Utilizing Mobile Technology to Promote Home-Based Cardiac Rehabilitation

Design Document

Group 7 Submission

University of Waterloo: PHS 612/CS 792

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A. Design Purpose:

Cardiovascular disease (CVD) is the leading chronic disease and the number one cause of death globally. Cardiac rehabilitation (CR) has become an integral part for post-surgery patients with CVD and life-style changes in secondary prevention of CVD.

A typical CR program consists of three phases: phase I, an inpatient evaluation program prior to hospital discharge; phase II, an outpatient program designed to assist patients to return to normal activities; and phase III, a maintenance program for regular exercise and control of risk factors. Phase I is taken place in acute care, while phase II and III occur in an outpatient clinic within the hospital infrastructure with a multi-disciplinary team comprising of hospital staff.

Our project focuses on a solution for allowing patients to conduct CR program phase II at arbitrary places. Two of the core components of a comprehensive model of CR program, *physical activity counseling* and *exercise training* will be implemented, including the interactive communication of the treatment and follow-up physical activity plans with patient and family members/ peers in collaboration with their primary healthcare givers.

The aim of designing this web-based mobile application is to provide an effective and reliable two-way communication platform for patients and their primary healthcare givers on physical activity and exercise for outpatient CR program at phase II, as well as any feedback on their individual treatment and/ or personalized CR program. The application is accessible on both computers and mobile devices (including smartphones and tablets), and is easy to use for general CR patients with basic computer knowledge. No specific training is needed on how to use the application, which will empower patients' engagement on home-based CR program.

B. Use Cases:

1. Intended uses and users:

According to the general use case, the system offers CR patients two major functions: data collection and communication. Data collection includes exercise report, which corresponds with each exercise planned by the healthcare givers before and after each exercise; and regular report, which is to collect the regular data in a longer interval, such as weekly, helping the healthcare givers modify the plan and give advice. Communication is the most critical factor that determines the success of a CR system. Patients should be able to use the system to ask their healthcare givers specific questions, and read the instructions/ feedback from their healthcare givers.

There are two types of users in this system, patients and their healthcare givers. From the patients' perspective, their interactions with the system include login, report before and after exercise, regular report, post questions, and read feedback. From the healthcare givers' perspective, their interactions

with the system include check reports, prescribe exercise/ feedback, check questions, and supplemental education. Various types of data is collected and processed by the system, which makes the data management an essential challenge for this project.

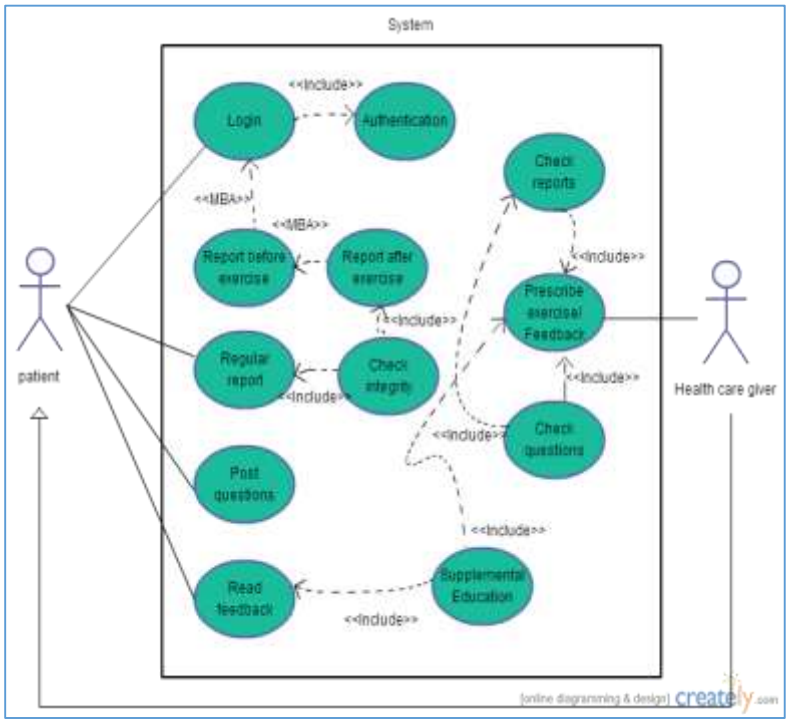

Figure 1: Use case diagram for the whole Home-based rehab system

Considering the restriction on the size of the design document, we highlight the most important two use cases in the tables below.

