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The Design of a Cloud and Mobile Healthcare System

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Abstract

The aging society will become a serious problem for most countries in the world. Under the constraint of limited medical resource, the self-health management becomes important. In this paper, a mobile healthcare system is implemented. One can easily monitor his/her physiological data through the using of a smartphone that is wirelessly connected to different medical detection devices. A cloud database is established for storing and analysing these physiological data. The guidance of suitable physical exercises to individuals is then given in the system. This paper shows the details of the system implementation.

Keywords

E-Health, Healthcare, Cloud Computing, Smartphone, Bluetooth

1. Introduction

In the coming aging society, the problem about eldercare becomes very important. Under the constraint of scare medical resource, pervasive medical services become limited. Fortunately, information communication technology (ICT) nowadays can simplify the medical treatment process and extend medical services to remote or residential areas. For example, digital medical records shorten data retrieval and maintenance cost. Network and communication techniques realize telemedicine. All of these raise the trend of e-health [1].

With the advance of wireless communication and portable hardware, there raises another trend of m-health (Mobile Health) [2]. For example, some smartphones provide sensing abilities to detect the heartbeat and the amount of exercise. Some medical devices such as blood pressure and body fat monitors can wirelessly transfer measured data to a smartphone which in turn forwards the data to a cloud server.

The concept of keeping healthy and fit is getting more attention. However, a busy lifestyle usually makes people ignore their health conditions. A convenient way to know personal body conditions in our daily life becomes attractive. The wearable computing now can realize this goal. For example, a smart watch or bracelet can sense the body motion and hear beat to indicate the calorie expenditure. These devices are mostly connected to smartphones for data integration. There are several commercial solutions such as Apple's Health and Samsung's S-Health that provide sports and health management applications on the smartphone.

Instead of showing a single-function e-health application, this paper demonstrates the design of a multi-func-

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tion e-health application on the smartphone. One basic function is to record personal health data by wirelessly integrating different medical detection devices. Another function is the involving of the expert role into the system. This expert can give a body exercise schedule to a person according to the individual condition.

The developed system is mainly based on the techniques of android development framework, google app engine (GAE), and Bluetooth low energy (BLE). The first one is for developing a mobile application on an android device. The second one is for data storing in the cloud, and the last one is for the wireless connection with portable devices.

The rest of this paper is organized as follows. Section 2 discusses related e-health applications and researches. Section 3 briefly introduces the ideas of a smart homecare system. Then, we show the system architecture and design philosophy. Section 4 demonstrates various system functions. Finally, we make some concluding remarks in Section 5.

2. Related Work

It is expected that ICT can increase the quality of medical treatment. Most hospitals have their own medical information systems which integrate registration, treatment, surgery, and hospitalization services. These information systems can also be used remotely such that the treatment records about patients can be accessed for remote or home care [3] [4].

Some traditional medical detection devices are huge, but they have become small and portable now. For example, the biomedical detection platform (**Figure 1**) used in our developed system integrates several measurement functions (electrocardiograph, blood pressure, oximetry, pulse, breath, and body temperature) into one package of suitcase size. This kind of platform can wirelessly export the detecting data to a computer. There are three typical wireless interfaces used in the medical and health field: BLE (Bluetooth Low Energy), ANT+, and NFC (Near Field Communication). The comparisons of these air interfaces [5] are briefly listed in **Table 1**. The BLE is more widely used in the market.

The smartphone which is getting popular in these years naturally provides wireless connection to external portable devices. Several health related applications are developed based on the smartphone. For example, a continuous cuff-less blood pressure monitoring device combined with a smartphone is designed [6]. The smartphone can wirelessly connect to medical devices and forward the detecting data in a secure way to a server [7] [8]. The ZigBee technology is used to construct a body area network that connects the heartbeat and electrocardiograph sensors on a human body. The collected data are also forwarded to a data server using a smartphone [9].

Figure 1. Multi-function medical device.

Table 1. Comparison of difference wireless interfaces.

	BLE	ANT+	NFC
Standard	IEEE 802.15.1	Propriety	ISO 13157
Range	≈100 m	≈100 m	<0.2 m
Frequency	2.4 GHz	2.4 GHz	13.56 MHz
Data Rate	≈1 Mbps	≈1 Mbps	424 Kbps
Power	<15 mA	15 mA/17mA	<15 mA

A web-based server that integrates electronic health records is constructed such that a doctor can retrieve these data remotely using the smartphone [10] [11]. The smartphone can not only forward health data to the Internet but also emit an emergency message out if needed [12] [13]. There are also many research studies focused on the fall detection using the internal motion sensors in the smartphone [14]-[16]. Moreover, the exercise and rehabilitation process can be guided by using the smartphone [17]-[19].

