Mobile Personal Health Care System for Patients with Diabetes

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Abstract. In this paper, we propose a personal diabetes monitoring system which integrates wearable sensors, 3G mobile phone, smart home technologies and Google Health to facilitate the management of chronic disease - diabetes. Our system utilizes wearable sensors and 3G cellular phone to automatically collect physical signs, such as blood glucose level and blood pressure. It allows users, especially seniors with diabetes, to conveniently record daily test results and track long term health condition changes regardless of their locations. It does so without having to ask users to manually input them into the system. Our system also utilizes Google Health to manage Personal Health Records (PHRs), which not only bridges the gaps between patients and different health care providers but enabling accesses to patients' PHRs anywhere and anytime by taking advantage of the universal accessibility of Google Health.

Keywords: diabetes monitoring, health care, behavioral modification, personal health record, Google Health, smart home.

1 Introduction

Diabetes is one of the most widely spread chronic diseases. In the United States, nearly 13 percent of adults aged 20 and older have diabetes. Diabetes is especially common in the elderly: nearly one-third of those aged 65 and older have the disease. It is suggested in a publication of the Department of Health and Human Services that in order to keep glucose at a healthy level, people with diabetes need to keep a balance between three important aspects: diet, exercise and diabetes medicine in daily routine [1, 2, 3]. Therefore, continuous self-monitoring of the blood glucose (blood sugar), daily diet, physical activity and medicine intake are crucial for the management of diabetes.

In recent years, small and wearable sensors have become widely available, which allows convenient and non-intrusive monitoring of patients' blood glucose, medicine intake and life styles, e.g., daily diet and exercise. In addition, contemporary 3G smart phones incorporate unforeseen computational powers which include internal database, voice recognition, GPS position and continuous access to local wireless networks and the Internet. The latest International Telecommunication Union (ITU) statistics reveals that there were about 4.6 billion mobile-phone users by the end of the year 2009

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as compared to the total number of the Internet users was just above 1.5 billion [4]. This makes newer cellular phones a very promising mobile platform for advanced applications. To complete the picture, we observe that the growing popularity in the third-party online PHR management platform with security and privacy features, such as Google Health, Microsoft HealthVault and open-source project Dassia. The advantages of these PHR management platforms include: (1) facilitate information sharing between patients and multiple health care providers; (2) avoid unnecessary expenditures (i.e., duplicate lab test costs); (3) prevent adverse drug conflicts;(4) maintain comprehensive PHRs and provide easy access to the patient's own PHRs from any locations at any time [5].

There are many wearable and pervasive health monitoring systems in the market, and we summarizes some of their representative features. The mobile health monitoring systems for heart disease, using wearable ECG sensors and smart phone were developed in [6, 7]. Using mobiles with a multi-access service for the management of diabetic patients was proposed in [8],which was designed to collect data, either manually or automatically from the blood glucose meter; to monitor blood glucose levels; to suggest insulin dose adjustment when needed ;to deliver monitoring data to a health care center.

In our smart home lab at Iowa State University, several subsystems have already been developed to facilitate the people's daily activities, especially with respect to seniors' healthcare. For example, Smart Microwave and Smart Fridge can identify food and nutrition facts by scanning Universal Product Code (UPC) barcode with the help of U.S. Department of Agriculture (USDA) National Nutrition Database (USDA-NND) downloaded from USDA website, record the person's dietary history, and check conflicts with medicines taken. Watchdog is built not only for house safety but for reminder, like reminding the diabetic patient to carry the medicines and snack when leaving the house. The Medicine Information Support System (MISS) is designed for checking medicine conflictions and facilitating the person to take medicine in compliance to completeness and timeliness, with the support of a Global Medication Conflict Database (MCD) [9, 10].

The major contribution of this work is the design of personalized, integrated, and collaborative care system for self-monitoring and managing diabetes. Our mobile health care system has two major improvements compared to the system proposed in [8]. First, it not only monitors the blood glucose levels, but collects information about the daily diets, medicines taken and exercise done and makes it possible for patients to monitor their own health conditions, to receive warning and guidance to adjust their behaviors during their daily routines, and to be able to navigate intricate interactions among diet, exercise and medications. Second, it does not directly deliver data to a specific health care center. Instead it integrates mobile-based and smart home-based health monitoring systems with Google Health, breaking down the wall between the patient, patient's family members and different health care providers such that they can now provide collaborative care for the patient.

