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A Context-Aware Model to Improve Usability of Information Display on Smartphone Apps for Emerging Users

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ABSTRACT

Smartphones have become a reliable technology for accessing information and services in rural communities. Mobile applications, such as social media and news apps running on smartphones, are no longer exclusively utilised by users in developed communities. Mobile applications are accessed in highly contextualised environments. This paper discusses a context-aware model that was implemented to improve the usability of information presented on smartphone applications for emerging users. User evaluation was conducted within a remote area in South Africa with a sample of users, most of whom did not have prior experience in using computer applications. The results of the evaluation present empirical evidence that the model can improve the usefulness of mobile applications and their adoption in rural areas by emerging users who primarily rely on smartphones for accessing a variety of information sources and services. The findings can be utilised as a blueprint for implementing sustainable mobile interventions for emerging users.

Keywords

Context-aware, usability, product catalogue, emerging users.

INTRODUCTION

Access to online mobile information and services is increasing as a result of the increase in the use of Internet-enabled, handheld (smartphone) mobile devices and recent improvements and innovations in wireless Internet (Zhang and Lai, 2011). The combined influence of recent enabling technologies such as Web 2.0, App stores and improved network speed have accelerated the use of online applications that allows users to access various types of information on mobile devices anytime, anywhere (Rose, Hair and Clark, 2011). Examples of such applications include social media apps such as Facebook^{TM} and Twitter^{TM}, banking applications such as First National Bank (FNB)^{TM} (FirstNationalBank, 2013), news such as BBC News^{TM} and many other apps that have been adapted for mobile interfaces.

These trends are no longer only apparent in developed communities; most rural communities in Africa where mobile devices such as smartphones are regarded as computers are experiencing similar developments. Mobility and Internet connectivity are two influential, enabling technologies that are being used daily by people to gain access to information and services. This is specifically applicable in rural African communities where such connectivity did not previously exist (Gumede, Plauche and Sharma, 2008). The high penetration of smartphones and the increased adoption rate of various forms of mobile technologies are acting as catalysts for these trends. The impact of mobile technologies has further significantly improved the lifestyles and living conditions of people in rural communities (Sife, Kiondo and Lyimo-Macha, 2010; Gupta, Thies, Cutrell and Balakrishnan, 2012).

Despite the positive impact of the enabling technologies identified, accessing information and services on smartphones is cumbersome because these devices possess inherent limiting physical properties that make browsing and interaction a tedious task. Examples of such factors include limited processing power, small screen size and limited user input modes such as a small keyboard (Xining, Jiazao and Lian, 2010; Zhang and Lai, 2011). The fact that many users in rural communities have little or no experience in using software applications is also an inhibiting factor. Furthermore, rural communities are characterised by inadequate infrastructure which includes limited connectivity and high illiteracy levels (Friedland, Merz and van Rensberg, 2008). All these factors contribute to affecting the usability and adoption of mobile applications by users in rural communities.

Recently, context-aware computing that aims at utilising context within the user environment to improve usability of applications has gained wide recognition (Bohmer and Bauer, 2010; Lowe, Mandl and Weber, 2012). The literature discussed in the context and context-awareness section of the paper indicates that current efforts in context-aware computing seem inadequate to ensure improved usability of information presented on smartphones for emerging users.

This paper discusses a context-aware model that was implemented and evaluated with the aim of improving usability of information presented on smartphone applications for emerging users. In this study emerging users are users with increasing experience in using smartphone (mobile) applications but with limited desktop computer applications experience. Product catalogue information for a mobile procurement (eProcurement) application was utilised to test the model's capabilities. The eProcurement application was primarily implemented to assist small-scale traders to perform basic business operations, such as online purchasing of stock in the local community of Kgautswane in Limpopo, South Africa (Ngassam, Ntawanga and Eloff, 2013). The authors' motivation to undertake the research was based on gaps identified in the literature, previous research experience in the study area and specifically for ICT4D for small businesses in developing regions.

The objectives of the paper are as follows:

- Define context and the context-aware model;
- Demonstrate the applicability of the developed model to address the challenges of information presentation and usability on smartphone applications; and

- Discuss the results of the usability evaluation conducted with a sample of emerging mobile application users.

The following section covers background literature on context and context-awareness, product catalogues and usability in general. The third section presents the deployment of an eProcurement solution in the Kgautswane community. A discussion on the eProcurement and the context-aware model that was conceptualised and implemented to improve the presentation and usability of product information on the eProcurement application that was deployed in Kgautswane community follows in the fourth section. The evaluation process and results thereof are discussed after examination of the implementation of the model. The final section of the paper reports on the conclusions and possible further use of the context-aware model.

BACKGROUND

This section discusses fundamental background literature for the three main concepts discussed and presented in this paper, namely: context and context-awareness, usability and product catalogues.

Context and Context-Awareness

Context-aware computing is a relatively new area in computing and a number of aspects thus need to be clarified. This section provides an overview of context-aware computing by defining the concepts of context and context-awareness. In addition, types and classes of context information are explored. The section further covers the acquisition and uses of context information in enhancing usability of software applications.

Context Definition

A number of definitions for the term context are provided; however, this paper adopted the following definition by Dey (2001) that has been widely cited by other authors (Dey, 2001; Bohmer, Bauer and Kruger, 2010; Asif and Krogstie, 2012; Lowe et al., 2012; Poulcheria and Costas, 2012):

> *"Context is any piece of information that can be used to characterise a situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves."*

The definition relies upon context being "relevant" which implies that any context parameter that can be derived for use in an application has to be relevant for a particular situation or purpose (Bohmer et al., 2010; Asif and Krogstie, 2012; Lowe et al., 2012). Context parameter, in this case, refers to the set of data elements that constitute, define and provide the characteristics of a context entity (Poulcheria and Costas, 2012). The implication is that context only becomes meaningful when a context parameter is available. Examples of common context parameters which developers use to improve usability include location and user preferences (Orjuela-Parra, Carrillo-Ramos and Martinez, 2009; Asif and Krogstie, 2012).

Two types of context information exist, namely static and dynamic context information. The type of context information is determined based on the time interval that elapses before the value of a piece of information changes (Poulcheria and Costas, 2011; Vieira, Caldas and Salgado, 2011). Context information is static when its value does not change during interaction between the user and the application. A typical example is the user's mobile device (and its features) which remains static for the period of interaction.

Dynamic context information is information where the value can change a number of times during interaction. A device's Internet connection strength is a typical example of dynamic context information in a mobile Web environment because connectivity strength usually fluctuates during interaction (Yao, Kanhere and Hassan, 2008). The mobile environment is generally considered as dynamic because of the fact that there is huge diversity in terms of users and devices used to interact with mobile applications.

Categories of Context Information

Currently, there is limited agreement on the classification of context information. Different authors categorise context information differently. This paper has adopted a three-tier context classification that is widely utilised by researchers (Barnard, Yi, Jacko and Sears, 2007; Poulcheria and Costas, 2012):

1. *User-specific:* User-specific context information is directly related to the user and provides characteristics about the user. User models (customer profiles) are generally used as a source of such information in mobile and desktop applications. Examples of user-specific context information include gender, age and emotions.
2. *Device (or technology-specific):* This is context information that is related to the use of the device during interaction with an application. Examples of device/technology-specific context information include keyboard (touch vs. keypad), camera and microphone.
3. *Environment-specific:* Environment-specific context information is available in the environment where the user is during interaction with an application. Common examples of environment-specific context information include weather, time, and bandwidth, especially when it comes to Web applications.

Figure 1, adapted from Kim et al. (2005) and Coursaris and Kim (2006), illustrates the general categories of context information in the mobile Web. The figure shows the tree structure for context classes, sub-classes and selected specific examples of context parameters for each branch.

