An object-oriented mobile health system with usability features

Krystle Escarfullet

Department of the Navy,
Naval Education Training Professional Development and
Technology Center,
6490 Saufley Field Road,
Pensacola, FL 32509, USA
Email: krystle.escarfullet@navy.mil

Cantera Moore

Department of the Army,
3909 Halls Ferry Road,
Vicksburg, MS 39180, USA
Email: cantera.c.moore@usace.army.mil

Shari Tucker

Defense Finance and Accounting Service,
8899 East 56th Street,
Indianapolis, IN 46249, USA
Email: shari.tucker@dfas.mil

June Wei*

Department of Management/MIS,
College of Business,
University of West Florida,
11000 University Parkway,
Pensacola FL 32514, USA
Email: jwei@uwf.edu
*Corresponding author

Abstract: Mobile health (m-health) comprises the concept of utilising mobile devices to carry out the task of viewing electronic medical records, reserving medical appointments with a patient's medical provider and electronically refilling prescriptions. This paper aims at developing a m-health system to improve usability from a user's perspective. Specifically, it first developed a m-health model by logically linking characteristics of the m-health system together based on information flows. Then, the system requirements were collected by using a developed questionnaire. These requirements were structured and further in-depth analysis was conducted by using an object-

oriented approach based on unified modelling language, such as use-case, sequence and analysis class diagrams. This research will be beneficial to decision makers and developers in the mobile healthcare industry.

Keywords: m-health; mobile health; electronic medical record systems; OOSAD; object-oriented systems analysis and design; mobile technologies; electronic finance; electronic healthcare.

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Biographical notes: Krystle Escarfullet received her M.S.A. in Human Performance Technology and her B.S.B.A. in Management Information Systems with a Minor in Management from the University of West Florida. Since receiving her degrees, she is now working as an Information Technology Specialist with the Department of the Navy for the Naval Education and Training Command.

Cantera Moore received her M.P.A. in Public Administration with a concentration in Government Contracting from Troy University and her B.S.B.A. in Management Information Systems with a Minor in Management from the University of West Florida. She is now working as a Program Assistant with the Department of the Army.

Shari Tucker earned her B.S.B.A. in Management Information Systems with a Minor in Management from the University of West Florida. She is currently working as an Information Technology Specialist at Defense Finance and Accounting Service (DFAS). As a former Leader in Motion (LIM) at DFAS, she obtained Microsoft Certified IT Professional Server Administrator and Enterprise Administrator certifications. She is also CompTIA A+, Network+ and Security+ certified.

June Wei is an Associate Professor of the Department of Management and Management Information Systems at the University of West Florida. She earned a PhD from Purdue University and an MS from Georgia Institute of Technology. She is an Editor-in-Chief of three peer-reviewed journals. She is also an associate editor, a guest editor, and an editorial board member of many other journals. She has over 100 publications in peer-reviewed journals and conference proceedings. She has over six years of industry working experience, and also has extensive working experience as a software engineer with enterprise information systems development.

1 Introduction

Mobile health (m-health) comprises the concept of utilising mobile devices to carry out the task of viewing Electronic Medical Records (EMRs), reserving medical appointments with a patient's medical provider, electronically refilling prescriptions and paying medical balances. M-health is limited to an EDGE (2.5G), 3G, 4G and Wi-Fi network and is targeted towards mobile devices that have a full access keypad and wide display screen. The m-health system is targeted towards an environment with a national IT solution (Thomashauer, 2008). This includes a universal EMR e-prescribing system (Edlin, 2009; Null and Wei, 2009; Wei et al., 2011).

According to the Deloitte 2008 Survey of Healthcare Consumers, over 70% of consumers want their hospital to provide online access to an integrated view of their medical information, including test results, doctor visits and hospital stays, while the actual percentage of hospitals that have deployed a true patient portal is still in the single digits (Electronic Health Records, 2008). Patients wish to review test results electronically; and while there, order pre-approved medications and refills and schedule follow-up visits with their prescribing physicians (McBride, 2008).

The consolidation of medical healthcare services through technology has been a grave investment in the healthcare industry for the past ten years. The development of health information systems and patient portals to integrate patient information has become a driving force that has changed the entire industry due to paper medical records, and those on disks and servers being incredibly vulnerable (Walker, 2008). EMRs are not only being welcomed by healthcare providers as a way to improve care delivery but also serve as a catalyst and gold standard for development (Williams and Boren, 2008).

Health information technology tools such as electronic prescribing, email and electronic health record systems, if properly designed and implemented, can improve the efficiency of a patient medication safety plan as well (Friedley, 2008; Lee et al., 2011). With a high investment cost of $700 million, according to the Certification Commission for Healthcare Information Technology, significant increases in efficiency and productivity for medical providers and drastic decreases in costs related to errors have proven to be the outcome of these technologies (Electronic Health Records, 2008).

