A Platform for Personalized Mobile u-Health Application Design and Development

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Abstract—In this paper, we propose an application platform and development environment to enable medical specialists such as doctor and therapist to design and develop personalized mobile u-healthcare applications based on patient’s health conditions and environmental situations. The personalized applications are specified in the form of application scenario using XML document which is downloaded and played on mobile phone. The platform provides models, functions, and facilities for medical specialists to design their own u-health applications. They design u-health application scenarios, and application scenario player of the platform executes the application scenario on the patient’s mobile phone. We confirmed that the suggested platform is useful and adequate in developing personalized mobile u-healthcare applications by implementing an actual stress application on the platform.

Keywords- u-Healthcare, u-Healthcare Application Model, Software Development Environment, Application Platform Architecture

I. INTRODUCTION

Many portable and small-sized bio-sensors are developed and integrated with mobile phone, and there are many efforts to develop applications for patients to manage their health at anywhere, anytime. Mobile applications for specific diseases such as stress, obesity, and diabetes are developed by many research groups in universities and companies. Some of them have already been commercialized. Not only specific applications, but general application frameworks are also in the stream of the researches [1].

Currently, most of the mobile u-healthcare applications are focused on general patients. As a result, the applications have difficulties in reflecting patient’s specific environments, situations and health conditions. For instance, if a patient interested only in abdominal obesity, we need not consider the fat of other parts of a body such as arm, face, and leg.

This situation is quite common in u-healthcare service environments. That is, personalized mobile u-healthcare applications are much more meaningful than the common general u-health service to a specific patient. However it is non-trivial to develop personalized applications for individual patient. Employing software developers to implement each personalized application is not a feasible approach in economical point of view, and the software developers do not have sufficient knowledge on the personalized u-healthcare applications considering the conditions of the patients.

Therefore, an application platform is essential for medical specialists such as doctors, physicians, therapists, and so forth to design and develop personalized u-healthcare application based on the health conditions and environmental situations of patients.

In this paper, we propose a u-health application development platform which enables medical specialists to develop their own personalized mobile u-healthcare applications. We assume that medical specialists are not trained to develop applications, software systems. Nevertheless, they develop their u-healthcare applications on the application platform.

The key idea of enabling medical specialists to develop their own personalized mobile u-healthcare applications is to represent the application in the form of an XML document which contains service scenarios. In the application platform, we provide a workbench to the specialists to design their own application scenarios. The workbench is equipped with facilities including scenario design tools and it provides an easy-to-use and intuitive user-interface on the web. Once the application scenario is developed, the application scenario is distributed on an application portal and is downloaded to patient’s mobile phone. Then, the application scenario player installed on mobile phone executes the downloaded scenario, so the patient can use the application designed by the medical specialist. We developed and tested the prototype of the platform by implementing a stress application on the prototype platform. From the results, we confirmed that the u-healthcare application developed on the platform works fine in the mobile phone environment.

This paper is organized as follows. In the next section, we propose a general application model for mobile u-healthcare applications. Section 3 suggests a platform architecture, on which u-health workbench is developed and deployed to support the development and execution of personalized mobile u-healthcare applications. Section 4 illustrates how the platform is implemented and validates the platform by implementing an actual application. We draw conclusion, and discuss the limitations and the future work for our platform in section 5.

II. MOBILE U-HEALTHCARE APPLICATION MODEL

There is no standard model or rule to design and develop mobile u-healthcare applications. In order to support the
medical specialists such as doctor, physician and therapist for developing personalized mobile u-healthcare applications, an application model for the mobile u-healthcare applications should be defined prior to the implementation of the workbench. Here, we suggest an application model of mobile u-healthcare applications as presented in Figure 1.

The suggest application model consists of five phases. Sensing phase collects various vital signs of patient from mobile bio-sensors such as thermometer, ECG (electrocardiogram), PPG (photoplethysmography), fat measurer. The sensors are usually connected with mobile gateways through wired or wireless connections. Questionnaire phase collects health data that cannot be obtained by sensors. Many kinds of questionnaire are used according to the types of diseases. Data processing phase is to process the data collected by the first and second phases. The collected data is analyzed to decide the status of patient’s diseases. Sometimes training data is used for the decision. Disease treatment phase provides or suggests appropriate treatment programs based on the analyzed results of the previous phase. For example, deep breathing and meditation can be recommended for the patients suffering from mental stresses. The final feedback phase is for getting user’s feedback like the satisfaction of the service, or the improvements of the symptoms.