Acquisition of Context Information

Context information is acquired through different sensors that gather pieces of context parameters and supply the information for interpretation and utilisation in an application (Chin-Chih and Shih-Tsung, 2012). Two types of sensors exist: physical and logical sensors. Physical sensors are sensors that detect (or collect) context information through the use of some form of a physical electronic device (Schmidt, Aidoo, Takaluoma, Tuomela, Laerhoven and Velde, 1999; Tao, Pung and Da Qing, 2004). Logical sensors are sensors that utilise some form of software in order to detect (or collect) context information (Tao et al., 2004; Poulcheria and Costas, 2011). For example, there are software plug-ins and Application Programming Interfaces (APIs) that are used to determine mobile phone device parameters; one example is the Wireless Universal Resource File (WURFL) which is an eXtensible Mark-up Language (XML) file that contains specific features of all known handheld mobile devices (Scientiamobile, 2013).

The acquired context information is utilised by the application to streamline the interaction between the user and an application in order to improve usability of information presented on the interface. Applications that utilise some sort of context information for the purpose of improving usability of applications fall under context-aware systems. The next section discusses the general use of context information in achieving the goal of improving usability.

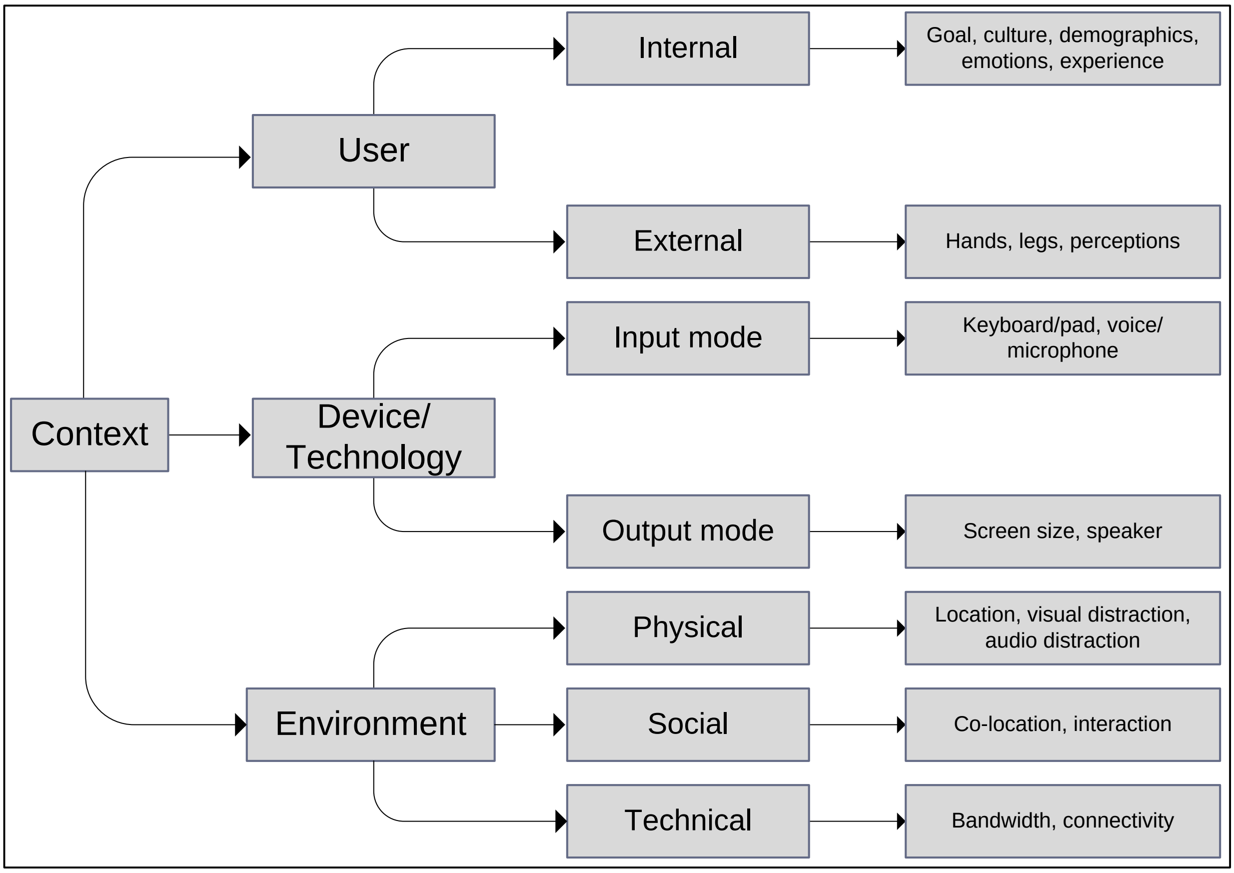


Figure 1. Context classification.

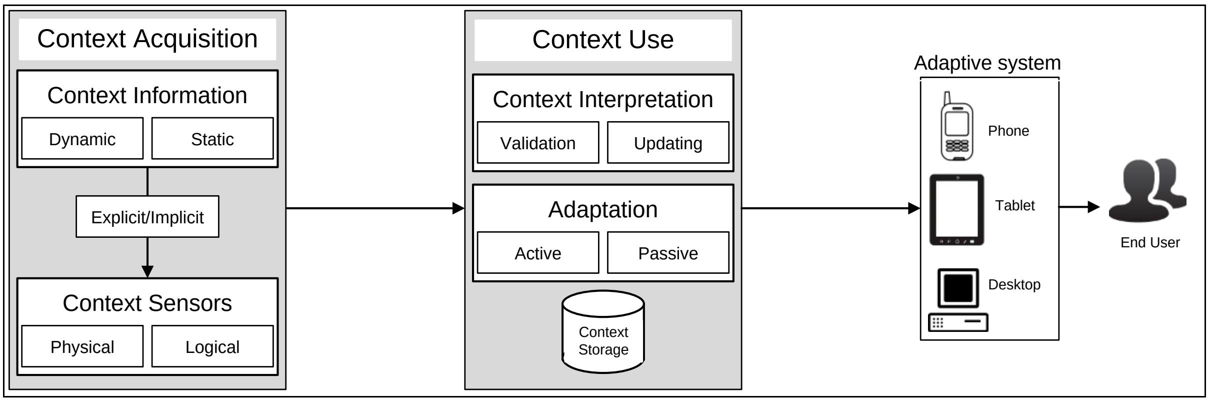
Usage of Context Information

Context information is principally utilised for improving usability in both mobile and desktop applications. Context-aware applications perform the following four main types of adaptations during interaction with the user in order to help users achieve their goals and improve usability (Orjuela-Parra et al., 2009; Lowe et al., 2012; Poulcheria and Costas, 2012):

1. *User interface adaptation:* User interface adaptation refers to the ability of a system to alter the application's user interface or interaction mode based on the user's current context information.
2. *Content adaptation:* Content adaptation refers to the ability of a system to select relevant content for processing and presentation of output to the user. Based on the available context information, context-aware systems adapt content to meet the user's goals for interacting with the system.
3. *Functionality adaptation:* Functionality adaptation refers to the selection of relevant functions that have to be performed by an application based on the available context information.
4. *Device adaptation:* Device adaptation is an adaptation that performs the above adaptations (1 to 3) to suit the features of the particular device being utilised by the user during interaction. Device adaptation research is recently receiving much attention in mobile computing because of the increase in the use of diverse mobile devices and applications.

The adaptations show the direct relationship between context information and end user support. Figure 2 shows the architecture for a context-aware system adapted from Lowe et al. (2012) and Poulcheria and Costas (2012). The figure shows the main components of a context-aware system and the core steps during context acquisition, processing and utilisation.

Figure 2. Architecture for a context-aware application.



Gaps in the Design and Evaluation of Existing Context-Aware Models

Existing context-aware models were found to offer limited functionalities to support usability of context-aware applications. The following are main gaps identified in the literature (Dey, 2001; Lowe, et al., 2012; Poulcheria and Costa, 2012):

- *Lack of generality and inclusive context-aware information:* existing context-aware models lack generality, for example, some models could not work in a mobile environment and comprehensiveness of context-aware information, for example, models were found to be focusing on mainly either of the location or user details;
- *Clarity of context-aware information processing:* Existing models do not offer clarity on how context is processed from acquisition to usage. The models do not show the different components and how different set of context information is processed from the source up to until its use;
- *Quality of context:* Existing models do not cater for quality of acquired context information which can eventually affect implemented adaptations; and
- *Evaluation:* Very limited evaluations could be found to have been conducted on existing models.

