The Role of Context in m-Commerce and the Personalization Dimension

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Abstract

The rapid development of mobile devices contributed to the introduction of m-commerce whose growth is expected to exceed that of e-commerce. The interface usability of mobile applications is a critical factor for the acceptance of m-commerce, as a good interface design allows users achieve high performance when using mobile applications. However, this it is especially difficult to achieve due to certain limitations of mobile devices; limited processing power, low-bandwidth communication, small display and overall device size, limited mobile internet coverage, delays in standardization and poor quality of service. In this paper, we discuss the particular characteristics of the mobile setting, survey available design guidelines and stress the crucial role personalization can play for alleviating the aforementioned problems and allowing m-commerce reach its full potential.

1. Introduction

m-Commerce is a special branch of e-commerce, in which mobile devices and their network connection medium are used to buy, sell and promote products, services and information. Nowadays, m-commerce focuses more on the facilitation of enhanced information network access and less on supporting and realizing transactions. The use of wireless technologies extends the nature and scope of traditional e-commerce by providing the additional aspects of mobility (of participation) and portability (of technology) [1].

The slow rate in the adoption of the new technology is due to many reasons as far as the consumer perspective is concerned. The mobile setting and the physical constraints of mobile devices are the two characteristics that mostly influence the design decisions. Although mobile devices offer consumers many advantages, such as instant internet access, they also impose many constrains due to their limited processing power, the low bandwidth connections and the inefficient input/output mechanisms and layouts. When investigating the m-commerce domain, one has to consider all implications of using wireless mobile devices, which include their ubiquity (they are affordable and portable), personalization (a typical PDA belongs to and can be identified with a single individual), and location awareness (a connection established in the wireless medium can be used to determine the physical location of the device) [2].

The mobile setting is characterized by *spatiality*, *temporality* and *contextuality* [3]. Spatiality encompasses the mobility of both users and devices by referring to the ability of consumers to have internet access anywhere when carrying their mobile devices. Temporality means that users can access the internet instantly, even when engaged in a peripheral task. Contextuality is related with the way in which users conduct their tasks, such as the degree of interaction with others. A context-aware mobile application requires context information to support its decision-making activities related to delivering relevant information to the right customers. The context information is made up of very diverse elements from various sources with different levels of knowledge abstraction [4].

Mobile devices are portable due to their small size but their display sizes are limited and as a result they employ fewer resources than desktop computers [5]. Some devices have larger screens but they are still smaller than the smallest desktop display. The display covers a large part of the surface area and keyboard-based text input methods have been the most efficient way to reduce the slow input speed. The m-commerce interface should be designed to address the limited

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physical display of the mobile devices. It is imperative to improve the user interface design for mobile applications in order to enhance consumer adoption of the new technology by simplifying the use of mobile devices and personalizing the content based on specific user needs.

The increasing amount of stored content in mobile devices and the limitations of the mobile user interface introduce a usability challenge in content management [6]. While information is necessary for many applications, the human mind is limited in terms of the information volume it can efficiently handle. The multi-tasking nature of consumer behavior requires m-commerce interfaces to be designed taking into account the attention they can draw on the part of the user is by definition limited [7]. For example when a user is involved in a peripheral task, such as listening for a bus driver to announce the next stop, his cognitive resources assigned to a transaction, like purchasing a concert ticket using his mobile phone, are limited.

One way to reduce information overload and enhance the interface design is through the use of context information. It is a great challenge to design m-commerce applications and interfaces based on context. In mobile and ubiquitous computing the use of context is simply equated with location, but is actually more complex [8]. The environment of a mobile application changes continuously and the user needs are different each time. The contribution of content management to the interface design is of critical importance as well. Content management provides users with a safe and easy way of retrieving and searching the relevant content automatically through the use of contextual information.