Our u-health application development platform is implemented in the form of a workbench so that the medical specialists develop their own u-health services according to the guideline derived from the application model in the above. The following activities of medical specialists are supported in the workbench. Once the type of diseases for service is decided, the medical specialists design questionnaires to gather symptom or other environment information. Under the assumption that the health data is successfully obtained in manageable form through bio-sensors and questionnaires, the medical specialists design the analysis method for the input health data. A simple health index may be used or some sophisticated analysis method such as expert system or some learning method may be designed or adopted. The degree of freedom of this phase is so high and thus this part is so platform dependent. Our application development platform also provides a unique and general matrix-based two-category classification method for this phase. The medical specialists may design a training based disease group identification method using the method.

The spectrum of disease treatments is as wide as the analysis methods of health data. Each medical specialist may develop one’s own treatment method or program. Under the assumption that numerous u-health treatment methods for a specific disease are available on the Internet, our workbench provides a treatment recommendation or ranking method based on user’s vital-sign and symptom combination information. Finally, the medical specialists design a feedback mechanism for gathering the responses from the treatments from the users. Sometimes the feedback data is accumulated to improve the analysis method or post-processing of services.

To help understand u-health services we have in mind, we introduce a service scenario of personalized mobile u-healthcare stress application. Suppose that a user has a mobile phone with the connection of a PPG sensor. Besides, the user can access the application portal through an application browser of the mobile phone. First, the user selects a personalized application for him/her, and starts the application then the application is downloaded on the mobile phone and is executed. The application let the user measure heartbeats using the PPG sensor connected with the mobile phone for 3 minutes and gather information from an SRI questionnaire. When the sensing and questionnaire phases are finished, the application makes a package of the health data, sends the data to the server, and starts data processing for the input data. The data processing phase calls the PPG sensor analyzer, symptom extraction, and stress decision web services. The stress result is sent back to the mobile phone and the phone displays the diagnosis results and recommends some programs to treat stress. Finally, the user returns optional feedback information to the application and close the application. Our u-health application development platform helps doctors and medical specialists develop similar u-health applications on the platform.

III. THE MUSS APPLICATION PLATFORM

The medical specialists are the most appropriate service providers for developing u-healthcare applications, and providing necessary actions or advises for treating or handling the health conditions of users. However, most medical specialists are not used to developing software applications. To help medical specialists develop their own u-health applications, we propose a MUSS (Mobile u-Healthcare Service System) service platform. In this section, we describe the architecture of the MUSS platform and explain how it enables the medical specialists to design and develop personalized mobile u-health applications without the knowledge of u-health application development.
A. The MUSS Platform Architecture

MUSS application platform consists of three layers as depicted in Figure 2. The component layer contains service components which are used for the composition of the services in developing a mobile u-healthcare application. The process layer includes healthcare processes which specify the logic of mobile u-healthcare application, and actual personalized applications such as stress, obesity, diabetes applications, and so on are placed on the application layer.

1) Component Layer

In MUSS platform, the service components are developed and deployed as web services. Basically, we assume that the web services are developed by third-parties and the platform provides a u-health component register facility with discovery and composition of service components. We provide basic primitive service components like sensing, questionnaire, disease decision, data analyzer, and etc., because there is not so many available service components developed by third-parties yet. The richness and quality of services in component layer is the key for the successful support of u-health service design.

2) Process Layer

MUSS Platform adopts a BPM (Business Process Management) concept in composing application scenario by connecting web services provided in component layer, and a PAL (Process Asset Library) to manage processes for application scenarios. In order to define an application process, we need to devise a standard message format to exchange data between the application process and the web services. We define a simple medical message (SMM) format and use it as parameters to call web services from the application process. The SMM is based on XML and it delivers information such as patient’s profile, vital signs, raw data of sensors, symptoms, results of analyzed data, and so forth. Therefore, we can use the SMM uniformly without extra works for message transformation to define application process.

Most service side logics for u-health applications are placed on and supported by process layer. Medical specialists can design the server side logics for applications using the tools, functions, and facilities provided in process layer. The primary activities of medical specialists in association with process layer include choosing vital sign, questionnaire design, design or deciding of input health data analysis method, design or recommendation of treatment programs, design of feedback mechanisms. These activities are guided to some degree by the application model explained in the previous section. But the application model is amenable to change by diseases and medical specialists, and process layer can cope with such changes effectively.