The next sub-section discusses product catalogues. Product catalogue information plays a crucial role in disseminating information about products that a business is offering on the market. In this study, a product catalogue was selected to test the implemented context-aware model's capabilities.

Product Catalogues

A product catalogue is defined as a collection of items and corresponding descriptions of products which a business is offering on the market (Callahan and Koenemann, 2000; Yuan and Fernandez, 2011). Each item in a product catalogue has attributes that describe specific characteristics of the item. For example, an item "television" can have the following as a set of its attributes (Chalakov, 2007):

- *Technical information:* This information can provide specific details about the television, for example, brand, screen size and signal type;
- *Selling information:* This information can provide details about the cost and how the television can get into the buyer's possession, for example, price, delivery method and stock availability; and
- *Other information:* This can include additional information that does not directly relate to the buying or selling of a product, for example, the seller's contact details.

There are two types of product catalogues that are defined according to the format and mode in which the actual product catalogue information is disseminated to potential customers, namely (Turban, King, Lee, Liang and Turban, 2011):

- *Paper-based product catalogues (also called manual product catalogues):* These are product catalogues that contain static information normally printed on paper in brochures and magazines. The items in a manual product catalogue are described by using text and images. Printing product catalogues on paper has been a tradition in business for a long time (Turban et al., 2011); and
- *Electronic product catalogues (e-catalogue):* These are product catalogues in which dynamic product information is presented in electronic media format and distributed via electronic means. The term "e-catalogue" is often interchangeably used with the term "online product catalogue". In this paper, however, a distinction is made between e-catalogue and online product catalogues which make up a sub-category of the e-catalogue that is widely used by businesses in e-commerce and m-commerce initiatives to showcase products that can be accessed on digital interfaces via the Web. An online electronic catalogue is usually implemented as a Web-based application and it is one important aspect of e-commerce and m-commerce web sites (Turban et al., 2011; Schneider, 2013).

Product catalogues play an important role in disseminating information about products which a business offers on the market in both the conventional way and in e-commerce (Jianyou, Ying and Shusheng, 2009). Efficient browsing of the product catalogue can increase traffic and sales in B2C e-commerce and m-commerce (Callahan and Koenemann, 2000; Mao Lin, Quang Vinh, Viet Cuong and Junhu, 2009). Traditionally, product catalogues have been printed on paper in magazines and brochures (Turban et al., 2011). Technology penetration has resulted in businesses distributing product catalogues electronically, for example, through CD/DVDs and via the Internet (Jianyou et al., 2009). The product catalogue was utilised in this study as an example of information to test and showcase the capabilities of the proposed context-aware model.

The next sub-section discusses usability. The term "usability" is generally used in computing to portray an assessment of the success of an application in addressing its intended functions. Usability testing was conducted to assess the implemented model's usefulness in addressing the challenges of presenting information effectively and efficiently on mobile devices.

Usability

The International Standard Organisation (ISO) defines usability as a process-oriented standard which states that a piece of software is usable when it allows the user to perform tasks effectively, efficiently and with satisfaction in a specified context of use (Tullis and Albert, 2013). The accepted standard ISO9241-11 of a system's usability consists of the following three main elements (usabilitynet.org, 2006):

a) *Effectiveness*: Refers to the accuracy and completeness with which specified users achieved specified goals while interacting with the system in a particular environment.
b) *Efficiency*: Refers to the extent to which a software product enables tasks to be performed in a quick, effective and economical manner.
c) *Satisfaction*: Refers to the degree to which a software product is giving contentment or making the user satisfied during and after interacting with it.

Usability evaluation is a systematic process undertaken by computer software developers or usability experts in order to assess the usability or practicability of a system or an item (Moritz and Meinel, 2010). The goal for conducting a usability evaluation of a system is to find possible areas of the system that can cause usability problems, confusions or errors and ultimately find ways to avert such possible problems (Balagtas-Fernandez and Hussmann, 2009; Trivedi and Khanum, 2012). The main methods that are utilised during a usability evaluation include the following:

- *User-based usability evaluation:* These include usability evaluation methods that involve the use of real end-users (or a representative sample of the users) to evaluate a system;
- *Expert-oriented (or analytical) usability evaluation:* These include usability evaluation methods where usability experts are recruited to evaluate a system based on their field experience and (or) heuristics (Moritz and Meinel, 2010; Trivedi and Khanum, 2012); and
- *Model-based usability evaluation:* These include task-based usability evaluation methods that involve matching the user roles to complete a task to those from a model in order to calculate the usability index. One of the most popular, model-based usability evaluation techniques that is used to predict the time and effort required by users to learn a new system is the Goals, Objectives, Methods and Selections rules (GOMS) introduced by Card, Moran and Newell (1986) (Sharp, Rogers and Preece, 2011).

The literature indicates that researchers do not agree on what are suitable usability evaluation methods in mobile computing, compared to desktop application usability evaluation that has well established techniques. For example, some authors argue that laboratory evaluation cannot provide reliable usability results in mobile computing because the laboratory does not represent the real environment (Ji, Park, Lee and Yun, 2006; Schmiedl, Blumenstein and Seidl, 2011), while other authors claim that laboratory and field evaluation studies for mobile applications provide the same results. Overall, it can be stated that usability evaluation with regard to mobile application is still in its infancy with a number of inconsistencies. Techniques utilised in the evaluation of the usability of desktop applications are often utilised for evaluating the usability of mobile applications. Designing an effective usability evaluation for mobile applications is more challenging than for desktop applications as there is less flexibility in terms of methods that can be used in order to achieve accurate results in usability evaluation. The research methodology section outlines how usability evaluation was conducted for this study in relation to this section.

Usability Challenges when Browsing Information on Mobile Devices

Limitations inherent in mobile devices make browsing information a tedious task for the user. Several authors have identified serious and troublesome problems that users experience when browsing a catalogue on a mobile phone, most of which are the result of the limitations of the device (Coppola, Mella, Di Gaspero, Menegon, Mischis, Mizzaro, Scagnetto and Vassena, 2009; Chang and Wang, 2010). The following is a list of such challenges which have been linked to product catalogues, since product catalogues are an example of the type of information being discussed in this paper:

a) *Limited space on digital interfaces to present many items:* Limited space results in long lists of products that are squeezed onto a small screen. This results in users having to continually scroll to find what they want.
b) *Product selection and decision making:* Making purchasing decisions is always a challenge because usually many choices are presented on small screens for customers to process. This results in overloading the cognitive process of decision making.
c) *Limited recommendations:* Research shows that device limitations affect implementation of recommender systems for applications running on mobile devices.

ePROCUREMENT SOLUTION DEPLOYED IN KGAUTSWANE

This section discusses an overview of the eProcurement application that was utilised to incorporate the context-aware model in order to test the model's capabilities and to provide a platform for end-user evaluation. The section introduces the remote area of Kgautswane where the application was implemented and also presents an overview of the application's functionalities and its core purpose.

Overview of the Kgautswane Community

Kgautswane is a community in the Sekhukhune municipal district in Limpopo, South Africa. The community is made up of a series of 20 villages with a population of about 120,000 people (Gumede et al., 2008). Unemployment is widespread, commercial farming is non-existent and crops such as maize are scantily grown by villagers for subsistence purposes. The main economic activities revolve around small-scale trading and slate mining. There are about 130 small traders in the community, which are the only conveniently situated suppliers of essential foodstuff within the community.

The community is characterised by the following environmental factors of a typical rural African community (Friedland et al., 2008):

- Fixed line communication is virtually non-existent;
- No tarmac roads and there is a lack of municipal services, such as sanitation, garbage removal and running water; and
- There are no available statistics, such as unemployment rate, average household income, and average household size.

