PRESERVING QUALITY IN THE DEVELOPMENT OF MOBILE COMMERCE SERVICES AND APPLICATIONS

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ABSTRACT
Mobile commerce is nowadays a continuously growing area, driving the need for advances in both the network characteristics and infrastructure, as well as in the available mobile devices used. The same need requires the development of quality software applications to facilitate and service m-commerce activities. This paper focuses on aspects of software quality for m-commerce services and applications, and proposes a set of quality characteristics and attributes to take into consideration during development. These quality characteristics are integrated during the analysis and engineering phases of the MobE process, which is a revised version of the spiral software process used in web engineering. The efficacy of the proposed approach in a real scenario is discussed.

KEY WORDS
M-Commerce, quality, mobile user requirements, mobile services and applications

1. Introduction

Mobile commerce (m-Commerce) services and applications are becoming more and more adopted in today's modern mobile computing society. Some factors that contributed to this end are the tremendous development of the Internet and related technologies, the understanding and exploitation of the business potentials that rest behind this development and the impressive growth of wireless mobile networks.

Recent studies have shown that the number of people using mobile devices to connect to the Internet has already exceeded that of stationary Internet usage in Japan and a similar trend is expected worldwide in the next few years [1]. This is due to various reasons, like the ability to connect to the internet or other mobile networks 24/7 to access both business and personal information, independent of user location. Location independence is the key benefit of mobile devices; in fact, wireless applications are likely to be inferior compared to their wired counterparts in all terms except mobility. Mobility can be seriously degraded though, due to difficulties arising from the limitations posed from both the mobile devices [2] (e.g. low screen resolution, limited battery life, etc) and the mobile networks [3] (e.g. frequent disconnections, slow connections, heterogeneous networks, etc).

As the diversity of mobile applications and services increases, these limitations urge the users to demand higher quality so as to receive services quickly, reliably and securely, and at the same time to spent as little time and effort as possible in dealing with network and device problems. Providing high quality mobile applications is an important factor not only for user satisfaction but also for achieving long-term customer loyalty. Therefore, the question raised is how do we safeguard or achieve quality in mobile applications?

The objective of this paper is to suggest a new approach for promoting quality in mobile applications, aiming at enhancing existing development methodologies. Our work relies and extends the MobE process [3], which is a software process for developing mobile applications and services based on the integration of mobile user requirements with the constraints of available mobile devices and networks. What we propose is a set of quality characteristics, along with their corresponding metrics, that developers of m-applications should address and incorporate for delivering high quality products. These characteristics are combined with the phases and activities of Mobe in such a way so as to reach to the desired quality outcome.

The rest of the paper is organized as follows: Section 2 briefly reviews the recent studies focusing on improving quality in mobile applications and presents the proposed set of quality characteristics and metrics. Section 3 describes the MobE process for designing and developing mobile applications and proposes a methodology for integrating MobE with the identification and integration of the desired quality characteristics. Section 4 demonstrates the proposed approach through the development of a healthcare mobile application. Finally, Section 5 presents the conclusions and suggests future work.

2. Quality in Mobile Software Applications

Little research effort has been devoted to the design and development activities of m-Commerce services and applications. Carlsson and Walden [4] mention that there are a number of open research issues regarding m-Commerce applications. One of their findings is that a methodology for testing and validating m-Commerce products and services is still in its infancy. Veijalainen, Yamakawa and Markkula [5], introduced a systematic way of gathering the requirements for m-Commerce applications and services.

Andreou et al. [3] suggest a new approach for designing and developing m-Commerce services and applications called MobE, taking into account the mobile user needs and requirements, as well as the constraints posed by mobile devices and networks. The present work will attempt to further refine and enhance the MobE framework by adding a set of quality aspects that can be incorporated in the analysis and engineering phases of MobE, so high quality mobile applications can be developed.