This paper is organized as follows. In Section 2, we describe the integrated architecture design including the software, hardware and communication interfaces between different components of the system. Section 3 gives the software architecture design in mobile phones and explains the implementation of web services in smart home. In Section 4, we describe behavioral modifications flowchart. Finally, summaries conclusions and future work are presented in section 5.

2 System Design

In this section, we introduce the sensors used, communication technologies between different components and functionalities of each component. Fig. 1 shows the overall picture of the system architecture of our proposed mobile personal health care system for patients with diabetes. We introduce this system in the following three levels:

(1) Wearable sensors which allows convenient, continuous and non-intrusive monitoring of people with diabetes for their test results, medicines, daily diet and exercise. In our prototype, Zephyr BT HxM with fabric sensors is used as an exercise tracker measuring the heart rate, speed and distance. Also, we are studying the UA-767PBT A&D Bluetooth Blood Pressure to trace the person's blood pressure and the Bluetooth-enabled blood glucose meter, MyGlucoHealth® Meter, to trace patients' blood glucose level. In our prototype, we simulated the blood glucose data.

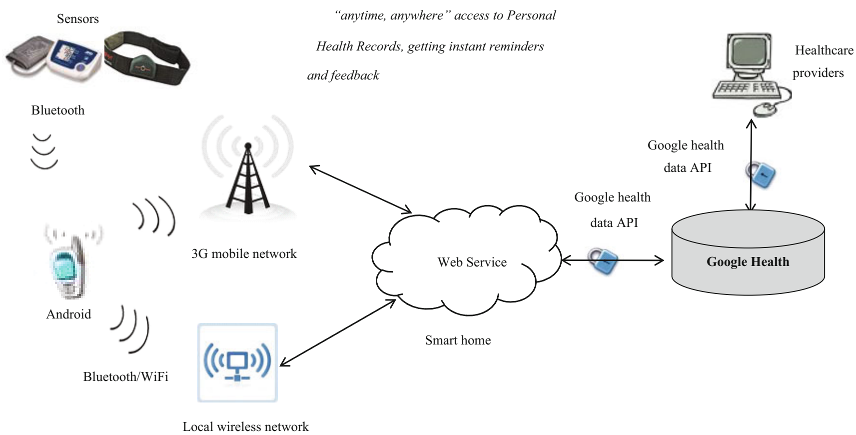

Fig. 1. System architecture of mobile personal health care system for people with diabetes

(2) 3G smart phone will gather, store and display statistical data from wearable sensors, update daily test results, diets and medicines taken, and get feedbacks and notifications from caregivers. There are two ways for smart phone to interact with Google Health. In LAN area, smart phone detect existing wireless Access Point (AP) and accesses Internet. Otherwise it resorts to 3G mobile network.

(3) Web services in smart home enable the interaction among the 3G smart phone, smart home subsystems and Google Health. Web service in smart home wraps Google Health data APIs and interacts with smart home subsystems like Smart Microwave and Smart Fridge for diet tracking. The smart phone utilizes KSOAP2 to interact with SOAP web service in smart home. Google Health is used to manage PHRs and facilitates information sharing between patients and multiple providers.

3 Software Framework

Multi-module software architecture is developed in Android mobile platform and integrates software components with web service technologies. Every module in the architecture is loosely coupled and is implemented by using Activities and Intents in the Android development simulator. Software Architecture of mobile personal health care system for diabetes is illustrated in Fig. 2, which includes GUI (Graphical User Interface) Module, Interface Module, Inference Module, Notification Module, common database operation interface with internal database Sqlite and KSOAP2 interface with SOAP web service in the home server.

GUI Module. The patient can retrieve or input data by interacting with GUI. The specific applications include: 1) Heath Care Team which contains the contact information of the person's health care team. 2) Health Care Goals includes the blood glucose, blood pressure, exercise and weight targets which are strictly set by the health care team. For example, the blood glucose target is 100mg/dL before a meal and is 140mg/dL after a meal. 3) Test Result Tracker displays daily, weekly or a custom time interval blood glucose test results in a graph that indicates whether the blood glucose is high, healthy or low. 4) Medicine Tracker, Exercise Tracker and Diets Tracker will track the information about medicine taken, exercise and diets. 5) Notification is for patient to check feedbacks from his or her health care team or family members and to read the reminders and suggestions from the scheduler in the smart phone.