Kgautswane community is equipped with a reliable mobile data communication system with new satellites being installed in other areas. Most people in the community own lower-end smartphones and use Vodacom[1] as a mobile service provider. Communication networks enable the community to access various services including mobile banking and e-commerce initiatives by using the deployed eProcurement system which is discussed in the next sub-section.

[1] Vodacom is one of South Africa's mobile telephone services providers.

eProcurement Solution

A mobile Web eProcurement application was conceptualised, designed and implemented with the aim of solving the challenges which the small-scale retailers in Kgautswane face, especially with regard to the stock replenishment process (Ngassam et al., 2013). The application enables registered users to login and navigate through the online, up-to-date supplier product catalogue. The online product catalogue contains real-time pricing and stock availability information that enables retailers to budget stock purchases beforehand without the need to travel to the suppliers' premises. Orders are placed weekly and the supplier makes a bulk delivery two to three days after the orders have been placed.

Figure 3 is an example of the interface of the main menu and product catalogue display pages of the application. The application runs on a number of mobile Web browsers including Opera Mini and proprietary mobile phone browsers. A context-aware model was implemented and incorporated into the eProcurement application in order to improve usability of product catalogue information presented on the mobile device interface. The next section discusses the context-aware model.

Figure 3. User Interface for the Mobile eProcurement Application.

A CONTEXT-AWARE MODEL

A context-aware model was conceptualised, designed and implemented to gather and utilise a number of context parameters in order to improve the retrieval and presentation of product catalogue information on the eProcurement application interface. This section presents the model.

Objectives of the Model

The objectives of the model were as follows:

- Gather context parameters from various sources; and
- Process and present context parameters to support determining optimal retrieval and presentation of product catalogue information on smartphone interfaces.

The results section outline how model has met the intended objectives.

Components of the Model

Context Sensor

The context sensor is the component of the model which has the purpose of determining context information from the user's current environment to act as input for the model to determine what information should be retrieved and presented to the user. A logical context sensor was developed to perform this task. The integrated logical context sensor was developed to determine the following context parameters: user profile, location, date and time, device profile (features) and bandwidth.

- *User profiles:* User profiles contain information that describes the user. Information about the user is usually modelled and stored in a data repository. The user profile sub-component was able to create an initial profile for the user which was continuously updated with the users' interaction history, for example, purchasing history;
- *Location:* The location sensor was utilised to determine the location from which an application was accessed. Location information in the sensor was presented as GPS coordinates, that is, latitude and longitude points. The reason for using coordinates rather than a location name is to accurately determine the distance between points. For example, by using the Vincenty formula that uses trigonometry sine and cosine rules, and two sets of a location's GPS coordinates, distance between the points can be calculated in miles or kilometres (Movabeltypescripts, 2013). For privacy and security purposes, during runtime the Geolocation sought the user's approval to share location information (w3schools, 2013);
- *Time of the day:* Time of the day was utilised to determine the actual time of the day at which the application was accessed. PhP DateTime function was utilised in this experiment to determine the actual time of the day when the application was accessed. The determined location (as discussed in the point above) was utilised together with the PhP DateTime function and world clock to determine a particular location's current time (PhP, 2013);
- *Device profile:* Device profile determines the features of a particular device in real-time. Many techniques are utilised to determine device features such as Open Device Description Repositories (OpenDDR) and 51 Degrees (51Degress, 2013; OpenDDR, 2013). This experiment utilised a WURFL to determine the characteristics of the device being used by the user to access the application. WURFL determines device properties by mapping HTTP Request headers by linking user agents (UA) to the profile of the HTTP client device, be it a desktop, mobile phone or tablet, that issued the request (Scientiamobile, 2013). The client UA is matched against the contents of the XML file. A match returns properties of the relevant device. Google and Facebook are examples of companies using WURFL in their web sites (Scientiamobile, 2013);
- *Bandwidth:* A mathematical method was developed to determine bandwidth. Formula i was derived to determine bandwidth:

$$b = {}^{d}/_{t} \qquad \text{(i)}$$

Where:

- *b* is bandwidth to be determined in bytes/second;
- *d* is the predetermined amount of data to be transferred from the server to the client (this can be any file with a known size in bytes or kilobytes);
- *t* is the amount of time in seconds taken between sending a request to the server and when the response or acknowledgement from the server is received by the client; this time is also called Round Trip Time (RTT) or ping time.

Data Retrieval

The function of the data retrieval component was to extract a subset of the product catalogue based on determined context information of the user's current environment. The data retrieval component was designed in a generalised way by using Service-Oriented Computing (SOC) principles in order to enable it to perform the intended function on any set of information. The model's data retrieval component performed the following main tasks in order to generate a list of products for a particular customer based on the current context information:

- *Determining the user's current context:* This included getting the user's current context information such as location, preferences, previous interaction history and location through the context sensor component;
- *Determining a list of other users who purchased similar items that the current user purchased:* This process aimed to gather an additional list of users who purchased a product similar to the items which the current user also purchased in the past;
- *Utilising various similarity techniques to determine which items from the items determined in the above two steps should be presented to the current user:* This process involved the use of techniques such as the Jaccard and Cosine Index to determine similarities between users; and
- *Ranking the results:* This process ranked the determined list depending on priority to the user. This means a prioritised list of items was presented to the user.

The following two matrices were utilised during retrieval and ranking:

- A 2-dimensional matrix (i x j) was utilised to determine a list of products that could be presented to the user, based on current context. The entries in the i x j matrix were presented as either 1 or 0, with 1 representing items which user i bought or preferred and j and 0 represents items which user i never preferred or bought; and
- A 3-dimensional matrix (i x j x k) was utilised to rank the results in order to assign priority so that items with higher priority, deemed to be more critical to the user, were presented first. The matrix utilises the frequency with which a product had been purchased by a particular user and the last date when the purchase was made in order to determine the priority of items in the retrieved data. No evidence could be found for such a product ranking mechanism on popular e-commerce web sites such as Amazon.com and kalahari.com (kalahari.com subsequently merged with takealot.com). However, news web sites, such as BBC News, utilise other mechanisms to rate and recommend news, for example, the number of stars a news item receives from previous readers, or the number of comments posted for a particular news item are utilised to determine whether to recommend an item to a reader or not.

Data Repositories

Two main data repositories were implemented in this experiment:

- *Product catalogue data repository:* The product catalogue data repository is the main source of information from which the context-aware model should retrieve a relevant subset to present to the user, based on specific context information; and
- *Personalised catalogue cache (temporary repository):* The personalised catalogue cache is a temporary repository that stores optimised, retrieved information for a particular user in order to eliminate repetitive backend calls to the data repositories in a limited connectivity environment such as the mobile Web.

Optimisation Engine

Optimisation is a popular technique in computing and mathematics that is utilised to determine the best options from a given list of options, especially under some restrictions. The mobile environment is characterised by limited and sometimes insufficient resources, for example, small user input and output features (keyboard and screen) and fluctuations in bandwidth strength (Jiazao, Xining and Lian, 2010; Xining et al., 2010; Zhang and Lai, 2011). In this experiment, a combinatorial optimisation technique was utilised on mobile device characteristics and bandwidth in order to determine the optimal amount of data to be transferred and presented on a particular mobile phone.

The following input parameters were utilised during optimal transfer and presentation of information on the mobile phone interface:

- *Data:* This is the retrieved subset of information that is based on the user profile;
- *Maximum waiting time:* This is the maximum time that the user can wait for a page to fully load on the mobile phone without refreshing or abandoning the operation;
- *Bandwidth:* The bandwidth determined in real time within a particular environment. This is the download speed of the connection that a user is using; and
- *Screen space:* This is the actual screen size of a mobile device that can be used to display the retrieved information.

User Interface (UI) Adaptation

UI adaptation is the component that was responsible for presenting personalised and optimised content on the smartphone user interface. There are four types of adaptations that can be performed in a system, namely: user interface, content, functionality and device. The main task of the UI adaptation component was to design the underlying UI layout design including positioning of UI controls and actual presentation of the optimised product catalogue information. The UI adaptation component had a flexible control container implemented that was capable of swapping around the positions of various UI controls, depending on context, such as device screen size.