Use Case Element	Description
Use Case ID	1
Application	Mobile application for outpatient CR program at phase II
Use Case Name	Report before exercise
Use Case Description	Patients send their feedback on questionnaires before each exercise to their healthcare givers through the system platform.
Primary Actor	Patient
Precondition	Patients successfully login to the system.
Trigger	Patients ready to do exercise

Basic Flow	1. Patients launch the application. 2. Patients answer a set of questionnaires before exercise. 3. System sends the patients feedback on questionnaires before exercise to their healthcare givers web interface.

Table 1: Use Case 1, Report before exercise

Use Case Element	Description
Use Case ID	2
Application	Mobile application for outpatient CR program at phase II
Use Case Name	Prescribe exercise/ feedback
Use Case Description	Healthcare givers prescribe exercise/ feedback to their patients report on the web interface.
Primary Actor	Healthcare giver
Precondition	Healthcare givers login to the system.
Trigger	Patients send their report through the system platform.
Basic Flow	1. Healthcare givers open the system web page. 2. Healthcare givers prescribe exercise/ feedback to their patients report on the web interface. 3. System sends the prescribe exercise/ feedback to patients' mobile device.

Table 2: Use Case 2, Prescribe exercise/ feedback

C. Data sources and format

We use SNOMED CT coding to code our attributes, SNOMED CT is the Global language of healthcare. It is also the most comprehensive and precise clinical health terminology management platform. We manually map our attributes to SNOMED CT code in this project. Data is all generated by users (patients and doctors) and it is stored in the MySQL database. Database design can be accessed by seeing our MySQL database file. We designed 11 tables and stored all the data the user input, including the questions the patients ask and the doctor's reply.

regular_report, *after_exer* and *beforeexer* tables are for the record of the patients' report. We add *pid* and time properties to record who submit this report and when he did it. Questions and answers tables are used to record the interaction between doctors and patients. *tb_doc_login* and *tb_doc_master* tables

record the information of the doctors while *tb_pac_master* records the patients' information such as phone number and e-mail. The *tb_doc_pat_map* is used to record the relation between the patients and doctors.

D. Architecture View:

1. Initiatives and resourcefulness in applying technology to solve health problems:

Cardiac rehabilitation is a very vital and costly process and it may cost thousands of dollars to get good cardiac rehabilitation process. At the same time, this process includes very little rehab specific tools and machinery and mainly includes health care giver's service. Through home based rehab system, we have tried to make rehab process easier for doctors and patient by making it a home based activity. We created mobile and web applications that help doctors and patients to interact with each other at the same time saving hard-earned money and time. This system makes it possible for doctors to attend more patients within same 24 hours. Home based cardiac rehab also helps the patient to live with their loved ones at home without being felt lonely and out left.

The most important motivation in this idea is the time flexibility that doctor and patient gets. Exercise can be regulated as per patients convenience and doctors can monitor without worrying about the tight deadlines and schedules.

2. Overall Architecture overview:

This solution includes the input/output for patients and care givers, respectively. Hence the data share is the key, a database system is deployed for the mobile application and Web application access. In practice, the database should be deployed on the care givers site, together with the Web application, to provide centralized management and security protection.