3. System Architecture

We plan to develop a smart homecare system that uses the popular smartphone as a powerful aid. **Figure 2** shows the different scenarios where the homecare system can provide instant help. These functions are briefly explained below:

Medical detection: The smartphone is connected with medical devices for collecting body health conditions. This paper just shows the design of such services.

Accident detection: Modern smartphones are equipped with different sensing devices such as accelerometers, gyroscopes, and magnetometers. The accelerometer (also called inertial sensor or G-sensor) can measure the proper acceleration felt by the smartphone, and hence can be used to detect body falls. The research result about this work is published in [20].

Operation guide to home appliances: Some home electronic appliances may be too complex to the aged, particularly those with bad memory. An idea is to use the smartphone to recognize the appliance type and then show the operation guide on the screen. Two possible recognizing approaches can be applied. One is to attach each appliance with the NFC or RFID tag. The other is to use the image processing technique through the phone camera. We have the similar work on building recognition using the software toolkit of augmented reality (AR).

Body training games: The computer games can be played for educational entertainment. We plan to design some interactive games on the smartphone to train the brain and eye-hand coordination of the elderly. For example, the figure cards that are connected to daily necessities and relatives can be used to enhance the memory of an Alzheimer's patient.

Hospital recommendation: In the big data age, some useful information can be derived from many similar cases. There are some web pages or forums where people leave evaluation scores to some hospitals. Based on the personal disease and the current location, a system function can be designed to recommend a suitable and close hospital to a user.

Social analysis: The human relationship is a good point to decide whether a person is isolated from others or not. The closeness of two smartphones can reflect the situation of human contact. Therefore, this social analysis based on the closeness data among smartphones would be beneficial.

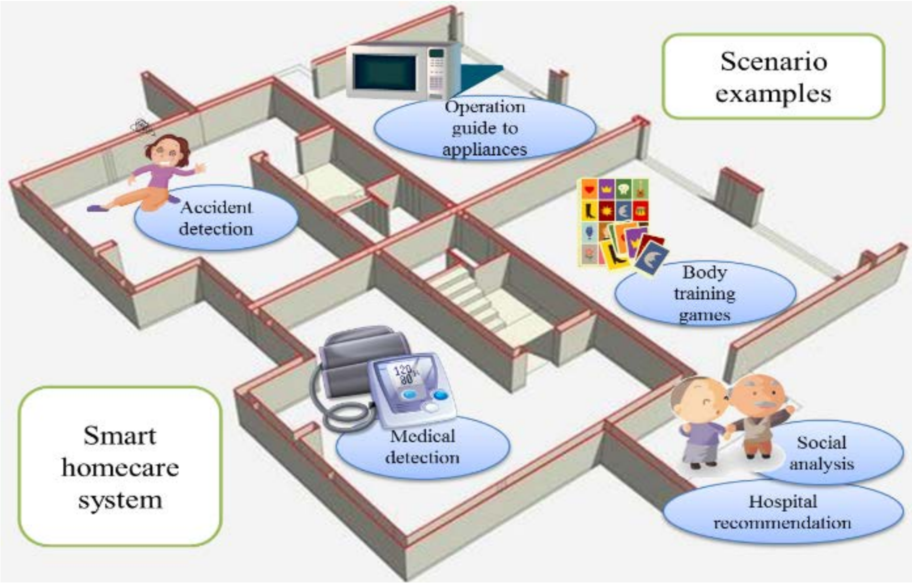


Figure 2. Different scenario examples showing the functions of our smart homecare system.

A smartphone-based self-care system is implemented in this paper. This system provides a cloud service platform that enables the interaction between a doctor and a patient using the smartphone. Basically, the system architecture is divided into front-end and back-end parts. Each part internally contains some software modules providing certain functions as shown in **Figure 3**.

The front-end part provides both doctor and patient sides' functions. A doctor can retrieve the health records of a patient and initiate a body training schedule accordingly. A patient can also review the personal health records and the statistical data analysed by the back-end server. Also, a patient will be notified with a training exercise, and therefore needs to feedback the body condition (*i.e.*, body fat, blood pressure, etc.) before and after each exercise.

The back-end part is a cloud server that mainly stores and analyses health records. This server would also recommend each patient a suitable exercise (*i.e.*, swimming, jogging, etc.) and provide a video link to watch the right way to do the exercise.