Figure 4 shows the conceptual diagram of the derived context-aware model and highlights the main components of the model that can be implemented or extended in order to develop highly adaptive and usable mobile applications for diverse characteristics of users and also taking into consideration up-to-date variations in context. All the components that are critical for both retrieval and presentation functions of an online information display application on mobile devices are clearly presented.

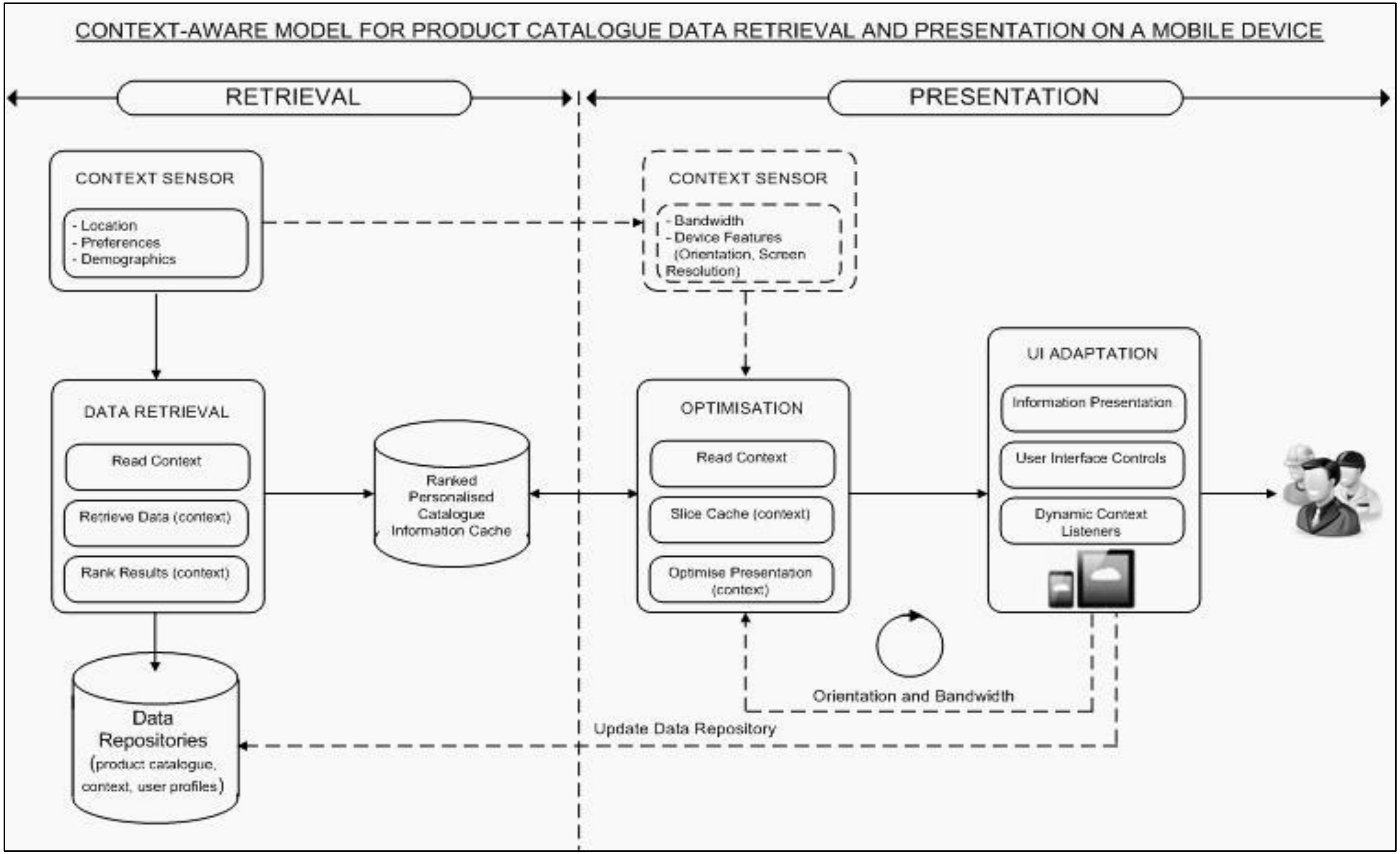


Figure 4. The Context-Aware Model for Product Catalogue Data Retrieval and Presentation.

Usage of the Context-Aware Model

The implemented model was incorporated into the backend of an existing eProcurement application that was deployed in Kgautswane in order to improve optimal retrieval and presentation of product catalogue data presented on the application interface on a mobile device. Figure 5 illustrates the context-aware model use case diagram that shows how the model was incorporated into the existing application. The diagram shows that the model was only incorporated in the backend and did not impact the user interface.

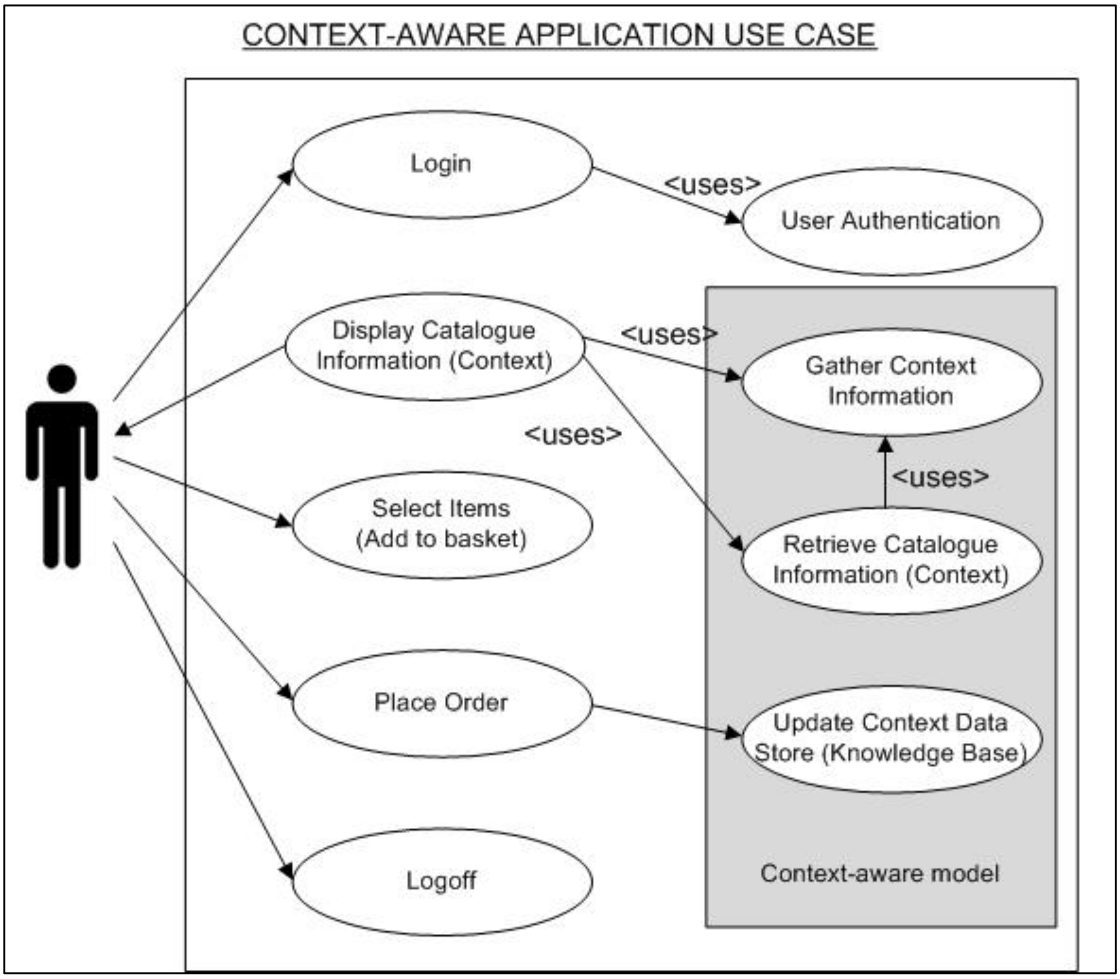


Figure 5. Context-Aware Application Use Case Diagram.