M-health takes the process of patient data integration and seamless access to physician practice-based EMRs a step further through enabling user access to applications and services via an internet enabled mobile device. As people become increasingly busier, they are also becoming more reliable on a mobile means of doing everyday activities. With the development of an m-health system, patients will be able to accomplish the tasks of refilling their prescriptions, making medical appointments and paying medical bills all at the convenience of their mobile device.

1.1 Descriptions of the m-health system

The system components of the m-health system will comprise an internet-enabled mobile device (such as cell phones, handheld computers or personal digital assistant). In order to enable a mobile device the system should feature the patient's data. The patient's data is relevant because the medical record system is the primary focus in order to execute the patient's health information process accurately and efficiently. The personal data input in the m-health system will feature age, height, weight, race, SSN, medical history, etc. Users in the system will include information technology professionals, medical and billing coders, computer programmers, system analysts and database administrators.

The interrelationships of the system include the appointment registration, payment procedures, and updating prescriptions. The user can only have access to the data from a model device (home computer, handheld computer, cell phone and EMR). External users, such as patients, will have the ability to manage their health account by inputting personal information: age, height, weight, race, password, and username. The internal user utilises the system by retrieving the information when needed to analyse the patient's health status.

The boundary of the system will be the user's input of required data. In the m-health system, the external user (patient) will include personal information that will not change.

This information will include the patient's name, identification number, birth date, race, etc. The component within the system represents the user's secured data, such as occasionally password changes for security purposes.

The overall purpose of the m-health system is to assist patients in making appointments conveniently, managing medical records, and refilling prescriptions. With fourth generation (4G), third generation (3G), second and a half generation (2.5G), and Wireless Fidelity (Wi-Fi) internet capabilities becoming an everyday aspect of life, the user's demand for the ability to perform activities such as this will begin to rise. Patients usually have to make calls to make appointments and many times the medical staff administrator may forget to book the appointment. According to research, on average the provider's staff spends three minutes on the phone scheduling an appointment; yet that same action would take a patient one minute to accomplish via a patient portal, without requiring assistance from hospital personnel (Kuhn, 2008). The system's ability to view medical records motivates the user to manage the user's own health and lifestyle. The patient's ability to refill prescriptions also makes medical procedures convenient for patients. The formulation of the m-health system will penetrate beneficial outcomes for the healthcare industry.

The environment of the m-health system includes everything that influences the system that is outside the system's boundaries. The patient will need documentation from the medical provider in order to know what required information is needed. After the user has entered the necessary input, the system will be required to send this data to the medical provider for verification and confirmation of retrieval. The need for this outside information enables the medical provider to initially disburse personal medical data forms. Therefore, the m-health system is thriving from the primary source using personal medical data forms.

The interface of the m-health system will be where the system meets its environment. The initial personal medical form meets the environment when the system is converted to the Medical Appointment System (Going Paperless). This will include a user-friendly interface that will be easily compatible with all mobile devices. With an m-health system, the interface contains numerous features for users to access. However, intricate interfaces pose a large problem in the usability of a mobile system due to the limitations of the screen size and its resolution. Studies have shown that the relevance of the content is perceived as a greater importance on a wireless system than a web-based system. Ease of use and made-for-the-medium also ranked high with wireless users. This made-for-the-medium idea goes beyond shrinking webpages down to the accessibility of a mobile device (Venkatesh et al., 2003). The idea is to devise an application made strictly for mobile use. The design of the m-health software will rely on cutting back on cumbersome features in order to provide users with a system that will allow them to access different information and pages while using little effort.

The input of the system will come from the user. The user will enter in the necessary data that is required by the medical provider, pharmaceutical company, and financial institution in order to make an appointment, request a refill, view medical records or make payments. This input will include, but not be limited to, a username and password for security, personal information such as the user's name and address, the user's social security number, the required input from the user's medical information, and the user's banking information if the option of direct deposit is selected. The output of the system will be the computed value of the patient's accumulated medical appointment fees or amount owed, email verification, and an email confirmation that the data has been received by the medical provider.

The input and output mechanisms of the m-health system will feature the patient's personal information and the distinguished institutions included in the system. Input mechanisms (age, weight, height, username, password, preferred appointment time, prescription refill number, social security and other related attributes) will improve the patient's m-health system service. Output mechanisms represent the distinguished institutions affiliated with the system. The medical provider, financial institutions, and the pharmaceutical institutions are the distinguished organisations within the system that will display the output mechanisms. The list of available appointment times, appointment time confirmation, list of refill prescriptions, and medical records display illustrates the output mechanisms.