The notion of adapting application behaviour to context has received considerable criticism in the literature [9]. Even though the goal of context-aware computing is well-established, developing devices that can sense the situation and adapt their functionality and behaviour appropriately faces one fundamental problem; context awareness demonstrated by people is radically different from that of computational systems [10]. Hard-coded, fully automatic actions based on context information are not always useful, and incorrect or undesirable automatic adaptations can be frustrating for users. It is not always possible to enumerate a priori a limited set of contexts that match the real-world context and even if such a set is found and is considered valid today, it may be inappropriate at any other later time because of *"internal and external changes in the social and physical circumstances"*. Moreover, determining the appropriate action from a given context may not be such a definite and straightforward decision for a computer application.

However, it is not necessary to pursue the triggering of fully automated actions as the only goal of context awareness [9]. Mäntyjärvi et al. in [11] propose a tool for personalizing mobile terminal applications according to context information and distinguish three different levels of automation of context-dependent actions: *manual*, *semi-automated*, and *fully automated*. Manual actions refer to actions executed by the user based on context information detected by either the device or the user. At the semi-automated level the user may predefine application actions based on context detected by the device, or choose from the actions proposed by the device based on context. At the fully automated level the application automatically undertakes pre-programmed actions according to the context it detects without involving the user in the process.

The semi-automated adaptation model partially overcomes the problem of determining an appropriate action based on context. If the event-action behaviour is defined by the user instead of the application developer, a higher degree of flexibility and user control is achieved. Further flexibility is provided by letting the user change the event-action configurations when the circumstances change over time.

The approach of learning contexts by example from a set of primitives from multisensor data faces a fundamental problem: all primitives function as inputs for every context, acceleration, orientation, temperature, sound, light, humidity, heart-beat, etc [9]. Therefore, when the user attempts to train the device in a certain context, the training data usually contains irrelevant inputs that are unintentionally included in the model. For example, if the user trains walking by walking near a road with a high rate of traffic, the model may learn that traffic noise is a part of walking and not recognize it without it. On the other hand, if walking is trained in silence, it may not be recognized in noise. With an accurately predefined ontology for predefined sensor and other inputs, and accurate rule definition by the user, context-action rules will contain only those inputs that are actually meaningful for a given context for the user.

2. Context attributes

In the work that first introduces the term 'context-aware,' Schilit and Theimer [12] refer to context as location, identities of nearby people and objects, and changes to those objects. Other definitions have simply provided synonyms for context; for example, referring

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to context as the environment or situation [13], [14]. As with the definitions by example, definitions that simply use synonyms for context are extremely difficult to apply in practice. The definitions by Schilit et al. [15] and Pascoe [16] are closest in spirit to the operational definition we desire. Schilit et al. claim that the important aspects of context are: where you are, who you are with, and what resources are nearby. Pascoe defines context to be the subset of physical and conceptual states of interest to a particular entity.

While context can be analyzed in terms of a large number of different attribute types depending on the situation domain at hand, we are mostly interested in studying the contribution of context attributes to content management. We thus focus on a small number of attributes which are the most 'descriptive' for content management and are also practically embedded in real products, such as *date*, *time*, *location*, and *proximity* (i.e. nearby Bluetooth devices).

The first two attributes, date and time, are the most commonly used by a wide range of applications for organizing both digital and analog content, for searching and automatically retrieving relevant content. For example, many cameras add automatically the date and time a photo was taken. In addition, the place where content is created is another useful attribute for searching it. Mobile devices give users the possibility to create content in many different locations, so users associate location with content and use it as the primary attribute for locating easier a specific content item.

Proximity on the other hand, may play an equally important role in content management. Bluetooth for example, which is a short-range wireless technology used to create personal area networks among user's devices and with other nearby devices, can provide information both in social and physical context and is a technology available on most mobile phones. Each Bluetooth device can be uniquely identified, and thus they provide a source of information on nearby people by identifying their mobile phones. An example for physical context is the case of a Bluetooth based hands-free car kit that can be used to specify that the user is in a car.