RESEARCH METHODOLOGY

This section discusses the research methodology that guided the research process. Research design, participants sampling, data collection and analysis are covered.

Research Design

A positivist research philosophy was adopted in this research. The research aimed at proposing and implementing a context-aware model, and measuring the benefits of the model in improving usability of information presented on mobile web application by using an example of product catalogue information in m-commerce environment. Evidence were gathered from similar research indicated that context information, such as location, play a useful role when taken into consideration during design and run-time of mobile applications (Coppola et al., 2009; Ismail et al., 2009; Orjuela-Parra et al., 2009). This fact complemented the suitability of a positivist approach that was utilised in the research study.

A software development methodology which is defined in software engineering as a framework structure for planning and controlling the software development lifecycle processes during the development of a software product was utilised during the development of the context-aware model (Sommerville, 2011). Specifically, prototyping was utilised during the actual development of the proof of concept prototype in this research (Olivier, 2009).

Participants' Profiles

Purposive sampling was utilised in this evaluation phase in order to identify participants who had prior experience with an existing eProcurement system into which the context-aware model was incorporated. A suitable sample was found within Kgautswane community, Limpopo Province, South Africa. Thirty (30) small-scale retailers with prior experience in the use of the originally deployed eProcurement application in the area participated in the study. Figure 6 shows an example of a typical shop and operators who were part of the sample. Descriptive statistics of the composition of the sample is discussed in the results sections of the paper.

Figure 6. An Example of a Shop and Operators.

Data Collection

Survey questionnaires were the primary data collection tools used during the evaluation. Two different questionnaires were designed with specific usability metric features that were utilised to assess usability (effectiveness, efficiency and satisfaction) of the eProcurement system. The questionnaires were based on a combination of aspects obtained from various well-known usability assessment questionnaires such as the Computer System Usability Questionnaire (CSUQ) and the Questionnaire for User Interface Satisfaction (QUIS) (usabilitynet.org, 2006; Tullis and Albert, 2013).

Secondary evaluation data was collected through a system log file. The system log file collected details of the interaction between the participant and the context-aware eProcurement system. The log file helped to verify participants' interaction with the system before completion of the questionnaires since the participants had to interact with the application during their own time. Information collected in the log file included the following:

- User login code (or username);
- Date and time when participant logged into the application;

- Total interaction time in minutes;
- The GPS coordinates of the position where the participant accessed the application;
- The make and model of device that was used to access the application;
- Categories and specific items the participants browsed; and
- Items that the participant selected for purchase during the evaluation.

The next section discusses the evaluation of the model. An evaluation of the model was conducted in order to establish the effectiveness of the model with regard to gathering accurate context and utilising the information to determine optimal retrieval and presentation of product catalogue data for presentation on a smartphone screen.

EVALUATION OF THE MODEL

This section discusses the evaluation conducted to validate the model's usefulness and applicability within its context of use. The topics of discussion are the objective of the evaluation, participants' profiles and the evaluation procedure that was followed.

Evaluation Objectives

Specific objectives of the evaluation were:

- To validate the effectiveness and usefulness of the context-aware model; and
- To collect end-user based evidence to measure the model's effect on usability of product catalogue information presented on mobile devices.

Evaluation Procedure

In order to achieve the first evaluation objective, a special international evaluation was conducted independently on the context-aware model prior to its incorporation into the existing application. Thirty participants from various locations across the globe participated during the evaluation. The general user profiles were users with at least a first degree and 2-5 years of Internet experience. This was a requirement so that users can critically analyse context information presented by the context-aware model user interface. The evaluation was conducted online and users were requested to access a link where the context-aware was hosted through a user interface at their own free time. The users were given the freedom to use any Internet enabled mobile device, such as smart phones and tablets. They were, however, notified that any Internet charges were to be covered by themselves. Results of this study indicated that the model was able to achieve its intended goals of gathering accurate context information such as the users' mobile device type, model and characteristics, time of the day, current location (when a user allowed to share the location details with the models' user interface) and perceived bandwidth in real-time. Comprehensive evaluation procedure and results were dedicated to a different publication (Ntawanga, et al., 2013).

A field study was conducted to achieve the second and core objective in which documents translated into Sepedi were utilised during this evaluation phase. Sepedi is one of the eleven official languages in South Africa that is spoken by people in the Kgautswane community. The following documents were utilised during the evaluation:

1. *Information about the evaluation:* This document introduced the overall experiment and explained the evaluation, its goals and objectives.

2. *Task list:* The task list described the step-by-step tasks that the participants were requested to complete during the evaluation with specific focus on actual user interaction with the application and completion of the questionnaires.
3. *Two sets of questionnaires:* The questionnaires were designed to gather responses from the participants on their experience with the original eProcurement application and how they felt after interacting with the more recent version of the eProcurement ordering system that included the backend context-aware component.

The participants were supplied with data bundles that they could utilise for Internet charges during interaction with the application in order to complete the evaluation tasks.

A pilot analytical usability evaluation was undertaken with a sample of consisting of four computer software developers and four usability experts prior to conducting the final evaluation with the field participants. The evaluation was conducted in order to assess the usability of the implemented solution. Shortfalls of the solution that were identified during the pilot study were rectified in the solution in preparation for the final evaluation. The next section discusses the results of the evaluation.

RESULTS

This section discusses the results obtained in the evaluation of the research and the implications of the findings. The descriptive, quantitative statistics obtained during the evaluation are examined. The results presented in this section were analysed from various perspectives such as the sample characteristics, experience of smartphone versus computer use and Internet experience, access to the eProcurement application and usability.

Descriptive Statistics of the Sample

The sample consisted of 50% (n = 15) male and 50% (n = 15) female participants. Ninety-seven per cent (n = 29) of the sample was black and 3% (n = 1) was of mixed race. Ninety-three per cent (n = 28) mentioned Sepedi as their home language and 3% (n = 1) were Afrikaans- and Zulu-speakers. The majority of the participants, 46% (n = 14) had attended high school but did not matriculate. Forty per cent (n = 12) had reached matric, 3% (n = 1) had a tertiary qualification and 10% (n = 3) had reached primary school level.

Smartphone Ownership and Experience

The participants indicated that they owned a smartphone. Participants were encouraged to use their own smartphones to conduct the evaluation because general usability literature shows that user experience can be affected when a participant uses an unfamiliar device to access an application. The use of their own devices ensured that lack of experience with a particular device would not affect the results as the participants would use devices they use and are familiar with.

The majority of the participants (n = 21) owned low-cost, lower-end smartphones from manufacturers such as Nokia, HTC, Huawei, Samsung, LG and Blackberry. A few participants (n = 9) indicated that they owned complex mobile phones such as HTC Wildfire and Blackberry 9800. The reported main uses of the smartphones ranged from making and receiving calls to instant messaging using an application such as WhatsApp. Figure 7 summarises the findings of the main uses of smartphones by the participants with the corresponding number of participants inserted in the bars.