Table 1: Proposed Software Quality Model for Mobile Applications

General Characteristics	Sub-Characteristics	Attributes	Metrics
Functionality	Interoperability	Platform Independence	Number of platforms supported
		Operating System Independences	Number of OS supported
		Hardware Compatibility	List of mobile devices supported (PDAs, Palm. etc)
	Suitability	User Satisfaction	Level of user satisfaction (e.g. on a scale form 1 to 5)
		Service Satisfaction	Ratio of the functions desired by the user to the functions provided by the m-application
		Achievability	Provided or Not - Ratio of the functions provided by the m-application to the functions required by the user
	Security	Data Encryption	Provided or Not
		Access Control	Provided or Not
	Compliance	Network Standards	List of mobile standards supported
		Communication Standards	List of communication standards supported
	Accuracy	Correctness	Ratio of correct results to total results
Reliability	Service Stability	Crash Frequency	Number of crashes per unit of time
		Error Handling	Provided or Not
		Error Comprehensibility	Provided or Not
		Availability	Average operation time without serious errors
	Fault Tolerance	Recoverability	Provided or Not - Level of recoverability (e.g. on a scale form 1 to 5)
		Transaction Rollback	Provided or Not
Usability	Learnability	Time to learn and use	Average time for a user to learn how to use the m-application
		Rate of user errors	Average number of user errors per unit of time
	Operability	Set-up Effort	Average time to set-up the application according to user needs
	Contextuality	Timeliness	Provided or Not
		Promptness	Level of user satisfaction in the process of accessing information
	Interaction	Structurability	Level of user satisfaction arising from the structure of m-application
		Presentation ability	Level of user satisfaction arising from the presentation of information
		Navigability	Level of user satisfaction arising from the navigation to the system
	Help Tools	Help Support	Provided or Not – Listing of support tools provided
		Help Completeness	Provided or Not – Level of satisfaction
Efficiency	Response Time	Throughput	Number of request per unit of time
		Capacity	Number of concurrent users
	Power Consumption	Battery Life	Performance/Per Watt
	System Overhead	Memory Utilization	RAM size
		Processor Utilization	Level of processor speed
		Storage Media Utilization	Secondary Memory Size
Maintainability	Changeability	Expandability / Upgradeability	Level of satisfaction
		Versions Compatibility	Provided or Not
		Customizability	Provided or Not
	Testability	Test Materials (e.g. demos, test cases)	Level of Satisfaction
Portability	Adaptability	Applicability	Provided or Not

In comparison with conventional software applications, where the focus is mainly on functionality, a wide range of other quality characteristics are desirable in mobile software applications, like usability, security, performance and availability. Table 1 lists a number of suggested quality aspects, along with functional metrics for achieving higher quality in mobile applications. This quality framework is built mainly by modifying the quality model of ISO9126 [6, 7, 8, 11, 12] because it is evident that not all characteristics of conventional software products are applicable to mobile applications. There are six general characteristics namely functionality, system reliability, usability, efficiency, maintainability and portability.

Functionality refers to a set of characteristics that bear on the existence of a set of functions. These functions are those that satisfy stated or implied needs along with the ability of the system to provide services under specific conditions. *Reliability* refers to the capability of the software to maintain its level of performance under specific conditions for a given period of time. *Usability* indicates the understandability of the software product, as well as the easiness to learn and operate it. *Efficiency* bears on the relationship between the level of performance of the software and the amount of resources used under certain conditions. *Maintainability* refers to the means provided by the software to be tested, upgraded and customized. Finally, *Portability* bears on the ability of the software to be transferred from one environment to another. Each general characteristic is decomposed into various sub-characteristics, which are in turn broken down to specific attributes that are easily identifiable and measurable. The last column of Table 1 suggests metrics with which a certain quality attribute can be evaluated. Using these metrics developers will be able to define practically the distinct features they would like their mobile application to include according to the desired level of quality for each of the sub-characteristics forming the relevant quality category (first column). Analytically:

Functionality is divided into the following sub-characteristics and attributes:

- Interoperability: Platform Independence (ability to be used in different web or mobile platforms/architectures), Operating System Independence (ability to be installed in different operating systems), Hardware Compatibility (ability to run on various mobile devices).
- Suitability: User Satisfaction (the level to which the m-application meets the user requirements), Service Satisfaction (the level to which the m-application offers everything required for the service advertised), Achievability (whether the m-application can provide a higher degree of service and/or more services than expected).
- Security: Data Encryption (ability of the m-application to offer encryption services to protect the data it handles), Access Control (presence of access control mechanisms like authentication and authorization in accessing the services).
- Compliance: Network Standards (ability to support various network standards), Communication Standards (ability to support various network standards).
- Accuracy: Correctness (ability to return correct results).