3) Application Layer

While process layer is to support the development of server side logics, the primary purpose of application layer is to support the development of client side logics for mobile devices. The application layer contains three important components; application scenario player, application designer, and application portal. The application designer is a tool to support medical specialists to develop personalized application scenarios, and application scenario player is a software system deployed on mobile phone to execute an application scenario developed by medical specialists. Medical specialists can design various client side service scenarios on the application designer. Like the server side logics, the client side service scenario is defined without the help of expert programmers as well. Application portal is a market place to distribute the personalized mobile u-healthcare applications to general users. Besides, the application portal is used to compensate for the limited resources of mobile devices. More abundant information is provided through the portal.

B. Application Execution Model

In order to support medical specialists to develop personalized application running on mobile devices, it is not a good idea to go through all the steps for implementing u-healthcare applications such as designing, coding, compiling and deploying mobile u-healthcare applications. The key of application execution model of MUSS platform is the application scenario as presented in Figure 3. The medical specialists develop personalized application scenarios on application designer, then the developed application scenario is downloaded to mobile phone and executed by application scenario player.

![Figure 3. Application Execution Model](image)

$$\begin{align*}
\text{app:application} & \text{Stress Application/}
\text{app:title} & \text{...}
\text{app:process} & \text{...}
\text{app:activity} & \text{...}
\text{app:property} & \text{...}
\text{app:category} & \text{Sensing/}
\text{app:type} & \text{PPGSensing/}
\text{app:property} & \text{sensing-part/}
\text{app:name} & \text{finger/}
\text{app:property} & \text{time/}
\text{app:name} & \text{120/}
\text{app:property} & \text{...}
\text{app:activity} & \text{...}
\text{app:application} & \text{...}
\end{align*}$$

Figure 4. An Example of Application Scenario

The execution mechanism of a specific application scenario is as follows. At first, the patient selects an application and download it into him/her mobile device. The application...
scenario player parses the application scenario in XML format and executes each activity step by step as defined in the application scenario. Each activity is associated with a scenario form, so the scenario player executes the activity then the scenario form is popped on the display of mobile phone. For example, the activity is a PPG sensing, then the mobile phone shows a user-interface form for patient to sense heartbeats using PPG sensor. After the execution of sensing and questionnaire activities, all the health data of a user are collected and are stored in the form of SMM format and passed as input parameter to the process which will be executed on BPM engine. When the process is invoked, the BPM engine calls web services such as PPG raw data analysis service, symptom extractor service and stress decision service defined as in the process. Once the server side process execution is over, we get the stress index and sent it back to the mobile phone through the SMM message. The application scenario player receives the SMM message and show stress index form on mobile phone display with the stress index value from SMM message. The disease treatment and feedback activities are executed in a similar way.

Finally, the key for the support of the personalization mechanism is the notion of application scenario. The application scenario is presented in XML document as shown in Figure 4. The application scenario document includes information of the application process, and the process consists of various kinds of activities. Each activity is one of both a task is performed either by a user on the mobile phone or by calling the associated web service on the server side.

IV. IMPLEMENTATION AND EVALUATION

We implemented the proposed mobile u-healthcare development platform and implemented a stress application on the platform to confirm whether our original purpose of supporting the development of mobile u-healthcare services by medical specialists is achieved or not. Some pieces of implementations for core components of process and application layers are also introduced to help the understanding of our approach.

Samsung Blackjack smart phone is used for the client in the implementation, and Windows Mobile is used for operating system. An application scenario player for the mobile phone was implemented using Microsoft C# language. Also, we used Axis 2 framework and Apache Tomcat for all web services running on a server, and WebVine[2] is used as a BPM engine for the support of server side logics.

A. Service Components

The MUSS platform provides various fundamental service components for each step such as questionnaire, data processing, disease treatment, and user feedback.

1) DCAP Service

DCAP(Disease Combination Appearance Probability) service is a newly designed disease group identification method for doctors and medical specialist to summarize user’s health data based on vital sign and symptom combinations [3]. DCAP keeps the summary information in a matrix data structure, and it can be used for predicting the probability of a user belong to normal or disease group using the vital sign and symptom data of the user. MUSS provides user interfaces and utilities to create and manipulate the structure of the matrix for individual disease as shown in Figure 5. If necessary, medical specialists can easily create their own DCAP matrices for a certain disease. Figure 6 shows the result of the DCAP construction for a stress application. Doctors can apply their own data for the construction of DCAP matrices.