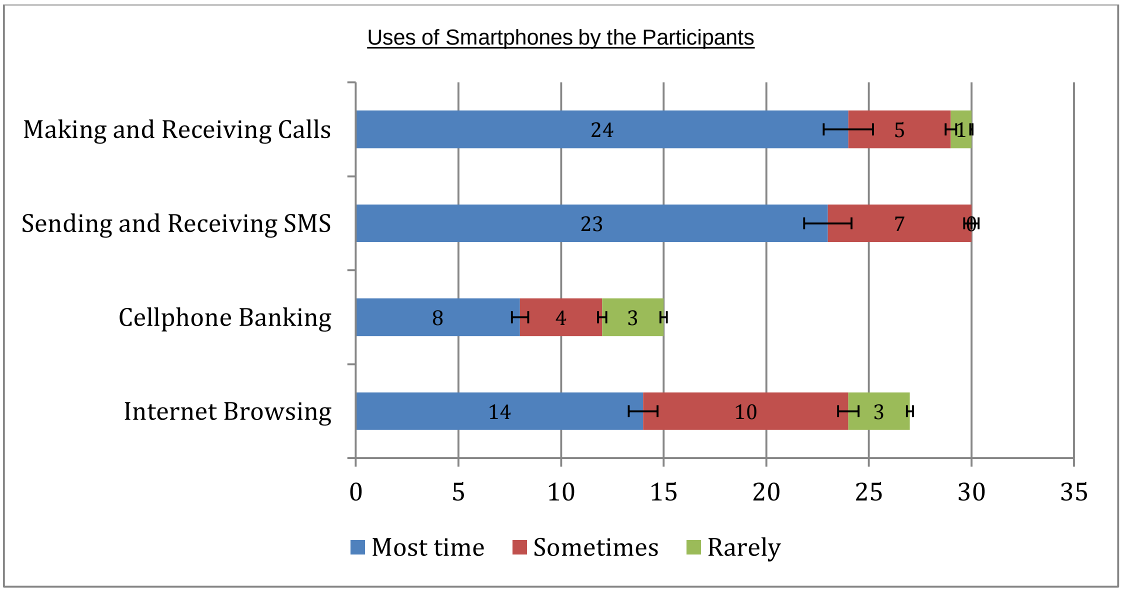


Figure 7. Uses of Smartphones.

Computer and Internet Experience

Forty-seven per cent (n = 14) of the participants indicated that they did not have access to a computer nor did they have computer experience. Ninety-three per cent (n = 28), however, indicated that they did have Internet experience. This indicates that the participants were able to access the Internet using the smartphones that they owned. Figure 8 summarises the participants' Internet experience. Sixty per cent (n = 18) of the participants rated themselves as having intermediate-level Internet experience. This response was deemed a true reflection taking into consideration the number of participants who had access to the mobile Web and would usually access the Internet daily for less than an hour. Thirty per cent (n = 9) indicated that they had novice Internet experience and only 3% (n = 1) indicated that they were expert Internet users. The novice levels of Internet experience did not affect the participants' performance during the evaluation because the participants had been trained during deployment of the eProcurement application.

One significant factor that emerged from the results was that almost half of the participants (47%, n = 14) had no computer experience and yet had access to the Internet and had gained experience in using the mobile Web. This observation confirms reports and findings by other researchers of the potential of mobile Internet in solving social-economic problems in many rural areas (Sife et al., 2010; Gupta et al., 2012; Ngassam et al., 2013).

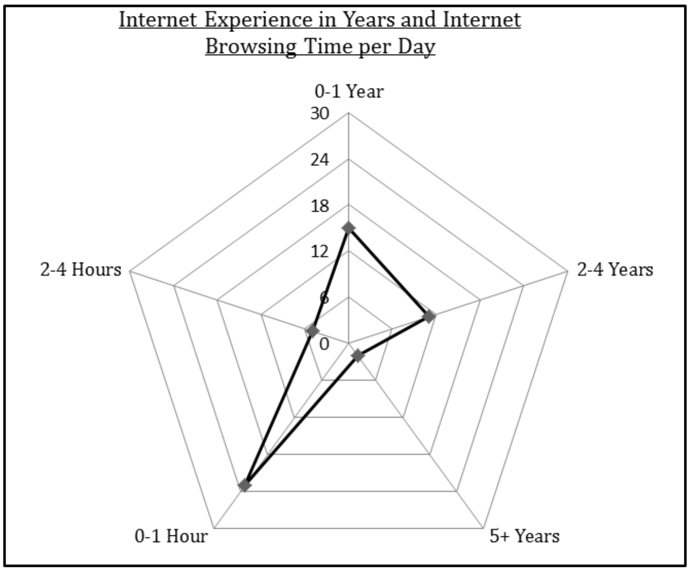


Figure 8. Participants' Internet Experience in Years and Internet Browsing Time per Day.

Access to the eProcurement System

Participants were asked to indicate whether they had access and experience in using the eProcurement system. Results indicated that 97% (n = 29) of the participants had access to the eProcurement system. Seventy-three per cent (n=22) indicated that they had purchased stock online using the eProcurement system.

In order to determine experience level, the frequency of ordering and the South African rand value of stock ordered via the eProcurement system were assessed. The goal was to determine the experience levels of the participants with regard to using the eProcurement system. For example, the higher frequency and greater rand value spent when a retailer ordered stock using the system, the greater the experience. Frequency of orders was measured by the number of replenishments made in a week and in a month. These assessments were conducted in order to ascertain the experience levels of the participants in using the eProcurement system.

The results indicate that the users had reasonable experience using the eProcurement system. Based on the participants' experience with the eProcurement system, the sample was deemed suitable for providing feedback that can be utilised to assess the objectives of the model and the evaluation. The following sub-sections cover the results of the evaluation that are specific to meeting the goals and objectives of the implemented model.

General Usability of eProcurement System

General usability aspects of the eProcurement system were evaluated by asking users questions, using a 5-point Likert scale, to score specific usability features of the eProcurement system. Figure 9 shows a summary of the scores obtained with regard to the usability of the eProcurement system. The figure shows the mean, mode and standard deviation of the ratings that participants scored in each aspect of usability of the eProcurement system. According to Tullis and Albert (2013) a usability score of less than 60% is considered poor, a score of between 60% and 80% is considered good, while above 80% is considered very good. The usability factors of the eProcurement system scored "good" because the average ratings were between 2.9 to 3.4 (58%-68%). The figure shows that the rating values of most of the participants were very close to the mean as indicated by the mode and the smaller standard deviation. This means that participants shared almost identical feelings about the usability of the eProcurement system.

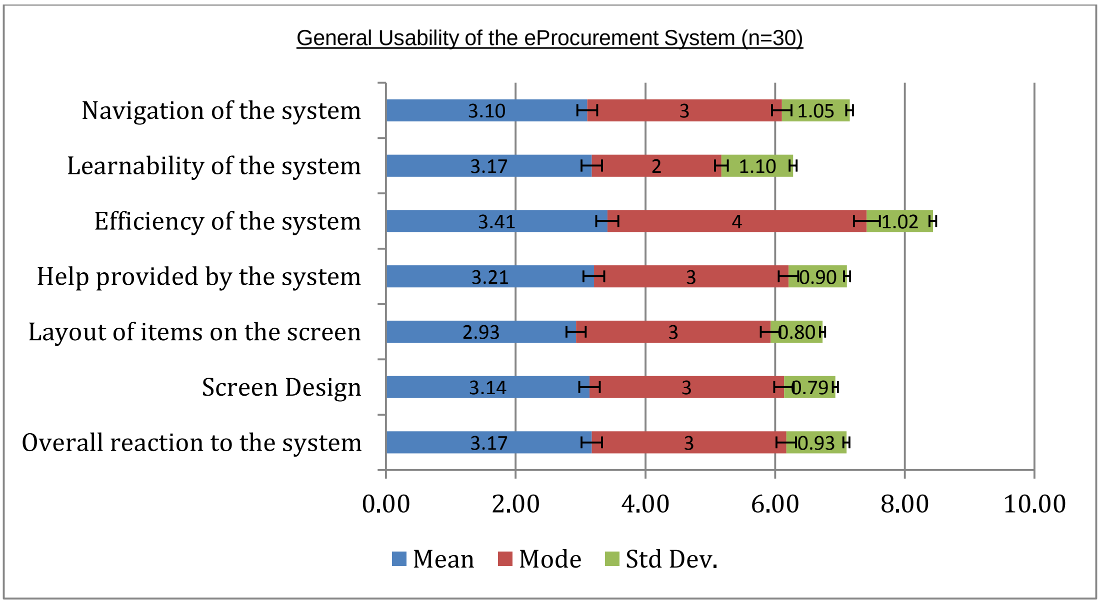


Figure 9. General Usability of the eProcurement System.