Limitations within the system enable the system to sufficiently perform the needed functions to maintain a reasonable and reliable system. The m-health system will have limited functions available. The m-health system will position time availability within a specific timeframe. Patients will also to be limited to the type of prescriptions to refill.

There are also certain specifications of the mobile device that are required in order to implement the m-health system. The mobile telecommunication technology must be 4G, 3G or 2.5G. The mobile device is required to have the ability for real web browsing (HTML) and/or be Wi-Fi enabled. The user must have access to mobile email in order to receive updates sent by the online m-health system. The mobile device's battery capacity must be 1100 mAH with a minimum talk time of four hours and a standby time of up to seven days. Finally, the minimal screen resolution must be greater than or equal to 480×320 and the device requires a QWERTY keyboard, whether it be a physical or virtual keyboard. Examples of mobile devices that fit these specifications are the iPhone, BlackBerry smartphones, T-Mobile's Sidekick and the Google G1.

2 Conceptual model

A conceptual model includes all the requirements needed for the new system. Figure 1 illustrates the conceptual model for the m-health system. This model includes 13 processes, two data stores, five sources/sinks and 12 information flows. This model was developed by authors and then by consulting subject matter experts in the healthcare field for validation. Table 1 presents the descriptions of 12 information flows in the m-health system. Table 2 presents the description of each information flow in terms of its usability feature.

Table 1 Information flow descriptions

Information Flow	*Name*	*Description*
F1	Mobile patient login	Flow 1 allows the recurring mobile patient to login and access the system.
F2	Mobile patient register	Flow 2 allows a new mobile patient to register and access the system.
F3	View EMR	Flow 3 allows the mobile patient to view their electronic medical records (EMRs) from the universal EMR database.
F4	Request refill	Flow 4 allows the mobile patient to request a refill from their pharmaceutical provider.

Table 1 Information flow descriptions (continued)

Information Flow	*Name*	*Description*
F5	Pay bill	Flow 5 allows the mobile patient to pay bills associated with their medical provider through drafting funds from the patient's financial institution.
F6	Request appointment	Flow 6 allows the mobile patient to request an appointment from their medical provider.
F7	Available appointment forward	Flow 7 allows the medical provider to check the availability of an appointment against the medical provider's appointment data store.
F8	Available appointments display	Flow 8 allows the available appointment times to be transmitted to the mobile patient.
F9	Mobile patient selects appointment	Flow 9 allows the mobile patient to select which appointment time they prefer.
F10	Appointment verification	Flow 10 allows the chosen appointment time of the mobile patient to be forwarded to the medical provider.
F11	Chosen appointment update	Flow 11 updates the medical provider's database based on the chosen appointment time of mobile patient.
F12	Appointment confirmation	Flow 12 authenticates the appointment and sends a confirmation number to the mobile patient.

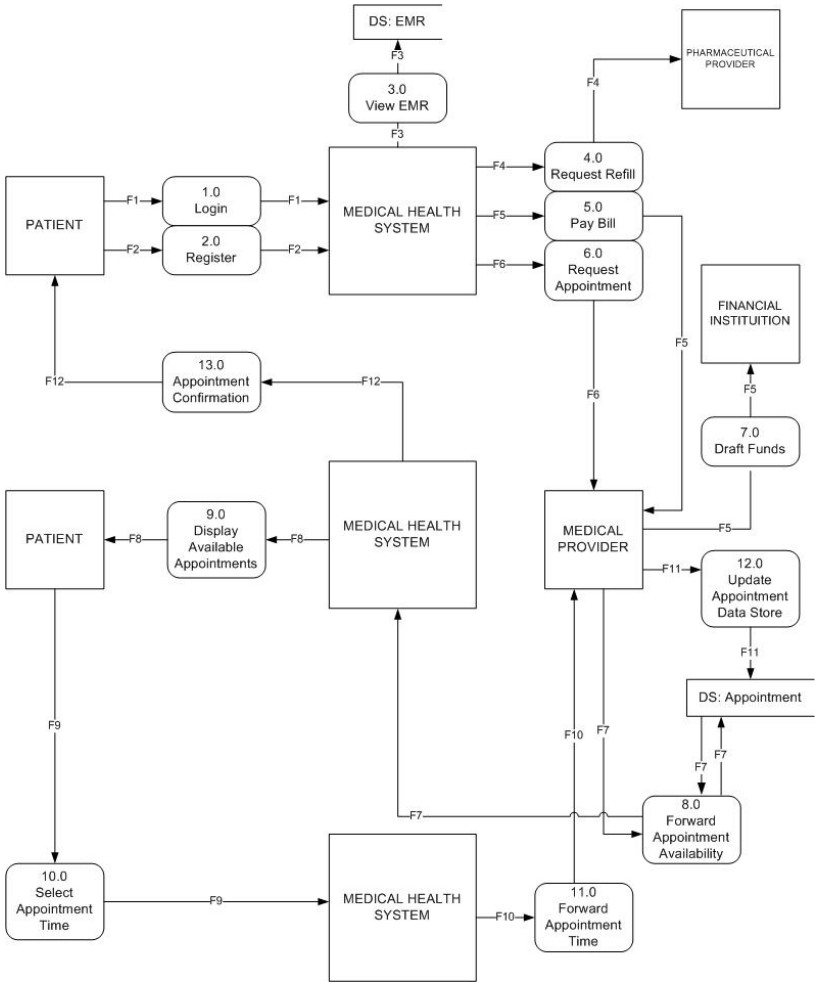
Table 2 Usability features and its descriptions in the conceptual model