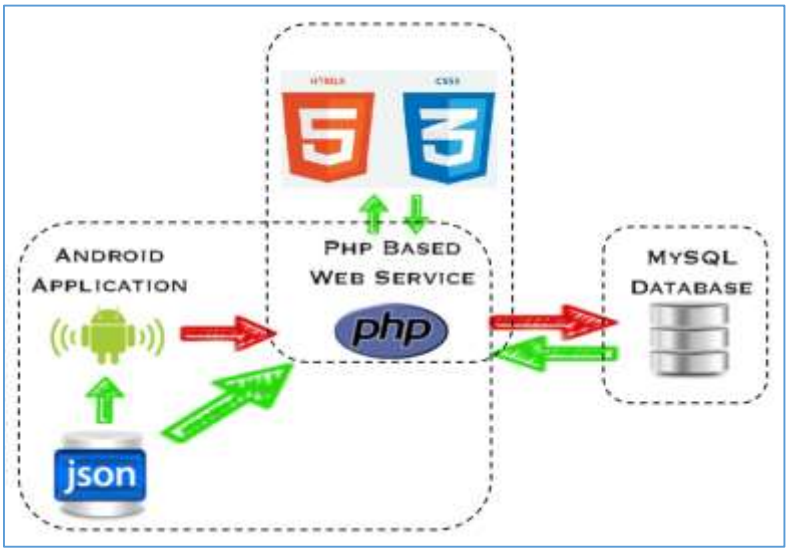

Figure 2. System Architecture

As Figure 2 depicts the system architecture. We use Apache + PHP + MySQL solution to develop this project, which is an open sourced, mature solution used popularly to deploy middle sized Web service. There are two purposes for building this architecture: the Web application can be developed using PHP and deployed conveniently; moreover, the Android application will access the database through a HTTP request to a dedicated service, which can also be implemented using PHP. MySQL is an open sourced, scalable database system, which is capable to handle the data generated in this system.

The mobile application is developed for Android platform. Android platform is open sourced, most popular smart phone operating system nowadays.

We use the standard HTTP over TCP/IP communication mechanism, all data access is done by HTTP requests (POST). For mobile application, the smart phone can access the service by Wireless network or mobile Internet access, such as GPRS/3G/4G. A general service is deployed for database access, and the mobile application generates SQL strings for the data access. The HTTP request will be posted to the service, where the SQL is executed, then the service will transform the results from database to JSON formed data, and return it to the mobile application. Upon receiving the response from the service, mobile application parse the response, extract the data for further process (display and store).

An Android application typically has two ways to access the database: built-in JDBC and HTTP service proxy. The main differences between the two ways are whether instantiating the connection from mobile applications. It is highly recommended to use HTTP service proxy for external database access, because the mobile application has higher probability to be closed improperly, which brings poor connection management. Moreover, server based proxy has lower communication latency, better load balance, higher reliability, and is more secure than the former way. Because it is easier to crack a mobile application than breaking the firewall and cracking a service. Hence, we take the second way to implement the communication between the mobile application and the database.

Web architecture design: Since the Apache publisher is deployed, develop the Web application using PHP is the fastest way to achieve a well functioned application for care givers. It is PHP + HTML5 + CSS3 application that works on all kind of electronic devise (computer, tablet and mobile) with customized website lookup for each device. Website facilitates the Doctors to interact with patients through various means of communications. Website uses MySQL database at the backend side accessed by PHP web services which are shared by the website interface and mobile interface.

3. Database:

The database is used by both the mobile application and Web application for interaction. Typically a pair of functionalities share a common table, for example, the health care givers use read from the “questions” table while the patients write to the “questions” table. A table is indexed by a record id, which is composed by patient id and date in a proper way, such as Hash function, to ensure its uniqueness. For example,

the “questions” table is indexed by question id (qid), which is an output of Hash function feeding a unique patient id (pid), combining with the date. Some attributes are used for certain functions, such as the “answered” attribute in table “questions”, which is used to categorize the questions for health care givers’ convenience.

4. Mobile application modules:

User management:

Patients need to register offline, and their accounts are created manually by the staff in the rehabilitation institutes. Patient are required to login to continue the use of the application, once they log in, the patient ID (pid) is used to retrieve the information related to him, such as question, and answers. The sent data is associated with their pid as well.

Health care givers are promoted an account and password for login as well. Moreover, the data access is restricted to the patients they physically assigned.