Reliability is divided into the following sub-characteristics and attributes:

- Service Stability: Crash Frequency (number of crashes per unit of time), Error Handling (reference to the mechanisms used to handle errors), Error Comprehensibility (provision of comprehensible error descriptions), Availability (duration that the m-application is available to offer its particular service).
- Fault Tolerance: Recoverability (the ability of to recover when errors occur (fault tolerance); in addition, it indicates the level of efficient recoverability i.e. whether data is lost etc.), Transaction Rollback (ability to rollback all changes if a transaction fails).

Usability is divided into the following sub-characteristics and attributes:

- Learnability: Time to learn and use (the time required for an average user to learn how to use the m-application), Rate of user errors (average acceptable rate of user errors).
- Operability: Set-up Effort (the effort required for an average user to set-up the m-application).
- Content: Timeliness (ability for timely content updates), Promptness (ability to promptly accessing the available content)
- Interaction: Structurability (level of satisfaction for the functional structuring of the m-application), Presentation ability (for proper data and content presentation according to user needs), Navigability (ability to navigate easily and correctly through the m-application).
- Help Tools: Help Support (denotes the presence of tutorials, demos, examples, on-line support mechanisms and/or support forums and newsgroups that will facilitate the usage of the m-application), Help Completeness (indicates whether help files are available for the m-application and the completeness of the help system).

Efficiency is divided into the following sub-characteristics and attributes:

- Response Time: Throughput (the speed of the m-application to serve requests and produce output over a given period of time), Capacity (defines the number of concurrent users that can be handled by the m-application simultaneously without compromising performance).
- System Overhead: Memory Utilization (designates the amount of memory needed by the m-application to operate), Processor Utilization (designates the amount of processing time (in CPU cycles) needed by the m-application to operate), Storage Media Utilization (designates the amount of storage space needed by the m-application to operate).

Maintainability is divided into the following sub-characteristics and attributes:

- Changeability: Expandability / Upgradeability (measures the easiness with which an m-application is upgraded to a new version), Versions Compatibility (designates whether a new version of the m-application is compatible with previous versions), Customizability (ability of an m-application to be customized according to user needs – e.g. offering parameters for GUI customization).
- Testability: Test Materials (denotes the existence of useful testing material like test demos, test cases, etc.).

Portability is divided into the following sub-characteristics and attributes:

Adaptability: Applicability (evaluates the ability of an m-application to adapt to a changing environment either automatically at runtime, or with administration effort).

The aforementioned attributes describing each general characteristic fall into two main categories, objective and subjective. Objective are the attributes that are based on facts and are faultless. An example of an objective attribute is throughput which involves run-time measurements like bits/second. Subjective are the attributes that are measured differently by each user group. Timeliness is a user perceived quality attribute, that is subjective because it is based on the user expectations and not on real metrics.

2.1 Integrating MOBE with the Proposed Quality Model

As mentioned in the previous section we will rely and expand the MobE process [3] for designing and developing mobile software applications. MobE is based on identifying mobile user needs and requirements using a classification of m-Commerce services and applications into two classes, namely the directory-oriented and the transaction-oriented class, as well as identifying the constraints of the current technologies for mobile and wireless computing.

More specifically, the proposed MobE process includes six phases (see Figure 1): a) Formulation, b) Planning, c) Analysis, d) Engineering, e) Implementation & Testing, and f) User Evaluation:

a. Formulation – Defines the tasks and goals of the m-Commerce service/application and specifies the length of the first increment.
b. Planning – Estimates the total project cost and the risks associated with it, and sets a timeframe for the implementation of the first increment as well as the process of the next increments.
c. Analysis – Identifies all the mobile user requirements and identifies the content items that will be incorporated.
d. Engineering – Involves two parallel tasks: (i) Content design and Production, and (ii) Architectural, Navigation, and Interface design.
e. Service/Application Implementation & Testing – Codes and tests the m-Commerce service/application.
f. User Evaluation – Evaluates the interaction and usability in the mobile context by utilizing several methods, such as empirical testing, discount usability, and cognitive and task analysis methods.

As depicted in Figure 1, the focus of the MobE process is mainly concentrated on the Analysis and Engineering phases: The identification of mobile user requirements and the classification of m-Commerce services is performed in the Analysis phase, while the identification of the constraints of mobile devices and technologies is carried out in the Engineering phase. The rest of the phases are similar to the ones found in the WebE process [9, 3].

