2116.90}{30} \]

\[ = 70.56\% \]

Same procedure was used to calculate for the other four stations and the results for 2010 and 2000 are as tabulated below.
Table 2 Table of Percentage Average Spectrum Utilization for the five Stations in 2000 and 2010

<table>
<thead>
<tr>
<th>Station</th>
<th>Percentage Average Spectrum Utilization, $U_{av}$ in Year 2000</th>
<th>Percentage Average Spectrum Utilization, $U_{av}$ in Year 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>47.23%</td>
<td>70.56%</td>
</tr>
<tr>
<td>2</td>
<td>16.20%</td>
<td>71.01%</td>
</tr>
<tr>
<td>3</td>
<td>75%</td>
<td>100%</td>
</tr>
<tr>
<td>4</td>
<td>56.8%</td>
<td>86.95%</td>
</tr>
<tr>
<td>5</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Therefore, bar charts were plotted using Microsoft Excel to illustrate spectrum utilization for the five television stations in years 2010 and 2000 as shown in figure 2 and figure 3 respectively.

Figure 1: Graph of Year 2010 Spectrum Utilization by Television stations in Nigeria

Figure 2: Graph of Year 2000 Spectrum Utilization by Television Stations in Nigeria.
4. DISCUSSIONS

When the results for spectrum utilization by the specimen television stations for year 2000 and 2010 were compared with each other, the following are observed:

i. For station 1, there was an increase in percentage coverage area and the time used for transmission, which in essence led to increase in its percentage spectrum utilization. The increase in coverage area was achieved by the establishment of booster stations in two senatorial districts of the state because her signal was rarely received by residents of these senatorial districts. Concerning the increased time of transmission, a better and new television transmitter was obtained for the station and installed by the state government. The new transmitter has the ability to transmit for 24 hours for 25 years continuously, unlike the former transmitter which was been used in 2000 had reduced performance both in time for operation and productivity of service. The station's spectrum usage growth rate is 2.68/annum and $U_{av}$ is predicted to be 97.57% by 2020.

ii. Likewise for station 2, a booster station was established in the state to boost their signal so as to cover more towns and villages in the state. The federal government also employed more staffs to join the manpower for the station so as to be able to run two shifts conveniently on a daily basis. Lastly, a better and new transmitter was also purchased for the station and installed appropriately. All these led to better spectrum utilization. Its' spectrum usage growth rate is 5.48/annum and $U_{av}$ is predicted to be 100% by 2020.

iii. Station 3 had an excellent percentage spectrum utilization (100%) by year 2010 due to the fact that it is the national headquarter and network centre for all the federal government-owned stations in the country. This is because it began to maximize its spectrum by starting 24 hours broadcasting of signals in 2003. In 2000, it was transmitting for an average of 18 hours per day. Presently, the said station is on satellite and as such transmits signal round the clock everyday for global compliance and preparation for full digital television broadcasting. Its’ spectrum usage growth rate is 2.5/annum and $U_{av}$ is predicted to be 100% by 2020.

iv. Station 4 is a private station, which started better than the government stations and had also maintained a good pace of growth and development. Of course as a private station, it is fully profit-conscious from the beginning and that is clearly seen from the data obtained for its spectrum utilization. Within its capability and resources, it started well and had utilized its allocated spectrum. Its’ spectrum usage growth rate is 3.02/annum and $U_{av}$ is predicted to be 100% by 2020.

v. Spectrum utilization by station 5 is not surprising as 100% because from its inception or establishment it had been on the satellite and has been maximizing its allocated spectrum since then. Its quality of service, signal and information is the best among the five television stations involved in this research. If it maintained this spectrum usage, its’ $U_{av}$ will still be 100% by 2020.

5. CONCLUSION

Since spectrum utilization is primarily a factor of coverage area by signal and time used in transmitting signal with the bandwidth as the constant factor of rationality; every television station that therefore wants to maximally utilize its allocated spectrum must consider to maximize coverage area and transmission time. With the growth experienced in spectrum utilization by television stations in Nigeria between year 2000 and 2010, it is hereby predicted that with this spectrum utilization growth rate by the year 2020, every television station in Nigeria will be experiencing 100% spectrum utilization. Hence, getting the best from their spectrum and delivering better services to the viewer of their stations.
REFERENCES