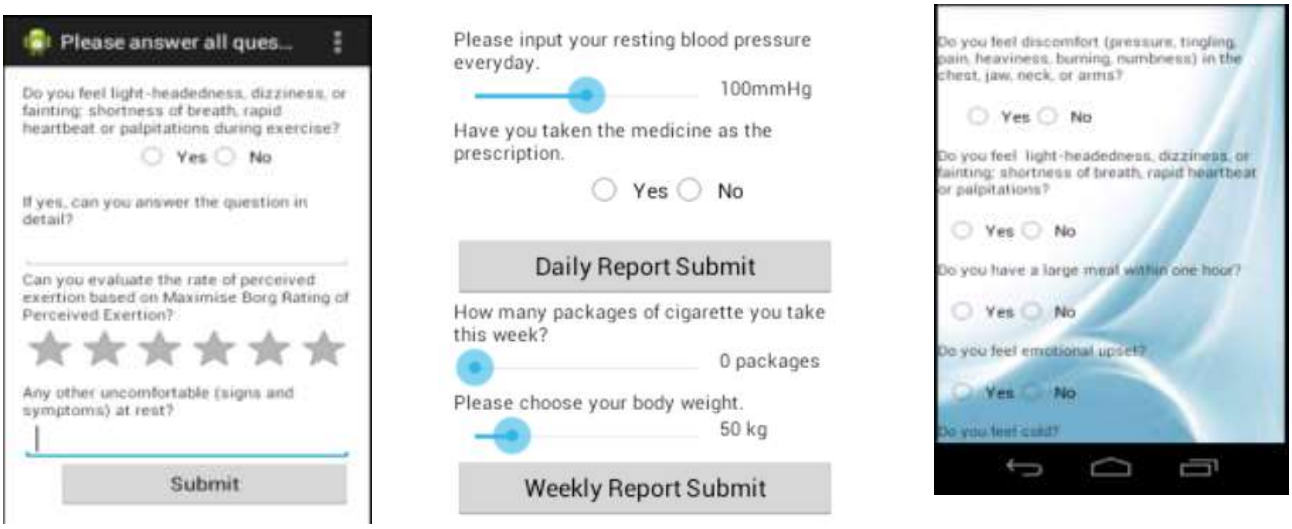

Figure 3: Mobile user interface for patients

Functionalities:

According to the proposal, the mobile application contains six modules: self-report on exercise, self-report regular, interaction (self-assessment and Q&A), education, configuration, and self-statistics. Due to the limited resources, we focus on the three core modules: self-report on exercise, self-report regular, and intera2ction (self-assessment and Q&A). These three modules incorporate the essential functionalities for a mobile rehabilitation.

In main activity, there are 6 imageView options. When users touch the views, OnClickListener will be triggered to allow the users go to activities what they want.

We implemented the Activity of self-report, regular-report and QA. After the user clicks the self-report imageView, he will be directed to the before-exercise Activity. In this Activity, we present a list of questions the user needs to finish before exercising. After he finishes the questions, the application will respond instantly by showing the report is sent successfully or a error encountered before he will be led to the after-exercise Activity. As for the regular-report Activity, we will show a notification every day on the message bar to remind the user to finish the daily report and also show weekly notification for weekly report.

All the reported data will be sent instantly to our MySQL database if the network is connected. We also store the reported data in Android's local database, SQLite, and the data will be used by the self-statistics module for self-review in the future and also as the off-line buffer. If the data is not sent to our MySQL database right after the report, we will send it after the network is connected.

In QA Activity, we have three option: self-assessment, ask a question, and check the feedback. For the Self-Assessment module, an Alert Dialog will pop up to alert users to choose 3 items that they want to know for the following week, then the selected items will be recorded and send to the database. For the Ask module, it is designed as an email format layout. Users can edit the subject, body, upload files, and then send the information to doctor. We use the Android built-in Google driver API to upload the local file to a care givers owned Google driver folder, and mark it as share to the care givers using their E-mail address. For the Feedback module, we use a TabHost which holds two TabSpec panels, between which, user can choose to view exercise prescription or feedbacks to the questions. In both of the two panels,

Mobile User Interface:

As the app's target user is patients, so the most important thing we consider is to make the GUI user-friendly and convenient to use. So the design is very intuitive and easy to understand. Firstly, we use many seekbars and radio buttons to ease the burden of input. Inputting number with seekbar will significantly reduce the input time and effort. We also use a star bar to let the user evaluate the perceived exertion after exercise, which is very comfortable to use. Secondly, we use light color and round shape to make the GUI soft and comfortable, thus keeping the user in a good mood when using this app. Thirdly, we design the app to make it give feedback instantly. Instant feedback will let the users know their operation is effective so they know the report is finished or not.