The proposed quality model aims at extending and enhancing the MobE process, which is appropriately modified to accommodate and include the quality factors of Table 1 in designing and developing mobile applications. Modifications are performed in both the Analysis and Engineering phases of MobE as follows (see Figure 1):

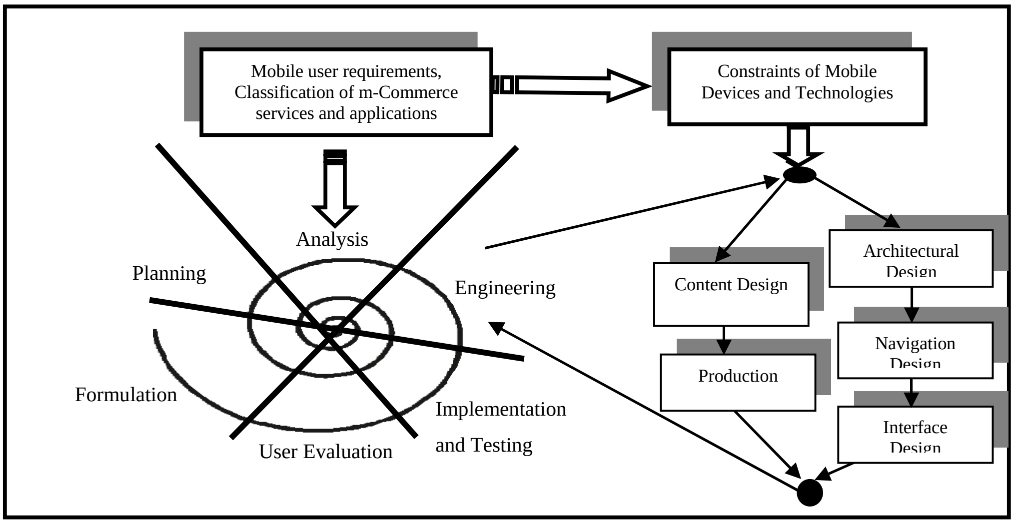

Figure 1: The MobE process for m-commerce services and applications

A. Analysis Phase

This phase includes a complete analysis commonly found in a Web engineering context comprising [9]:

- Content Analysis – The full spectrum of the content the mobile service/application contains (e.g. text, images, etc).

- Interaction Analysis – The detailed description of the navigation mechanisms of the mobile service/application.
- Functional Analysis – The identification and explanation of all functions and operations of the mobile service/application.
- Configuration Analysis – The identification of the protocols, technologies and infrastructure the mobile service/application will run on.