3. m-Commerce design factors

According to Rayport [17], the factors that influence the design of the user interface in a mobile application regard context, content, community, customization, communication, connection and commerce and should all be considered in order to design and built a useful and effective user interface for m-commerce. Their combination offers a solid framework for determining a personalized interface bearing in mind that in m-commerce applications content has to be structured so as to adapt to small screens. In this section we will refer to each of the aforementioned factors in more detail.

The use of context information is a way to reduce information overload and enhance content management. *Context* is any information that describes a content item, the location where it was created or received and can be used to aid users search, retrieve and organize the relevant content automatically [18].

Context is typically distinguished as *physical context* such as time, location, date, *social context* such as social group, friends, work, home, and *mental context*, which includes user activities and feelings [19], [20], [21]. Context information helps users find the content they need by enabling simple and multi-criteria searches (e.g. find images taken in Paris last year), example-based searches (e.g. find all the video clips recorded in the same location as the selected video clip), and automatic content organization for efficient browsing (e.g. location-based content view where content is arranged hierarchically based on the capture location) [22].

The mobile setting requires a set of functional features to allow users adopt m-commerce applications. The linking structure interconnecting web pages should be fully supported, so that even distracted consumers are able to navigate in a convenient way through available content. The structure of a menu with fewer levels but more choices per level is recommended (as opposed to a menu with more levels but fewer choices per level) because a deep hierarchy increases the cognitive burden by forcing more choices over more levels [23]. Another alternative structure is adopting a layered sequential selection process employing sub-menus linked to the tasks users are most likely to proceed to. This structure does not require users to return to the main menu to move on the next process [24]. Information has to be partitioned into separate pages due to the constrained display size of mobile devices. The issue of section breakdown should also be addressed, as users must scroll up and down more often in order to read the separate pages, which imposes more effort on users in terms of navigation and thus reduces significantly their performance [26]. Each page should be accompanied by a brief summary with key content so that users can better understand a body of information fragmented over separate pages [5].

The increase of storage capacity in mobile devices gives users the possibility to store large amounts of content in their phones. Users are able to store a huge

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variety of content such as contacts, text messages, ring tones, logos, calendar events and textual notes. Furthermore the development of novel applications has created new types of content which include images, videos, MMS (Multi-Media Messaging) data, e-mail messages, music, play lists, audio clips, bookmarks, news and weather information, chat, niche information services, travel and entertainment information, driving instructions, banking and shopping services [12], [15], [27], [28]. All these types of diverse content should be managed in an appealing way to support users in searching.

Content consists of what a web site presents and includes the offering, appeal, multimedia mix and content type [17]. The mix of product information, which is called offering mix, or promotional messages, which is called appeal mix, should be adapted to the purchase environment of consumers through the use of context aware applications. The method of proximate selection emphasizes the nearby located-objects and makes them easier to choose. These objects may include a non-physical service accessible only from particular locations, such as bank accounts or the set of places users want to know about (for example, gas stations or restaurants) [29]. The multimedia mix was introduced in order to overcome the limitations of display screens in mobile devices, as if we convert some part of content into audio format we manage to save a considerable percentage of display space [30]. Non-speech sound is also a good solution if we take into account that it is language-independent and very fast [31].

The community of users is formed around all interaction taking place among them, including interactive and non-interactive communication [7]. Interactive communication in the mobile setting gives users the opportunity to connect to others who reside nearby or have useful information about products of interest. Furthermore, interactive communication enables the exchange of opinions about products, which is an option well-received by consumers who often feel more reassured when shopping with friends and can be easily accomplished with information exchange methods available on a small screen (for example, Short Messaging Service (SMS) or graphics depicting products that are 'broadcasted' to a user's contact list).

As far as customization is concerned, it refers to a site's ability to tailor itself or to be tailored by users [17]. In a mobile setting, user's information enables the automatic adaptation of the mobile interface (tailoring). A part of this tailoring is associated with the mobile content. Information overload can be reduced through customization by filtering the unnecessary information, thus alleviating the limited visual display problem. As mobile devices are characterized by user's assigned identity, m-commerce provides potential for personalization (as will be discussed in section 4).