Information Flow	*Name*	*Description*
F1	Mobile patient login	F1a: User-friendly interface that is professionally designed and has an easy logical flow
		F1b: Remember username and password for later access and login
F2	Mobile patient register	F2a: User-friendly interface that is professionally designed and has an easy logical flow
		F2b: Help option which allows users to access information of specific fields in forms
F3	View EMR	F3a: Provides secure access to medical records
		F3b: Allows the patient to review test results
		F3c: Allows the patient to view entire medical history
		F3d: Email alert
F4	Request refill	F4a: Allows the patient to view how many remaining refills
		F4b: Confirmation email
F5	Pay bill	F5a: Secure transaction
		F5b: Secure socket layer encryption (or transport layer security)
F6	Request appointment	F6a: Real-time data entry
		F6b: Search by doctor, date, time and type

Table 2 Usability features and its descriptions in the conceptual model (continued)

Information Flow	*Name*	*Description*
F7	Available appointment forward	F7a: Real-time retrieval
F8	Available appointments display	F8a: Real-time display of available appointment times
F9	Mobile patient selects appointment	F9a: Real-time
F10	Appointment verification	F10a: Real-time
F11	Chosen appointment update	F11a: Real-time
F12	Appointment confirmation	F12a: Email confirmation mobile patient F12b: Confirmation number is sent via the medical health system to the user by means of text message

Figure 1 Conceptual model for m-health system



The usability features for each information flow in the conceptual model were further developed and illustrated in Table 1.

3 Feasibility analysis

3.1 Economic feasibility

Tangible benefits achieved through m-health include user accessibility to test results, reserving appointments with their medical provider and paying medical bills via their mobile device.

The cost effectiveness of this business solution has proven to be successful. One medical provider that has already implemented a patient portal reported an initial cost of $50,000 for software licenses, training, and the installation of the systems and a savings of $90,000 in overhead costs (Schock, 2007).

3.2 Technical feasibility

As for target hardware and operating environments, there are certain specifications for the target hardware of the mobile device that is required in order to implement the m-health system. The technology must be either 4G, 3G or 2.5G. The mobile device is required to have the ability for real web browsing (HTML) and/or be Wi-Fi enabled. The user must have access to mobile email in order to receive updates sent by the system and the mobile device's battery capacity must be 1100 mAH with a minimum talk time of four hours and a standby time of up to seven days. Finally, the minimal screen resolution must be greater than or equal to 480 × 320 and the device requires a QWERTY keyboard, whether it be a physical or virtual keyboard. Examples of mobile devices that fit these specifications are the iPhone, BlackBerry smartphones, T-Mobile's Sidekick, and the Google G1. The m-health system is to be adopted under a fully integrated and adopted EMR environment.

As for as system size complexity and the user group experience with similar systems, the targeted size of the m-health system is classified as a large project with low risk. It also requires a high familiarity with technology or the application area and is highly structured. This position is taken since a system in which the requirements are easily obtained and highly structured (fully integrated EMR) will be less risky than one in which requirements are messy, ill-structured, ill-defined or subject to the judgement of an individual. This project will be low risk due to the fact the user group is familiar with the systems development process and application area.

3.3 Operational feasibility

The likelihood that our project will attain its desired objectives is high. The objective and purpose of this system is to make the process of reserving medical appointments, requesting prescription refills, and paying medical bills more convenient to the on-the-go lifestyle that has been adopted by many today. This system will solve the identified business issues of efficiency and productivity and take advantage of the opportunities outlined. In order to achieve the set objectives for this project, it requires a clear understanding of how an information system will fit into the current day-to-day operations of the end user.