Interface Module. Interface Module is responsible for gathering raw sensing data and transferring it into internal message format, which is implemented by using an experimental unofficial Bluetooth API for Android.

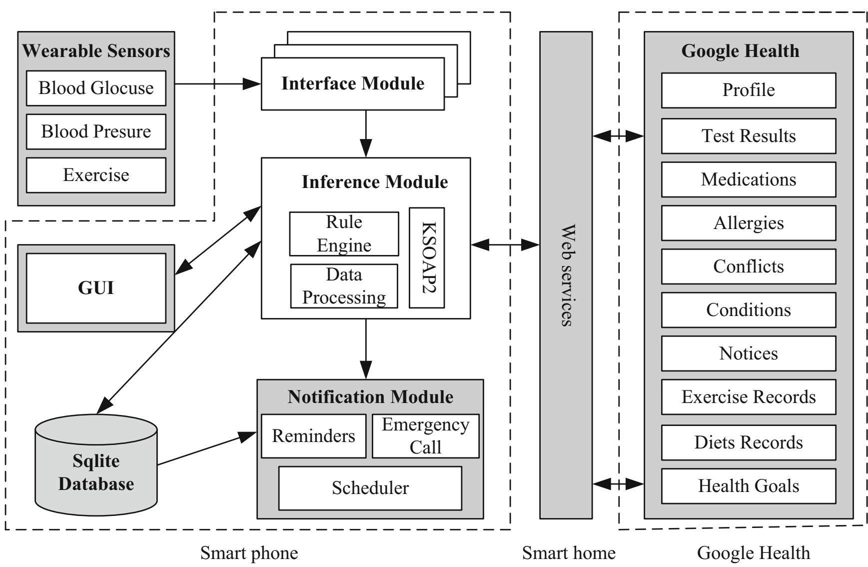

Fig. 2. Software Architecture of mobile personal health care system for people with diabetes

Inference Module. Inference Module is responsible for processing raw data from sensors via interface module and notices from Google Health through web service interface and interacting with GUI. After receiving the sensor data from the interface module, the inference module will store it into a database by calling the common database operation interface. It will also perform inference tasks based on pre-defined rules which are described in Section 4. The outcomes of the inference procedure are transformed into corresponding notification messages and then sent to the notification module. Inference module will periodically query if there are any notices updated from Google Health based on pull-based data consistency model. If there are notifications, it will trigger the corresponding action commands or notification messages. For example, when medications are updated in the Google Health by personal health team, inference module will get a notice whose message type is *MSG_ MEDICATONS_UPDATED*, and then it will release a command called *CMD_ DOWNLOAD_MEDICATIONS* to KSOAP2 interface. After getting the updated medications, it will notify the scheduler in the notification module to update the medicine taking schedule. Inference module also periodically updates the test results, diets and exercise records from wearable sensors or manual inputs into Google Health.

Notification Module. Based on the outputs from inference module, Notification Module will post reminders to the person or notices to health team. In emergency situations like when blood glucose is very high or the user has not taken medicine or blood glucose test for several days, notification module will make an emergency call to the person's health team. The scheduler in the notification module will post a text or voice reminder to remind the user to take medicine or anything pre- scheduled.

Web service. A Web service deployed in the smart home enables communications between 3G smart phone and Google Health. This Web service wraps Google Health data APIs to interact with Google Health. It also cooperates with other subsystems in home system, for example, to interact with MISS in smart home for medicine