Communication covers ways of dialogue between users and web sites and can be distinguished as broadcasting, interactive, or hybrid [17]. For instance, targeted advertising through SMS or video mail is an efficient way of communication in the 'limited' mobile environment. Time and weather changes are useful cues for the selection of a message that will be broadcasted (for example, selling skiing equipment when it snows). To allow though for consumer feedback, such as multiple-choice answers or multimedia formats like voice and video mail transfer, alternative solutions to the limited keypad input are required.

Connection refers to the extent of formal linkages between sites, consisting of outsourced content, percentage of home site content and pathways of connections [17]. In mobile devices, pathways to other sites provide users with information needed in dynamic settings. The adaptive map, which is linked only to the web sites of nearby stores, is a way to reduce the number of alternative pathways. The limited display sizes make it difficult for users to utilize navigation aids, such as a brief site map that helps users identify their location. As a result, consumers may still feel lost along these pathways and the insertion of an icon that leads to the starting page with one click of a cancel button is recommended.

Finally, e-commerce by definition should concern interfaces related to sales of goods and product services. In mobile commerce, secure payment methods requiring minimal attention are crucial for its wider adoption. By inserting a certificate of authentication into mobile phone consumers, financial service providers and m-commerce retailers conduct mutual authentication. Condensing a set of processes across several steps into an one-click checkout process becomes possible by taking advantage of the already known user profile containing the user's name, address and preferred delivery option.

3.1 Context parameters in an m-commerce setting

Usability in interface design is crucial for any application. Websites that are properly designed help ensure that users find what they are looking for and perform successfully their intended online transactions [8]. Context plays a crucial role in the design of m-

commerce applications, as nowadays, people may be anywhere at anytime and use a mobile application, unlike the traditional wired web, where a physical internet connection was required. Applications designed for a stable office or home environment may not work well on a loading dock or in a moving automobile.

Computer applications designed before the era of mobile devices had to consider only a limited number of context attributes that usually comprised organizational culture, user characteristics (skills, education), system goals and working environment conditions (lighting, noise) [8]. Unlike today, users used to perform tasks on computers that remained stationary. Contextual information could be taken into account during the design process and changed slowly after system completion. Context in mobile devices is a less predictable parameter that influences the design and usage of computer systems.

Mobile application usage can vary because of changing circumstances and diverse user needs. Context is usually distinguished in three broad categories: *environment*, *participants* and *activities* [29], [32], [33]. Environment refers to the properties of objects in their physical environment. Participants include the status of the users and that of other participants in the environment, while activities regard user, participant and environmental activities. Context also includes any *interactions* or relationships that may exist among participants, activities and the environment.

For each of the three categories there exist several representative characteristics such as location, orientation of objects, physical properties, brightness and noise levels, availability and quality of devices and communication, as far as environment is concerned. Contextual attributes for participants comprise location and orientation, personal properties (i.e. age, gender, education, and preferences), mental state, physical health, and expectations. Activities may refer to tasks and goals of participants, or conditions related to the environment (for instance weather conditions). Interactions refer to co-location, group dynamics, social situations, participant/environment relationships (for example worker/workplace), season, time-of-day, day-of-week, etc. [8]. It is worth mentioning that time is a crucial factor for context, as it allows for a context history, which in turn can be used for predicting future context.

When designing m-commerce applications, a number of challenges should be addressed within the boundaries of context. Many activities compete for gaining the attention of the user on web; services that send news stories, alerts about stock prices and notifications of e-mail messages. With wired e-commerce the environment outside the web is stable and most offices and homes function with a good amount of predictability, even if users experience a great amount of activity and they can allocate relatively consistent amounts of attention to performing tasks on computer [8].