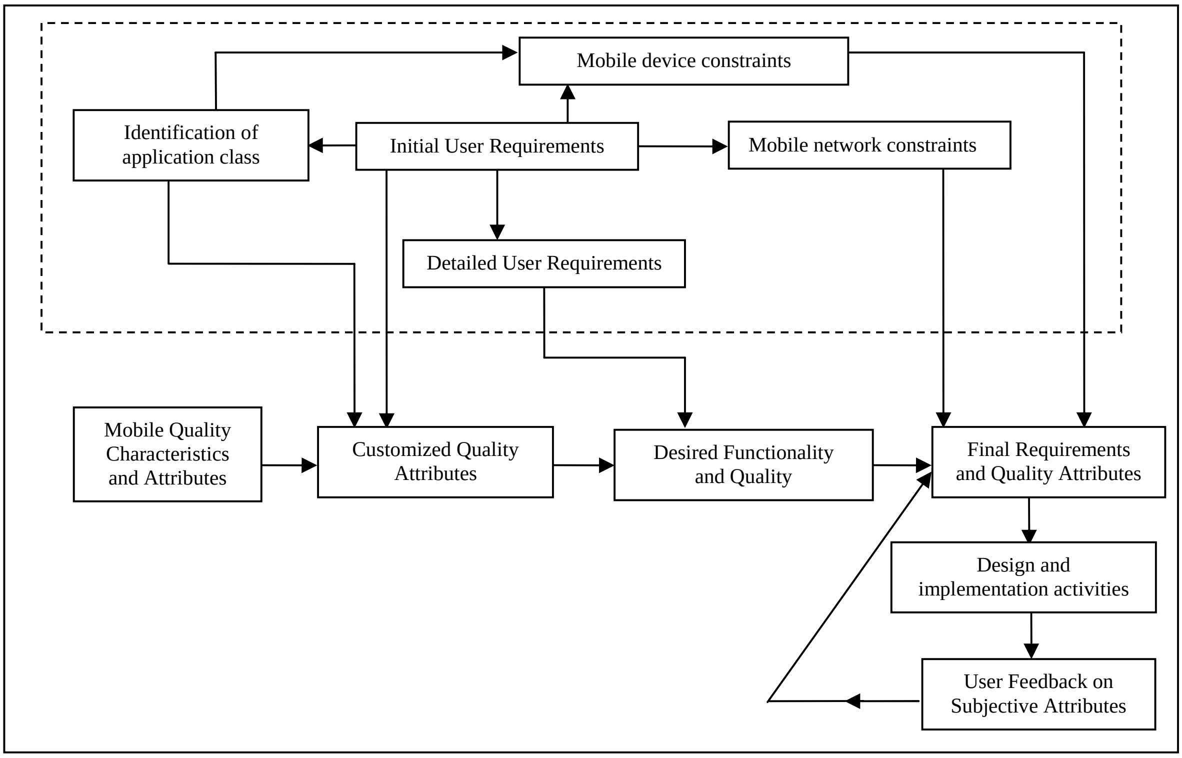

Figure 2: Proposed Framework for the Design and Development of Quality Mobile Applications (enhanced MobE process)

Our proposition for the revised form of the MobE Analysis phase is described by the following stepwise approach:

Step 1. Initial requirements elicitation:

The elicitation of requirements for mobile applications is quite difficult due to the absence of a clear group of users and requirements involved in the process. In the case that the user group is clear it is self-evident that this step is quite trivial. A mobile engineer may gather a set of general requirements from the client organization which will include all the necessary features for the m-Commerce service or application to be functional and run according to the organization's objectives.

Step 2. Identification of the class of service or application:

Once a set of general requirements has been formed, the service/application under development is classified in one of the two types proposed by the process, the directory- or transaction-oriented class. This is a key step in the development process; the mobile engineer, by defining the class of service, is able to examine the constraints posed by each of the two classes and further identify other distinct requirements for that specific class or reform/refine the collected general requirements according to the relevant constraints (e.g. navigation mechanisms, security, reliability, user interface, etc.).

Step 3. Detailed mobile user requirements elicitation:

This step builds upon the previous two steps and involves the gathering of the detailed mobile user requirements and the ranking of these requirements according to the user needs. After determining the class of services/application to be developed the analyst aims at refining to the best possible extent the set of general requirements collected in step 1 and oriented by the constraints identified during step 2.

Step 4. Identification of quality requirements

The mobile engineer uses the quality model listed in Table 1 and tries to customize/orient the list of quality characteristics and attributes so as to reflect best the functionality and usability described by the initial set of requirements collected. This involves assigning different levels of priority according to the class of application under development, as well as to the general business targets and needs. Finally, utilizing the refined set of requirements produced by step 3, the combined set of desired functional and quality requirements may be defined. This set will be further refined or modified according to the constraints of the both the available mobile network infrastructure and the selected mobile device features set. This step is depicted at the lower part of Figure 2 as a series of distinct activities outside the boundaries of the classic MobE process (dashed box).

B. Engineering Phase

As with the previous phase, this phase also utilizes design and engineering practices commonly found in a Web engineering context [9], comprising:

- Architectural Design – The overall structure and detailed layout of the information content.
- Navigation Design – The design of navigation pathways that will enable the user to access the m-commerce content and services.
- Interface Design – The design of the user interface of the mobile application.
- Content Design – The generation of m-commerce content to be used by the mobile application or services.
- Production – The production of the material (e.g. graphics) to be used by the mobile application or service.

In addition, in the Engineering phase the peculiarities of the mobile environment and devices (e.g. tiny displays, drain of batteries, connectivity problems, and diverse device profiles), together with the mobile user requirements and the quality characteristics of the specific class of m-Commerce services identified in the previous phase need to be considered. This consideration enables the orientation of both the type and volume of content, the form of the navigating facilities to access this content and finally, the m-Commerce device interface, as well as the architectural design of the whole system. Therefore, it is necessary to examine the constraints of mobile networks and devices and comply with restrictions they pose both at the architectural and the detailed design of the mobile service/application, as well as at the desired quality features.