Another important design is that we use second-person interaction by asking the user questions like a doctor. For example, some questions are in the format of "Do you have a large meal within one hour?" and "Any other uncomfortable at rest?". This kind of design will make the users feel they are cared and safe psychologically. When the users face up with the questions like asked by the doctor, they will not feel any difficulties and reluctance to finish the report.

5. Web application design:

User Management:

Web application was built to provide Health care giver (like Doctors) a platform that can be accessed anywhere around the globe. Web application can be used to check the status of a particular patient. Doctor can see his daily and weekly exercise details, their body factors and conditions and also his/her current health updates. Website provides few functionalities that integrates with Patient mobile application functionalities.

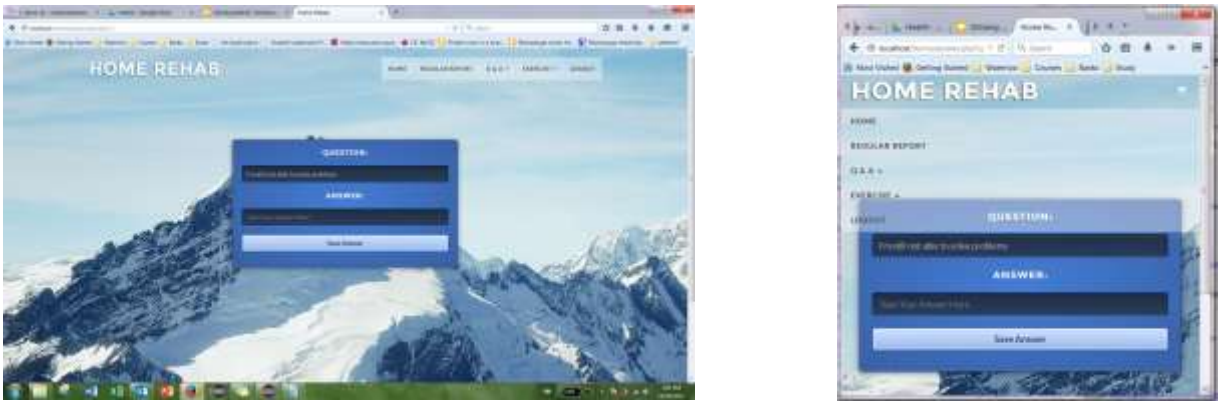

Figure 4: Web interface on computer and tablet.

Functionalities:

Web application module primarily focuses to provide interaction between Doctor and Patients. Patient's have mobile application interface to access facilities provided whereas, Doctors have this web application interface to reply to patient's queries. Through web application, Doctors can reply to questions asked by patients. Since, this is a home based cardiac rehab system, question and answering process between doctor and patient is very important. Queries about diet or about exercise or about daily physical activities can be asked through this interface.

Another facility of this web application is to monitor patient's exercise process. Doctor can see all the details provided by the patient through mobile interface and observe the growth of patient's health. Patient's are asked to answer few questions before exercise every day and similarly few questions after the exercise to monitor the health condition of the patient. Questions are majorly related to heart condition and patient's are expected to answer correctly. Once, patient has answered those questions, Doctors can see those answers and based on that can provide updates or further instructions to the patient. Multimedia provides more information than normal text and gives better understanding of patient's health to the Doctor. Hence, we have decided to extend our work by including videos, voice messages and images in question-answer process and also in exercise monitoring process.

One last very important facility provided by the web interface is regular report of the patient on daily and weekly basis. Since, cardiac relates with heart problems, it is very important to understand the alcohol and smoke intake of the patient and suggest them accordingly. This regular report helps them to collect data about such activities of the patient.

Responsive & Secure user interface:

Web interface is fully responsive and secured website which is accessible in mobile, tablets and computers. Responsive behaviour of the website helps the user to use the website conveniently without scrolling horizontally and also make the information and data easily readable. Responsive websites make the user interface very easy and convenient. Website is session oriented and cookie supported which makes the website more safe and secure.