Usability of Product Catalogue in the eProcurement System

For general information presentation, participants were asked to score a number of statements that were compiled by using a combination of existing usability evaluation methods. The reason for this was because no specific evaluation methods for product catalogue could be found. However, the questions were adapted to suit the purpose of the experiment, for example, words like "general information" were represented by product catalogue information in the specific questions (Tullis and Albert, 2013). Figure 10 shows the results that were obtained from this phase. The results show that the mean score for usability of product catalogue information was in the range of 2.90 - 3.48 out of 5. Therefore the results can be considered only as "good".

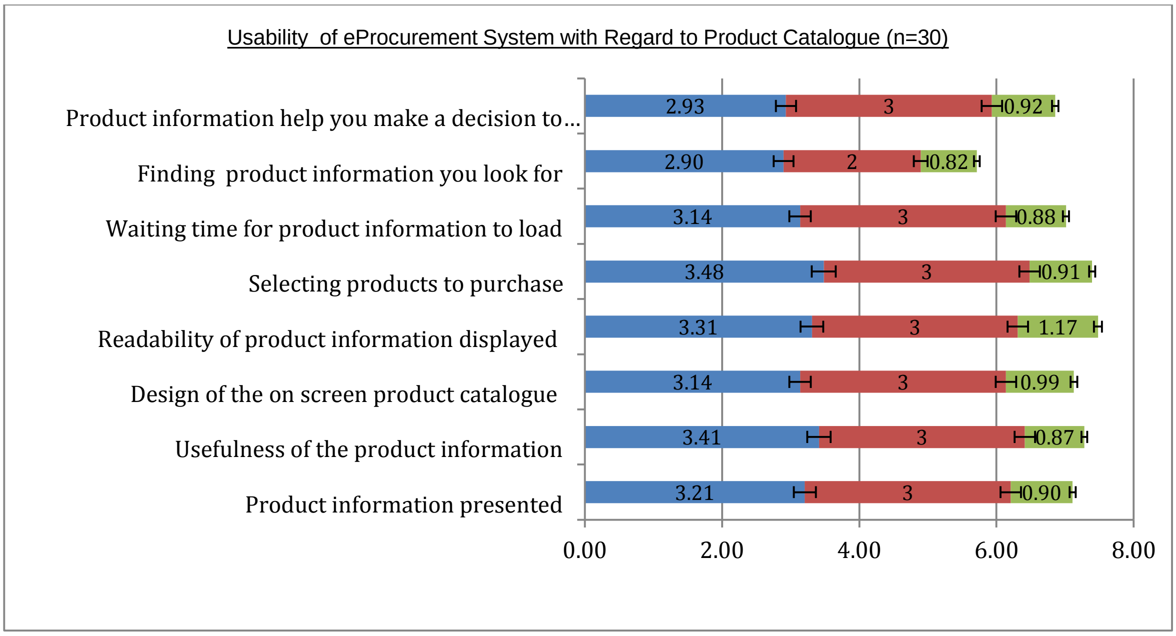


Figure 10. eProcurement System Product Catalogue Usability Evaluation Results.

Comparison of Usability with regard to the Product Catalogue (eProcurement System vs. Context-Aware eProcurement System)

Figure 11 shows the side-by-side comparison of the standard deviation, mean and mode of the results obtained. Results displayed in the figure show that the context-aware eProcurement system performed better with regard to the usability of the displayed product catalogue information. For example, most aspects of the context-aware eProcurement system were scored at around 4 out of 5 which is "pretty good", while ratings for the eProcurement system were around 3 out of 5, only "good" (Figure 10). Figure 11 shows that the average ratings for the context-aware eProcurement system were higher than those of the eProcurement system. Furthermore, the figure shows that the average standard deviation for the rating between the two systems is in favour of the context-aware eProcurement system. From these descriptive statistics it can be concluded that the context-aware model had a positive impact on improving the way product catalogue information was presented on the mobile device interface.

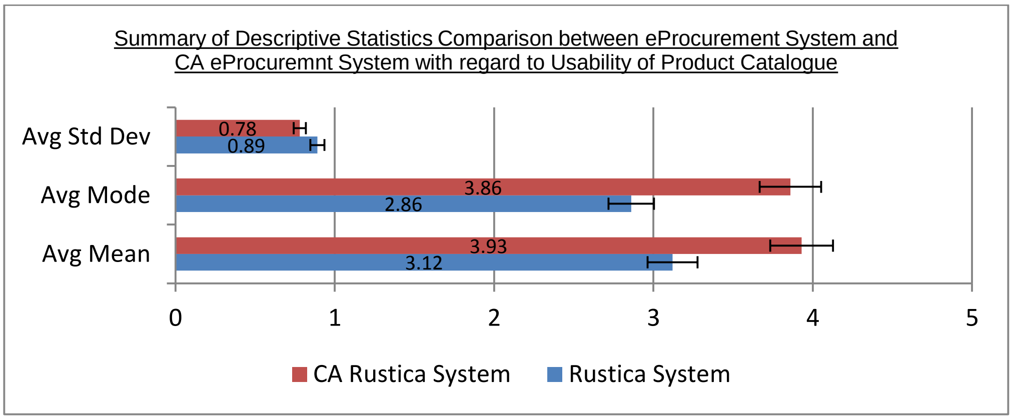


Figure 11. Summary of Product Catalogue Usability: eProcurement vs. Context-Aware System.

CONCLUSIONS

Mobile computing and associated applications continue to play a significant role in the everyday lives of people. Many activities that were restricted to desktop computers a few years ago can now be effectively accomplished on a mobile device by means of mobile computing. Examples of such activities include route planning using mobile map applications, accessing social media, reading the news, banking and online purchasing. Factors such as the decreasing cost of smartphones, improved wireless network capability and developments in Web development technologies have influenced these trends.

Users in rural African communities, who generally have little, if any, computer experience, are now able to access a variety of information sources and services by using smartphones through the mobile Web. Browsing various types of information on smartphone interfaces is beset by a number of usability challenges. The usability challenges are a direct consequence of the limitations of the devices and mobile Web environment, such as low memory, limited processing power, small screen size and limited user input modes, for example, a small keyboard and fluctuations in bandwidth strength (Schmeidl, Seidi and Temper, 2009; Xining et al., 2010; Zhang and Lai, 2011). The mobile environment, however, contains context information that the literature indicates can improve the usability of mobile Web applications (Asif and Krogstie, 2012; Poulcheria and Costas, 2012).

The use of context to improve the usability of applications, popularly referred to as context-aware computing, aims to utilise context within the mobile environment for the purpose of improving usability of mobile applications. Many context-aware computing development efforts, however, fall short of addressing critical usability issues. Reasons for shortfalls include lack of quality and lack of accurate context information for use during various adaptations and lack of techniques to determine context in real time, and lack of security and privacy among others (Turban et al., 2011; Asif and Krogstie, 2012).

This paper examined a context-aware model that was implemented to determine accurate context information in real time. The context information was aggregated, processed (interpreted/transformed) and utilised to improve the usability of product catalogue information with regard to retrieval and presentation on a smartphone device. The model was conceptualised and implemented into a prototype to demonstrate its feasibility. A product catalogue was selected as a case on which the model's functionalities could be tested. An evaluation was conducted in a rural community with users who had limited experience in using desktop applications and the Internet. An evaluation of the model was conducted to validate the model's usefulness and confirm its applicability.

Empirical results obtained from the evaluation indicate that the model achieved its goals and objectives. The model proved that the usability of product catalogue information retrieved and presented on a smartphone device interface had improved. The context-aware model discussed in this paper provides the basic building blocks for determining and utilising context information during retrieval and presentation of information especially on smartphone mobile devices. The context-aware model can be used by other researchers as a blueprint to implement complex, usable context-aware information retrieval and presentation applications.

The major limitation of the study was users not willing to share personal context information such as location. Most users would not allow sharing their current location with the application. This might have affected the model's effectiveness in determining current and accurate context information.

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