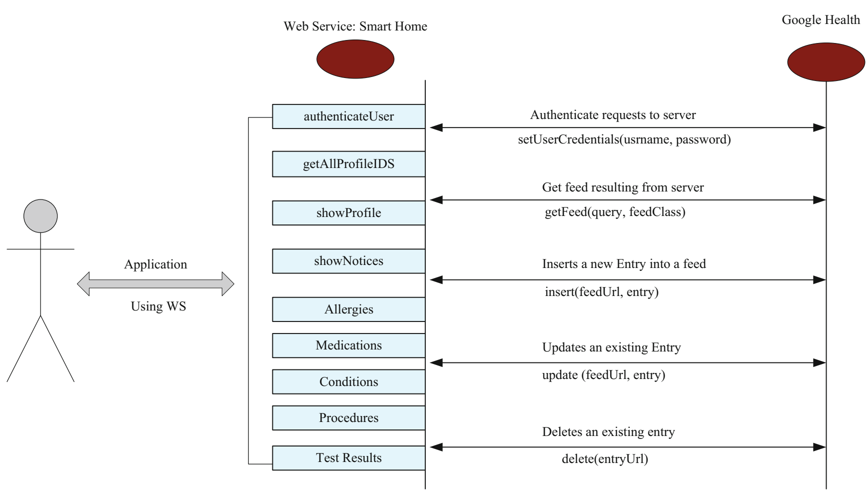

Fig. 3. Use case for interacting with Google Health

conflicts checking and interact with Smart Microwave and Smart Fridge Subsystems for diets management. Fig.3 shows a use case for interacting with Google Health.

Google Health. Google Health is a free online service for patients to maintain their personal electronic health records while allows appropriate access as needed with the permission of the patient to different health care providers.

4 Behavioral Modifications Flowchart

Through web service, we integrate smart phone, smart home and external systems like Google Health, MCD and Weather web service. With the help of these subsystems and wearable sensors, the mobile health care system traces the person's activities in exercise, diets and medications taken, and gives warnings and suggestions for preventing accidents and improving the person's behaviors during his or her daily routine. The behavioral modifications flowchart is illustrated in Fig.4. In our design, we use Google Health as PHR management system which breaks down the wall between the patient, patient's family members and different health care providers such that they can work together to continuously refine targets for blood glucose levels control, exercise and nutrition intake and give a prescription to the patient. The behavioral modifications steps are the following:

(1) When the person takes a blood glucose test, the system will automatically make an emergency call to prevent potential accidents if the blood glucose level is dangerously high or low. If it is relatively low or high, the person is suggested to eat food or take medicine under the guidance of the system.

(2) The system will remind the person to take medicines based on the prescription or whenever needed. With the helps from MISS and Google Health, the system will check whether there are conflicts or allergies among medications the person is taking. If there are any medicine conflicts or allergies, the system will suggest the person to consult with his or her doctors. The system can also indicate whether the person needs to take medicine with food and whether he or she is complying with completeness (right dose) and timeliness (right time) [10].

(3) Diet is an extremely important factor affecting a patient's diabetes. Based on the personal health situations, food allergies and other dietary restrictions, the health care providers make a list of prohibited foods. With the support of Smart Microwave and Smart Fridge Subsystems at smart home and barcode reader embedded in cell phone, the health care system can check whether the food is in the prohibited food list. If it is not in the list, then the system further identifies nutrition facts of the food, checks the person's daily consumption history and then takes different actions based on the percentages of carbohydrates and fats accounting for the person's daily caloric intake respectively. Also, by checking the person's medicine intake history, it can check whether there are conflicts with medicines taken.

(4) The system can suggest the person to exercise either indoor or outside based on weather information from the weather web service. When the person goes outside, he or she will lock the door by scanning a RFID tag identification. The Watchdog then will learn the fact that the owner will go outside and thus remind him or her to scan the RFID tag attached to the medicine bottle and the barcode on the snack packets to make sure the person brings the right medicine and snack. During exercise, the

exercise tracker sensor will monitor the person's heart rate. If the heart rate is more than 85% target heart rate, the system will give an alert and may suggest the person to slow down or even stop exercising.