In m-commerce there can be a significant number of additional people, objects and activities vying for a user's attention aside from the application itself. Since devices are completely mobile, this outside environment can change rapidly from time-to-time. A mobile commerce application may not be the focal point of user's current activities while a user may interact with a mobile device along with other applications, users or activities. The amount of attention a user can give to a mobile application depends on his priorities that can change unpredictably. The environment in which m-commerce applications are used is completely different from that of their desktop e-commerce counterparts [8].

Furthermore, in m-commerce environment users and applications must deal with devices, phones and handhelds that shrink in size and weight continuously. Although these devices are characterized by great portability, some usability issues are introduced. Keyboards are being replaced by buttons and keypads, screens become smaller which makes it difficult to read and inconvenient to use with one hand [8]. Moreover, when physical environmental conditions (brightness, noise levels, weather) change at a high rate, the use of mobile devices may be greatly affected. All these difficulties while using devices results in wasted time, errors and user frustration.

The variation of user location and activities arise safety issues. For instance, web access in cars creates potential problems associated with browsing while driving. When designing m-commerce systems for automobiles, if the application absorbs too much attention from the primary task of driving, the consequences may be too serious.

Security is another significant challenge in the m-commerce domain [34]. Although storing sensitive data such as medical, personal or financial information on mobile devices for use in mobile applications can be of benefit to users, there are serious risks involved (such as losing the device and its data, or allowing unauthorized parties to access these data). All these conditions call for ways to positively identify users prior to proceeding with a transaction.

Finally, m-commerce technology brings new social concerns to prominence. Many people resent ringing mobile phones and keyboard-tapping in public locations, such as theaters and restaurants [35].

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Mobility of devices raises the issue of appropriateness of use under certain circumstances.

4. Context for m-commerce personalization

Context-awareness can provide a solid basis for delivering personalized services in the m-commerce domain. According to Mulvenna et al. [36], the objective of personalization is to provide users with what they want or need, without having to ask (or search) for it explicitly and context awareness may greatly contribute to this 'implicit inference' of information pieces that match individual needs and preferences of mobile users. Context information, covering such aspects as location, time, weather, user activities and user preferences, is vital to this type of decision making activity [37] [33].

Primitive context information is collected from different sources with different levels of abstraction and is therefore usually not suitable for the necessary decision making. It must be processed, integrated, modelled and represented before it is ready to use for personalization purposes. More specifically, as depicted in Figure 1, the original elements of primitive context information exist in three forms: data, information and existing knowledge.

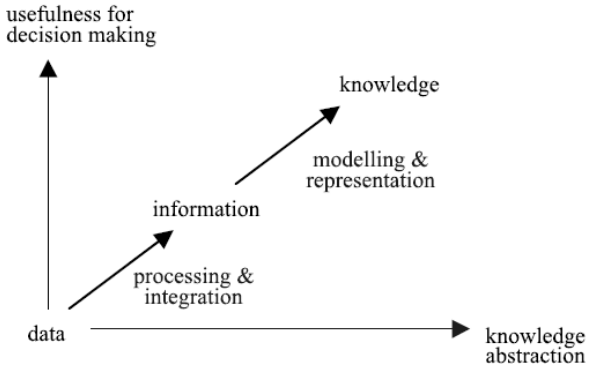

Figure 1. Elements of context information [4]

In the context of m-commerce these forms should be distinguished in terms of two dimensions: their usefulness for decision making and the degree of knowledge abstraction they use [4]. A well-established view is that "*data are raw numbers and facts, information is processed data, and knowledge is authenticated information*." [38]. Data are the preliminary history from collection by sensors, which are the main source of context information in m-commerce. After the processing and integration, 'data are classified, summarized, transferred or corrected in order to add value, and become information within a certain context.

Information serves to "*inform' or reduce uncertainty within the problem domain*." [38]. Unlike data, information has meaning. It can provide a range of possible alternative actions for the system to choose among, with a higher level of knowledge abstraction. Knowledge can be approximately regarded as personalized information (which may or may not be newly created) related to facts, procedures, interpretations, regulations, observations and judgments [39].