DCAP is not the only way to classify users into normal and disease groups. There are many other ways and techniques to diagnosis users. MUSS tries to accommodate such methods as long as possible in future. The point in this case is how easily and effectively doctors and medical specialists can use the methods for the services they are developing.
3) Health Program Recommendation Service

Mobile u-health services developed by doctors and medical specialists are announced through a health portal. This will bring the situation that a user has to choose one service that is most appropriate to his health condition among the numerous candidate services. Health program recommendation service recommends the most appropriate healthcare program based on the vital sign and symptom combination information of the user. For this, a reputation system is maintained for the services. One unique feature of our reputation system is that it keeps both the evaluation result and associated the vital sign and symptom information of the user. When there is a request for the service recommendation, the recommendation system gives a list of high reputation services with similar vital sign and symptom patterns to the user.

4) User Feedbacks

User feedback is one of essential steps that should not be omitted in u-health services. However the support of feedback design is one of challenging issues in u-health services. Diverse forms and types of feedback mechanisms are required depending on the types of diseases and service conditions. Besides the feedback mechanism is often tightly coupled with analysis methods like DCAP. Thus supporting all possible feedback mechanisms is not possible in practice. MUSS provides two types of feedbacks in accordance with DCAP; group feedback and private feedback. Other feedback mechanisms should to be supported in an ad hoc manner.

B. Application Designer

Application designer provides a canvas to draw client side service scenarios for mobile u-health applications as shown in Figure 8. Application designer provides a list of available services so that doctors and medical specialists to choose necessary services and integrate the services on the canvas. Numerous services will be necessary for the complete support of all the phases of the application model. At this time, only limited number of services is available. If a necessary service is not available then the service should be developed and registered to a service repository to be added in the list of services. Application designer is one of key elements that enable doctors and medical specialist to develop mobile u-healthcare services without the help of programming experts.

C. Application Scenario Player

Application scenario player is a software module which provides an enactment service for the downloaded application scenario on a mobile phone. With application designer, application scenario player plays key role to support the development of mobile u-health services by doctors and medical specialist. Application scenario player supports the execution of client side service scenarios. The client side scenario is usually specified in a sequence of forms. Application scenario player supports diverse types of forms. In fact, each form is a unit scene which is required in the activities of sensing, questionnaire, result delivery, disease treatment as illustrated in Figure 9. Diverse client side service

D. An Example: Stress Application

We implemented a stress application on the platform and confirmed its execution on a mobile phone to validate the usefulness of the platform. Stress application gathers user’s heartbeat information, performs the stress-related questionnaire (SRI) [4], and then gives the amount of user’s stress in...
probability using DCAP service so the user can be aware of how much stress the user has. Stress application is designed to go through the process in the follows.

- **Sensing.** A PPG sensor attached to a mobile phone via Bluetooth communication gathers user’s heartbeat information from contacting user’s finger part.
- **Questionnaire.** SRI questionnaire is performed on mobile phone to gather symptom and related information on users.
- **Data Processing.** Producing processed bio information such as LF, HF, SDNN, etc. analyzing raw data gathered from PPG sensor, and symptom information based on questionnaire result. Calculating stress index measure from DCAP service using produced information. The result is shown visually via mobile phone.
- **Disease Treatment.** Based on the analyzed data and information from the data processing step, recommending appropriate stress solving program via mobile phone.
- **Feedback.** Feedback returns the response of users for the delivered results to the system. The feedback result is reflected to the system to improve the system impromptu or in future.

The above scenario flow is developed on application designer and the result is delivered to a mobile phone as shown is Figure 10. Note that the application shown in Figure 9 requires work by expert developers who have expertise in developing mobile applications, and it usually takes long time and high cost. However we could implement the service simply and easily on this platform with the help of the application designer. Also, we can execute the new stress application on the mobile phone by downloading the application without additional program installation.

V. **CONCLUSION AND FUTURE WORK**

In this paper, we designed and implemented a development environment and a platform which enables doctors or health experts, who are not capable of developing software, to design personalized mobile u-health applications and to provide them to users. The core mechanism is to support doctors or health experts for expressing their expert medical treatments using application designer, producing those treatments as application scenarios in the form of an XML document so that users can access directly through application scenario player on a mobile phone. MUSS system is an actual implementation of this kind of platform. We confirmed that doctors or health experts who have no knowledge of software development can directly develop personalized mobile application by implementing a stress application and other applications. We also confirmed that users can use it directly.

However, this system is not complete yet. There is no good support of various kinds of sensors yet. There is not enough number of general sensors available for mobile phones, so currently it is difficult to develop applications which support various sensors. In addition, it is difficult to express various logics in application scenarios. Currently, activities are enumerated one-dimensionally in a way of pipeline and executed by application scenarios. It needs to be more improved enough to express various control logics such as branch, iteration, etc.

**REFERENCES**