3.4 Schedule feasibility

All potential timeframes and completion date schedules that have been projected for the development of an m-health system can be met. Meeting these dates will be sufficient for dealing with the needs of the end user. The completion date for this system is set for four months. This will include database development and implementation. This deadline also provides enough time for unexpected constraints and issues.

4 System anaylsis

4.1 Requirement collection techniques

The process of determining requirements is impertinence, impartiality, relaxing of constraints, attention of details and reframing. The system analysis process of the using requirement collection techniques enables the system developers to thoroughly understand the best method to address potential and current patient's preferences.

The pertinence process questions everything. Therefore, the questioning aspect can structure the overall m-health system. The following questions can be related to medical appointment record system, such as 'Can any patient access the system?' 'Is there an additional price to access the system?' and 'Is the medical appointment only for doctor appointments or for tests such as blood tests?'

Impartiality is how a potential system analyst finds the best solution. Therefore, the new medical appointment record system recommended feature may include the patient's social security or identification number. Patients may prefer a touch screen or a physical keyboard device.

The relaxing of constraints should be the required changes to adjust to the patient's needs. Therefore, if the patient indicates the system is not user-friendly, the system analyst should justify the patient's concern and make the system user-friendly.

Attention to details indicates the system should monitor the patient's data information. For example, the medical appointment system has private information. The system should identify the customer's log-in pattern and determine if the pattern is relevant to the user's previous and current appointments.

Reframing is part of the process that should consider better methods to accessing the medical system. The developer and analyst should recognise the needed change and implement a better system to better acquaint the patient's concern. For example, if the patient prefers to not display their social security numbers in the medical records section then the system should satisfy the patient's preference.

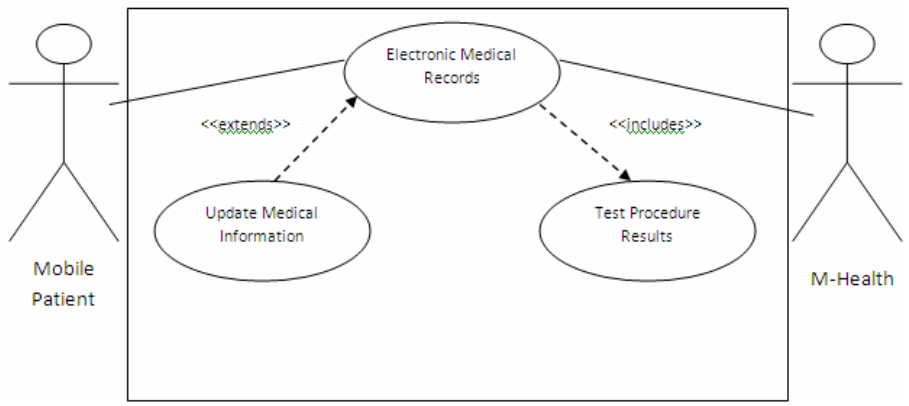
Questionnaires and interviews are the most suitable tools for gathering requirements in determining the best system for potential patients. The questionnaire is appropriate because we will able to reach a wide variety. The questionnaire can have questions with the numbers to rate how the patients feel about the system features. The questionnaire can also include spaces for comments.

The interviewing process is also applicable because questionnaires are not always desirable by patients to express their opinions. Therefore, if you communicate face-to-face to the audience then the system analyst will be able to thoroughly understand the patient's needs and concerns.

4.2 Use case diagrams

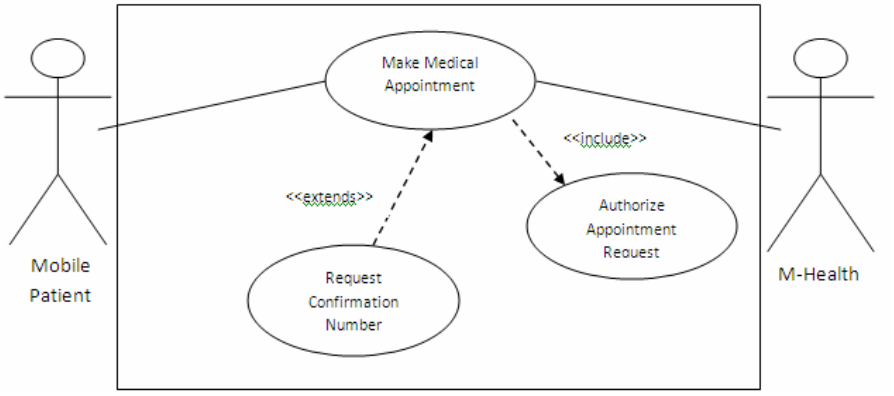
In the Access EMR and View Test Results use case diagrams, there are two main actors involved: mobile user and m-health system. The three use cases that are involved in the diagram are Update Medical Information, EMRs and Test Procedure Results. The two types of relationships that are involved are extends and includes. Once the mobile user accesses their EMR via the m-health system, they then have the ability to view any test results of any procedure they have had done. Figure 2 presents the use case diagram for accessing EMRs and view test results.