Recently, a significant number of context-aware applications aimed at delivering personalized services have grown in the m-commerce domain. Ala-Siuru and Rantakokko in [40] introduce a hybrid method for personalizing different interface features in a mobile phone based on combined data collected from GSM base stations and Bluetooth sources to determine user location and change the user profile according to location context. Kawsar et al. in [41] investigate personalization as a crucial factor for the success of the proactive services provided by context-aware m-commerce applications and adapt a middleware perspective for tackling the identification, extraction, storage and representation of user preference information. Georgiadis et al. in [42] stress privacy and security aspects focus on how the various customization and authorization concepts influence specific UI design elements in terms of content, presentation, connection, communication, community and commerce. They argue that adapting an appropriate context-sensitive model for authorizations, the overall flexibility of the established personalization mechanisms is preserved without compromising the stability of the required security precautions.

5. Usability issues

The expanded context dimension, which also includes location and proximity information, introduces potential usability problems [43]. Sharing context can be of benefit to users as they are able to store, access and share with others their own location based information along with videos and photos, and this exchange certainly increases the sense of community among them [44], [45]. But when it comes to proximity being included in the context information, the problem of privacy comes up. And even though users may usually accept a loss of privacy when they take into account the benefits of receiving useful information, they expect to be given full control over the release of such sensitive data [46] [47].

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When users share content, they should be able to decide whether they will share all the metadata bound to each content item or they will filter out all or some part of them. The cost for storing and transmitting such metadata is not a factor that actually influences this decision, as it is merely textual information. When a user receives location and proximity information attached to content, he may also know where and with whom the creator of the content was when the content was created. As a result, both the location of the content creator and the location of nearby people are disclosed. If this information is for some reasons private, the sharing of it could be considered as a privacy violation. In fact, this violation may be multiplied if the recipient forwards the content and the metadata to other users.

However, users seem willing to share context metadata attached to content, as it is convenient when context metadata are automatically generated along with the content and they do not have to add this information manually. Furthermore, on the side of the recipient it is helpful when received content is annotated with context metadata without requiring extra effort for annotating it from scratch. In this case the recipient goes through the editing process for only specific content items that their metadata need to be changed or enriched. There are cases where the filtering of context metadata is useless. For example, in cases with image and video content filtering out metadata on location and bystanders is senseless, since these same items appearing in the image or video can be identified visually by observing the content itself.

The context information that accompanies a content item should be meaningful, otherwise it useless. But what is meaningful information for the end user of a content item? It seems that users want meaningful information, but they are not willing to put too much effort in creating it unless this information is useful. This for instance applies in the case of location which is a type of context information that is not generated automatically (such as date and time) and users have to type the name of the place. Proximity information needs to be meaningful, as well. If the globally unique Bluetooth device address and the real name of the owner of the device could be connected, this functionality would give meaning and practical value to the sharing of proximity information [22].

Although it is hard enough to determine which information is useful, the situation gets even more complicated when also considering that what is useful information in one situation might be totally useless in another. For example, looking at photo albums, what is thought to be useful information varies a lot. When one is looking at pictures that were taken within the family recently, we probably think that it is needless to write down the names of the people, since they are all well known. But it is different looking at pictures of the same people taken many years ago when they looked quite differently and it would be nice to have their names written by the photos.

Summarizing, it appears that useful information may depend on the location of the user, the purpose for using this information and the time span it addressed by its use. To create meaningful information users need to put effort in acquiring the data, organizing it, as well as annotating it with the appropriate context metadata and this process calls for developing ways to minimize this effort and maximize the associated benefit.