The revised Engineering phase also follows a stepwise approach explained below:

Step 1. Examination/incorporation of mobile devices constraints:

This step is dedicated to address and examine in detail the constraints of the selected mobile devices in order for the mobile engineer to design the application to fit in those limits of each targeted mobile device. For example, an application that requires extensive input (e.g. a game) must be designed differently when it is run on a mobile phone than on a laptop. One constraint in this case is the small keypad found on mobile phones. While for a laptop this may not constitute a problem, alternative ways for inputting data using a phone must be offered.

Step 2. Examination/incorporation of wireless networks constraints:

Same as before, this step is involved with the detailed examination of wireless network constraints, which will assist the mobile engineer to design the application within the boundaries they pose. The mobile engineer should keep in mind the available network together with its limitations, capacity offered, coverage area and type of data to be transferred.

Step 3. Final requirements and quality attributes:

At this stage the findings of the former two steps are utilized to reach to a final, feasible set of functional and quality requirements that can indeed be offered by the mobile application under development. The constraints of the mobile devices and the network essentially reshape or modify the recorded, desired set of user and quality requirements and this enables developers to work towards a tangible functional and quality target. This is the point where the distinct quality characteristics and attributes, as these were oriented to a certain set of features after the conclusion of the Analysis phase, are finalized to reflect the quality level that will be pursued (i.e. removed from the set, modified based on how feasible or tangible are according to the mobile device and network constraints, etc.).

Step 4. M-application design:

This final step performs the actual design and implementation of the m-Commerce application or service based on the findings of the previous two steps, as well as those of the Analysis Phase. The design includes all the activities mentioned earlier, that is architectural design, navigation design, interface design and content design.

We need to clarify that after the implementation and integration steps are finished, there can be a quality assurance cycle based on the user perceived metrics on the final product. This step, will probably draw new quality requirements, that may lead back to any phase of the spiral model.

2.2. Integrating MOBE with the Proposed Quality Model

In this section we will briefly discus the efficiency of the proposed approach in the context of a real application, a health care software project called DITIS [10]. Although DITIS is not a "pure" m-commerce project, it exhibits a set of functional characteristics commonly found in m-commerce applications, with the only difference being that instead of customers DITIS services patients. Therefore, DITIS is a representative mobile application example for demonstrating the proposed approach.

DITIS is a system that supports dynamic Virtual Collaborative Medical Teams dealing with the home-healthcare of cancer patients. The main service is the dynamic creation, management and co-ordination of virtual collaborative healthcare teams for the continuous treatment of the patient at home (appointments, treatment, medication etc.), independently of the physical location of the team's members, or the patient. DITIS also supports the integration of new technologies in Telemedicine and the home care service for patients through the use of Mobile Computing Units. The use of mobile devices was considered a necessity since most team members are mobile workers, visiting the patients at home, and need to be accessible from anywhere and at anytime.

The development of the specific mobile application was performed using the proposed approach. During the Analysis Phase the functional and non-functional requirements of the mobile users, in our case the virtual health care teams, were identified as follows:

The mobile software application shall:

- Provide high availability
- Include easy navigation mechanisms
- Maintain a central database with personal and medical information for patients, as well as with appointments and schedules for the medical teams.
- Offer the ability to retrieve and present patient related information (personal, treatment, medication) as well as daily information (e.g. appointments).
- Offer secure, reliable and timely access to patient information
- Offer health care users the ability to add new records of information, modify existing records or even delete specific fields upon permission.

The requirements gathered enabled the classification of this mobile application under the transaction–oriented category, due to the fact that the system would allow the exchange of information via mobile devices with the central database, but would also enable the execution of health transactions (e.g. creation of a new or modification of an existing treatment and/or medication for a patient). Using the quality model suggested in Table 1, the primary quality attributes were clearly suggested by the collected requirements involving the low execution time of a transaction, the high data consistency and integrity, the need for interoperability, the high level of security for the exchange of patient information and the need for correctness of patient information delivered to the health care teams.

In the Engineering phase, mobile devices and network infrastructure constraints were examined. The mobile device selected for the health care teams was Sony–Ericsson P900, while the mobile communication was to be established over a GPRS network. Some of the constraints identified for the P900 mobile phone were the uncomfortable input mechanism, its limited memory, the small screen etc. Additionally, the GPRS network can achieve theoretically a speed of 114 Kbps, but still suffers from constraints that can influence the quality of mobile application. For example, the transmission speed is determined by the capabilities of the handset in use, while it has a limited cell capacity and potential delays may occur.