Figure 2 Mobile patient accesses electronic medical records and views test results



The use case diagram of reserving a medical appointment involves the patient actor, also referred to as the mobile user, and the m-health system. Three use cases, one extends relationship and one includes relationship are included in the diagram. Once the mobile user selects the option to make a medical appointment, the use case Authorise Appointment Request allows the m-health system to verify that the requested appointment type has available time slots. The request confirmation number allows the mobile user actor to receive a confirmation number that verifies the reserved appointment time that was made. Figure 3 represents the use case diagram for making appointments.

Figure 3 Mobile patient makes appointment



4.3 Sequence diagrams

A sequence diagram shows all of the interactions between objects. Interactions are displayed in a time-ordered manner. Sequence diagrams include stereotypes. Stereotypes include an entity class, boundary class and control class. Figure 4 displays the sequence diagram for viewing an EMR. Figure 5 displays the sequence diagram for making appointments.

Figure 4 Sequence diagram of the use case view EMR test procedure results (see online version for colours)

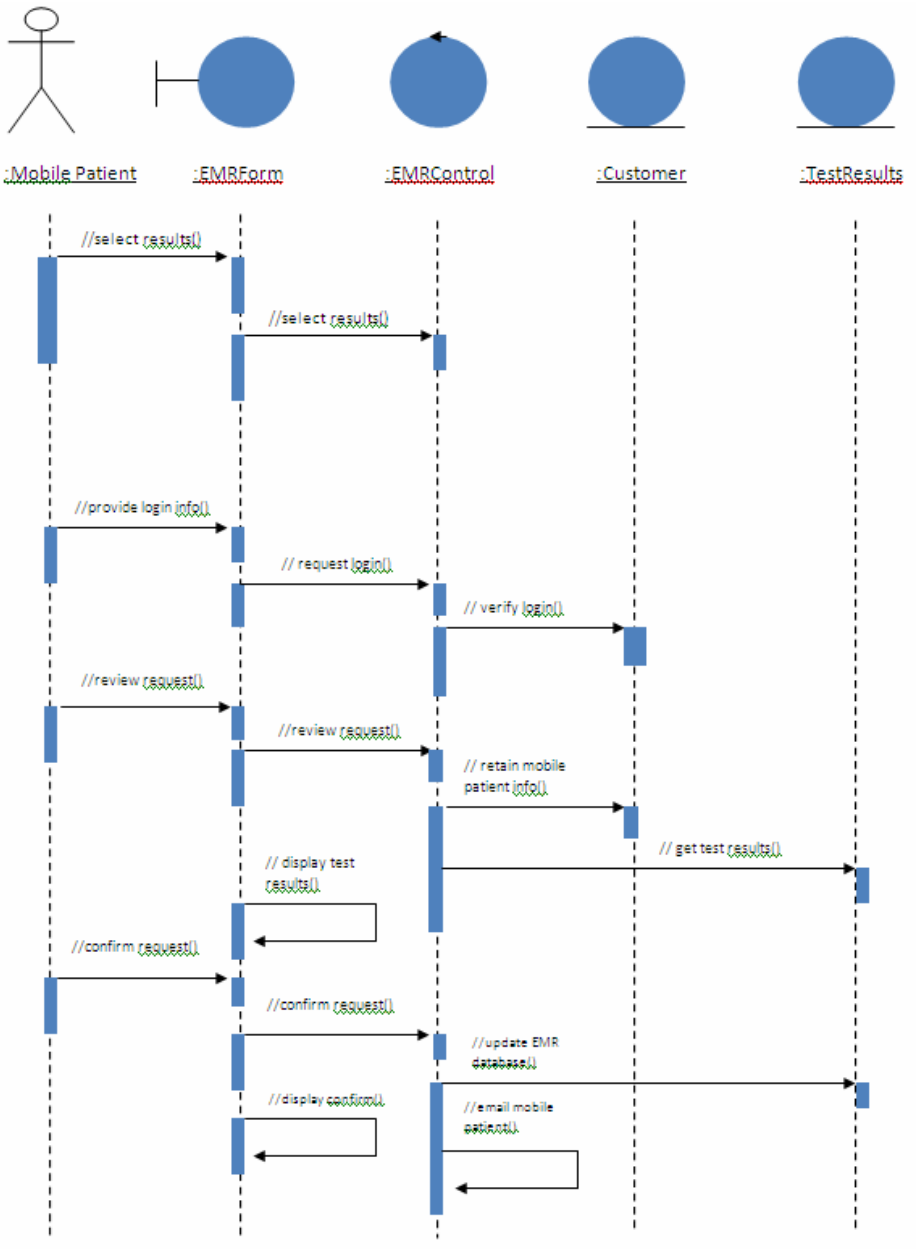
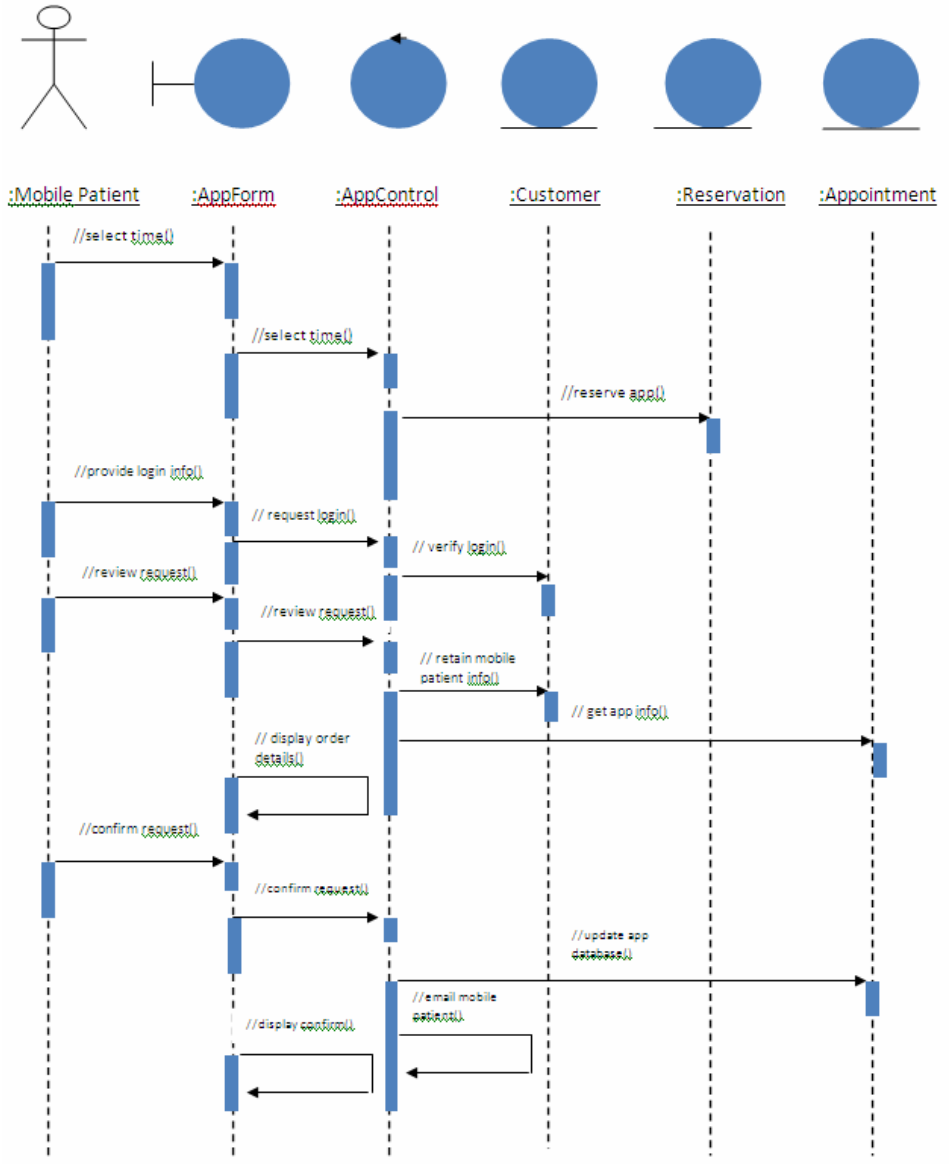


Figure 5 Sequence diagram of the use case make appointment (see online version for colours)



4.4 Security management

In general, health information should always be private (Wei and Loho-Noya, 2008). There has already been a rule enforced to aid this need for privacy. The Health Insurance Portability and Accountability Act (HIPAA) "protects the privacy of individually identifiable health information, and the confidentiality provisions of the Patient Safety Act, which protects identifiable information being used to analyse patient safety events and improve patient safety" (Health Information Privacy, 2009, p.26). In order to fully

emphasise this need for security for the m-health system, this same type of initiative needs to take place through Protected Health Information (PHI). All information passed through the m-health system must been done via encrypted messages. The creation of a universally unique patient identification number will aid in protecting the privacy of the mobile patient also. RAND Corporation has conducted researches about the privacy concerns of patients.