6. Answers to context challenges

There are many ways to address the problems and difficulties that occur when introducing context in the design and use of m-commerce applications. The increased demands imposed on user attention in dynamic mobile environments can be tackled with interfaces that require less concentration and thus absorb less attention. Pascoe, Ryan and Morse in [25] formulated the concept of Minimal Attention User Interfaces, which seek to minimize the amount of attention required to operate a device. They developed a PDA application used by field workers studying giraffes in Kenya, which allowed the user to count the number of bites taken from tree leaves without looking away from the animal, which was observed through a telescope. The applications used two existing PDA buttons for incrementing and decrementing the count and could be operated with one hand.

Mobile devices and applications may be designed in a way that allows for automatically adapting themselves to context changes. Mobile devices executing context-aware applications help users based on their knowledge [48]. For example, when using a context-aware application called ‘stick-e notes’, the messages typed in a mobile device are annotated with the location of the device at the time they were created [25]. When the user approaches the same location again, the notes reappear. In addition to location other context attributes can be used such as time, date, and temperature.

To overcome the physical limitations of mobile devices it is required to develop novel interaction techniques. Flexible input and output methods help adaptation to changing context and user needs. For example, text entry using a stylus or miniature keyboard on a PDA may be efficient when both hands

are free, but one-handed text entry using a thumbwheel is better when one hand is occupied [35]. An alternative is speech input as the devices are small and there is no need for buttons, but it would be an inappropriate approach for noisy environments or at places where noise is restricted, such as hospitals or libraries. Speech and sound could be used for output, taking the place of text or graphics. Holland and Morse [49] created an audio interface for a navigation system that leaves a user's eyes and hands free to concentrate on other tasks. The application used tones projected through headphones at locations relative to user (left, right, forward) to indicate the direction.

Concerning the security reservations emerging in mobile applications, a promising solution can be achieved through the use of biometrics [35]. In the future, mobile devices may include thumbprint identification or smart cards for assuring secure user authentication. The common sense of users and designers in combination with adequate legislation can guarantee the safe use of devices and applications. Many states have already set laws and specific regulating on the proper use of cell phones in vehicles. Technology may drastically contribute to enforcing what is by law considered as an appropriate behavior.

7. Conclusions

The primary motivation in the interface design of mobile commerce applications should be to reduce consumer reluctance in adopting m-commerce. One inhibitor is the intimidating existing m-commerce interface developed on the foundation of e-commerce designs [7]. New interface design methods should be developed that consider both user's limited attention span and the physical constraints of mobile devices. The main concern for users is the instant access to the desired information and the easy and simple transaction process. These changes will induce consumers to make more m-commerce-based purchases as they can make informed decisions in a more user-friendly environment.

Considering the complexities of context during the design and use of m-commerce applications is a challenging task, but it is necessary in order to achieve long-term success [8]. Design patterns and usability methods for wired systems may not necessarily be appropriate for mobile systems. Systems must function consistently under the changing environmental conditions, circumstances and user needs and priorities. Designers should take into account the interaction between people and their surroundings. Applications should be characterized by increased functionality and usability.

The increasing amount of stored content in mobile devices and the limitations of physical mobile phone user interfaces introduce a usability challenge in content management. The efficient management of large amounts of data requires developing new ways of managing content that incorporate advanced personalization services. Stored data are used by applications which should express information in a sensible way and offer users a simple and intuitive way of organising, searching and grouping this information. The inadequate user interface design results in poor usability and make an otherwise good application useless. Therefore, it is necessary to design and built context aware applications.

Issues of usefulness and meaningfulness in utilizing context metadata need to be studied further. Usefulness depends on the type of metadata. As far as location and proximity are concerned, experience indicates that the more time has passed from the recording of the data, the more accurate information is needed. Furthermore, in the case of location information, the closer to one's home or familiar places a location is, the more detailed information is needed. A main usability challenge is the automatic generation of meaningful context metadata, without having users add this information manually. And though there exist many ways of automatic context metadata generation, the meaningfulness of this information is questionable.

The issue of privacy requires a lot of further research. It appears that users are not non-negotiable on revealing private information provided that they do it for a good reason and that they fully informed about the sensitive data that are shared, and who they are revealed to.

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