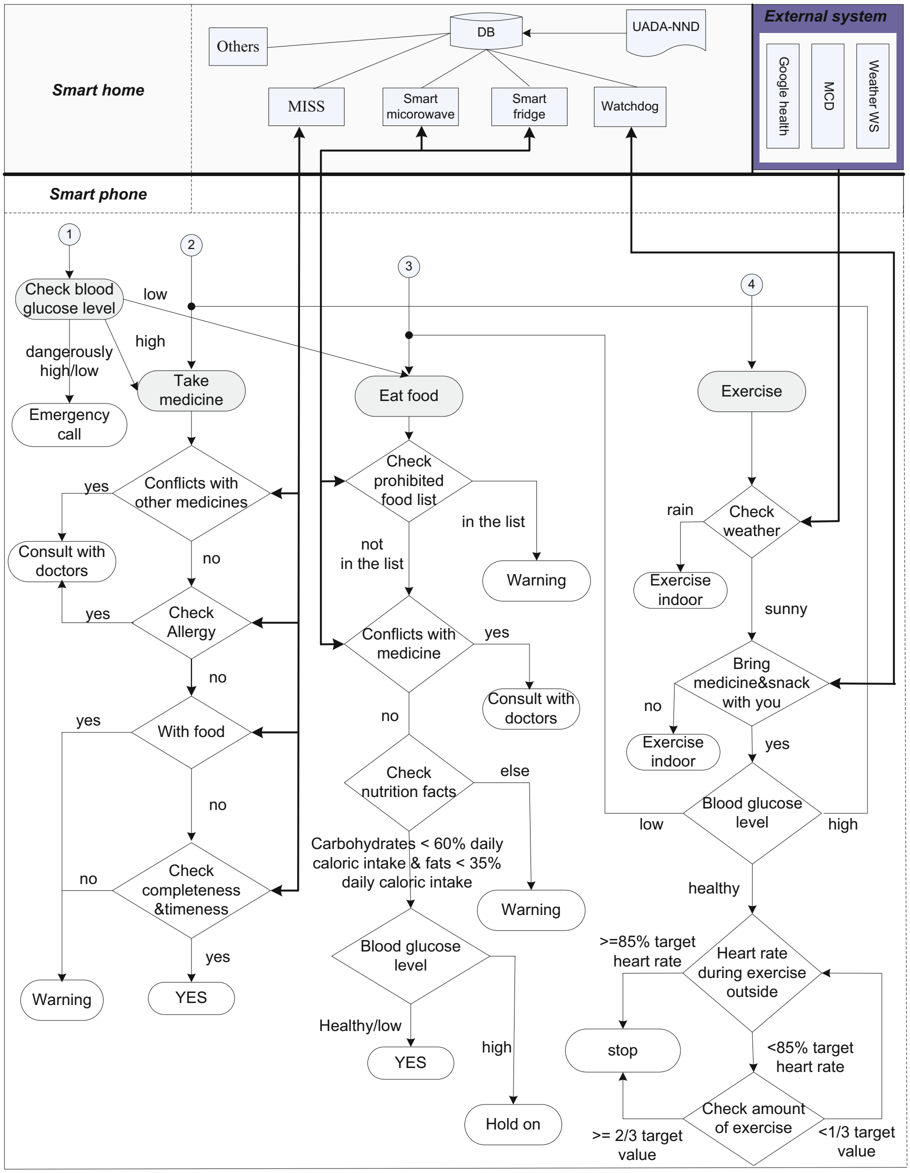

Fig. 4. Behavioral modifications flowchart

5 Conclusions and Future Work

This paper presents a personal diabetes monitoring system which integrates wearable sensors, 3G mobile phones, smart home technologies and Google Health to facilitate the management of diabetes conditions. This diabetes monitoring system not only assist with the tasks of diabetes management, but also improves the medicine and food safety by taking full advantage of features in existing subsystems in smart home and Google Health. Since there exists imprecision when collecting the exact data of diets and exercise (for instance, when a patient dines out or go to a gym), our prototype system supports both automatic and manual inputs of diets, medicine and exercise information.

We are currently working on 1) to improve the accuracy of automatically collected dietary and exercise information; 2) to enhance the accuracy and completeness of reasoning. One of our ongoing efforts is to explore the use of data mining tools, such as Intelligent Miner, DataMiner, Clementine, and 4Thought, to find the implicit relations between blood glucose, medicine, diets and exercise; 3) to establish a dynamic model of exercise, diets, medicine and weigh effects on the blood glucose level. Our goal is to establish a more comprehensive model than the current one on the effects of exercise on plasma glucose and insulin levels described in [11].

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