> There are privacy concerns surrounding the use of a patient ID system, but the RAND study concluded that many of those concerns could be addressed through the creation and enforcement of laws that severely punish those who misuse information retrieve with a health ID number. Also, the RAND study concluded that SSNs should not be used as a medical identifier" (Association of Records Managers & Administrators, 2009, p.38).

Figure 6 Class diagram of the sequence diagram view EMR test procedure results

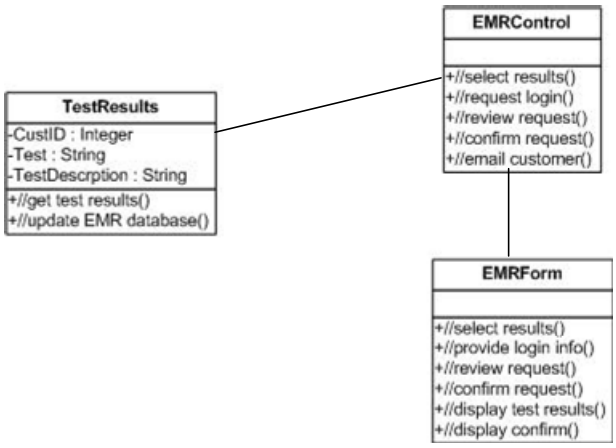
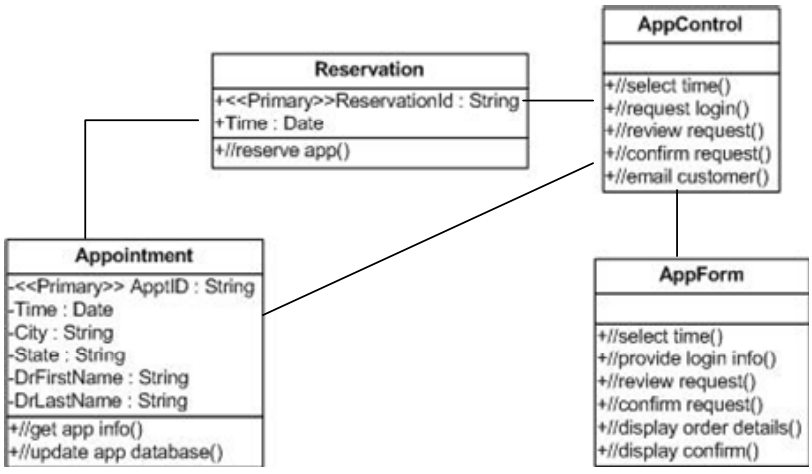


Figure 7 Class diagram of the sequence diagram make appointment



4.5 Class analysis diagrams

The two primary sequence diagrams for viewing EMRs and making appointments are unlisted to create the analysis class diagrams. The messages, within these sequence diagrams, are the operations of the associated class. For example, in the sequence diagram for making an appointment, the entity class and mobile patient are passing a message to the boundary class, AppForm. So, this message, or operation, between mobile patient and AppForm allows the mobile patient to select their desired appointment time. The same methodology should be used to translate the other sequence diagrams into analysis class diagrams.

5 Discussion and conclusion

The current research developed a m-health system by considering usability features. The research consisted of first developing a conceptual data model for the m-health system, and then breaking down the m-health data information flows from this conceptual model to determine what features need to be focused on. The findings from the research indicate that developing an efficient, user-friendly m-health feature is crucial to the success of the development of an m-health system.

Several techniques were utilised in the development of the m-health system. In the systems analysis phase, a questionnaire was developed to collect user requirements. After accruing the desired requirements, the description of the m-health system was then developed. Further analysis of the system was through the development of use case diagrams and then taking those use cases and constructing sequence diagrams to show the interactions between objects to perform critical pieces of use case behaviour in a time-ordered manner. The final step taken in the system analysis phase of the m-health system was the development of a security management plan and security methods. According to students by National Underwriter, the main objective to the development and integration of these systems is the concern about privacy (Bell, 2008). To ensure the privacy and protection of the mobile user (patient's) sensitive and valuable information, a wide rage of technologies to improve customer satisfaction were explored and adopted in the development of the m-health system (Kim and Eom, 2002).

Unlike other existing patient portals, m-health devices have limitations including limited size, display window, processing power and bandwidth (Tarasewich, 2003). The m-health human interface design not only needs to attract customers, but also have the capability to minimise other distractions competing for the user's attention in the mobile environment (Wei and Ozok, 2005).

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