Security, maintenance and scalability of the system

Website and mobile application is fully session secured and cookie supportive modules. Currently, there are no encryption methods involved in the data transaction but if this system is expected to go one step further then definitely data encryption and security would be the first step. Maintenance mainly includes and redefinition of questions and self-assessment modules which would help doctors to assess the patient's health more conveniently. Currently, questions can be changed in the database which will reflect in the mobile application and web interface.

Scalability can be easily handled by just making website and mobile application more scalable. Mobile applications and web modules can be made multi-threaded to support higher scalability. Also, this system can be proprietarily made available to local doctors and clinics which would not make the central database heavier from bandwidth perspective.

E. Conclusion & Future work:

Our solution combining mobile technology with Web application is demonstrated to be a fast prototype and effective way to help CVD rehabilitation patients. However, to make the system professional and acceptable by both the care givers and patients for replacing current on-site rehabilitation scheme, lots of work of requirements collection and analysis is essential. Nonetheless, mobile Internet application plays and will be playing an important role to relief the pains and promote the treatment today and in the future.

1. Better user friendly interface for Doctor's web application module which is easy and convenient for use. Also, better user interface can be provided in patient's mobile interface.
2. Provide all kinds of accessible interfaces for patients and doctors (at least web and mobile interface).

3. Strengthen the Q&A facility and exercise module by introducing multimedia attachments like video, images and voice.
4. A cascading question and answer template that allows the patients to add more questions on a topic and add citing operation.
5. More features, self-statistics, prescription notification (combining with Android calendar).
6. Investigate possible integration with APIs to manage the terminologies automatically, such as snofyre, Termlogic, and so on.

F. Evaluation:

Due to time constraint, we were unable to recruit CR patients and their care givers for trial of the application. To compromise it, however, we conducted subjective evaluation by randomly choosing ten members from our peers/ friends/ families to carry on independent pilot testing for the application's *functionality*, *usability*, and *usefulness*. Ten participants were randomly grouped by two, with five in each group, acting as "Patients" and "Healthcare givers" respectively.

1. Functionality

"Patients" were able to send their before exercise/ after exercise data, regular report, and questions from the mobile application to their "healthcare givers". Patients' data and report was accessible on their "care givers" web application. As well, feedback and supplemental education from their "care givers" was transmitted back to the patients' mobile application in real time. All six functions passed the integral functionality test.

2. Usefulness

The usefulness contained five items and assessed continued relevance of the home-based CR program, engagement of post-surgery patients with CVD, and ease of access with scores ranging from 0 to 5. A score of 5 denoted "Very useful application is available all the time, and is easily accessible and readable", and a score of 0 denoted "Not useful at all". The average score on usefulness is 4, indicating our solution is fairly useful in assisting home-based CR program.

3. Usability

The application was independently reviewed for usability by all ten participants. The usability contained six items characterizing suitability to user's need, ease of navigation, reduction in click stream, and appearance. For each desirable usability characteristic, raters scored "Yes", "No", or "Not applicable". One out of ten participants mentioned that she spent hours learning the basic features of the phone, and continued to launch unwanted applications and end calls accidentally. Three out of ten participants raised that the fond is better be larger, and the instructions are too long such that the idle

time out when they try to read an instruction. This is a concern for large-scale adoption, particularly for elderly population or patients with complications/ mental issues.

The application supports multiple users logging in to the system and using the services available simultaneously. With limited resources (all the services and simulators are running locally on PC), the maximum capacity that the system supports is not clear. However, there are many mature scale up ways for the architecture we used, hence the scalability of the system is not a bottleneck for large deployment. Moreover, conventional database and system security and failure over mechanisms are suitable to our system, hence the adaption of this system owns not only proved security and reliability, but also saves the maintenance training.

In terms of the effectiveness, research studies have shown that use of mobile applications for home-based CR programs has positive impacts on developing health behavior through active monitoring of patients' physical activity and exercise over time. We anticipate that by recruiting CR patients and their care givers in larger sample size for trails, a positive outcome is expected.