After the examination of the constraints posed by the selected mobile device and network infrastructure, the development team created a rapid prototype, with which users experimented for a while. The result of this experimentation was an enhanced set of factors that were considered critical for the quality of mobile application, including understandability, learnability and navigability features. For instance, since the input mechanisms for P900 were considered rather “sophisticated” the design of the application was such so as to minimize inputting data activities on behalf of the user, and offer alternative solutions like selecting fields from predefined lists where applicable. Furthermore, the small size of the screen constrained the amount of information that could be displayed, so the application was designed to include the minimum possible information on screen, with the minimum acceptable size for letters.

The rapid prototype also verified the importance of some of the quality aspects identified earlier in the Analysis phase, such as the interoperability, security and accuracy of the mobile application. The health care user needed to be continuously connected with the central database for the exchange of information. Therefore, the design of the mobile application aimed at offering high availability and reliability with the least possible disconnections. In addition, the application provided the user the alternative to store the information locally on the mobile device and at the end of the day to synchronize the device with the central database for information updating. Due to the limited memory size of the mobile device, there was a need to minimize the information stored locally on the device; therefore the application was designed to store only the patient’s data related to the specific health care user and not the entire set of patient records maintained in the database.

Selected sample screens from the DITIS mobile application are provided in Figure 3.

3. Conclusion

The development of mobile applications and services, as well as the adoption of emerging related technologies for accessing information anytime and from anywhere, has experienced a rapid growth over the last few years. This growth, however, necessitates the adoption of disciplined design and implementation frameworks for developing high quality mobile software applications.

This paper discussed the importance of certain quality aspects of mobile applications and services, and proposed a new quality model for mobile applications. The proposed quality model is based on the ISO9126 international standard on software quality which was modified and enhanced to reflect better the characteristics of mobile applications. The quality model was then integrated with a new approach for designing and developing mobile applications and services called MobE, extending and enhancing its capabilities. MobE focuses on identifying mobile user requirements and on examining the constraints associated with the available mobile devices and network infrastructure. This is performed by classifying mobile applications into certain classes, something which enables the easy identification of both the functional and non-functional parameters of the software system under development. The distinct phases and activities of MobE were combined with the quality attributes proposed in a stepwise form, aiming at achieving a high level of quality in mobile application and services.

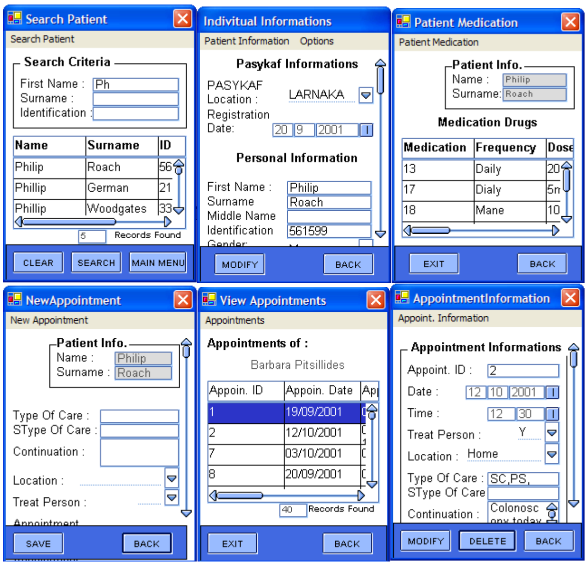

Figure 3: Sample screens of the DITIS mobile health care application

Due to the fact that the methodology is adapted to fit the current, modern network, mobile devices and software technologies, mobile engineers can improve the quality aspects of mobile applications by focusing on the proposed quality criteria and examining the effects of modern technology constraints. This, of course, generates an extra complexity and effort which must be put in the analysis and engineering phases. Nevertheless, the successful results of the methodology justify this overhead as revealed during the case study.

In addition, taking into consideration that some of the quality attributes is subjective in respect to the different user groups' perception, a final step was added after the installation and integration of the final product. This step is responsible for re-evaluating user satisfaction based on the final product and modifying it to meet the new requirements.

The proposed approach was utilized in the context of a real case scenario. More specifically, a mobile health care software product was developed by following the specific steps described earlier. Using this approach, mobile engineers were able to identify and incorporate certain quality features that enhanced the quality of the functional part, and highly contributed to the acceptability of the software product on behalf of the users.

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