All front-end functions are developed on an android-based smartphone as a mobile application. This smartphone can wirelessly connect to some medical devices through the BLE. The back-end services are developed using the GAE.

3.1. Front-End Functions

The front-end application can be used by two roles of persons: doctors and patients.

3.1.1. Doctor Role

A doctor can either initiate a new record for a new patient by typing some basic data, or browse the historical health records of existing patients. The body condition of each patient is also specified by the doctor with one of the following symptoms in the system: normal, diabetes, hypertension, and heart disease. For the purpose of

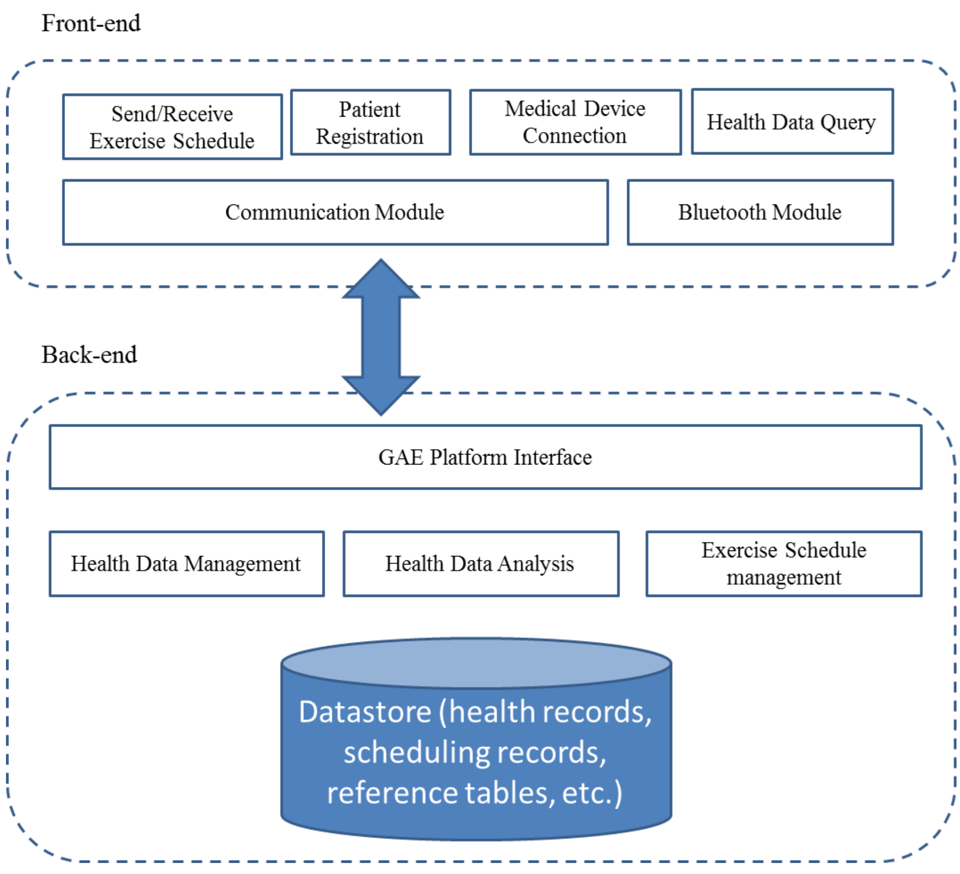


Figure 3. System architecture and function modules.

homecare, a doctor can assign an exercise schedule to a patient who needs daily rehabilitation. This assignment message is automatically sent to the corresponding patient's smartphone using the server push technology. The Google Cloud Messaging (GCM) provides such message sending services.

3.1.2. Patient Role

A patient can daily upload its health records to the back-end server by connecting its smartphone to a medical device. Our system currently supports the following medical devices: multi-function medical device, body fat meter, blood pressure monitor, and blood sugar monitor. A device connection module is designed for the support of scanning and matching other Bluetooth devices.

A patient can also be notified with an exercise schedule. The body conditions need to be measured before and after the exercise each time. All measured data can be retrieved from the back-end server. The system provides a curve view to see the trend of health data for the past one day, one week, or one month.

3.2. Back-End Functions

All the server functions are written in Java as Servlets on the GAE cloud platform. Health related data are stored into Datastore which is an object-oriented database system used in the GAE. Several data kinds which are similar to the tables are defined and created. In the following, the design of some core functions is discussed.

The health condition can be automatically derived by matching the measured data to the regular data. The following **Tables 2-5**, which are provided by the Taiwan's ministry of health and welfare, are used in the system.

Some typical statistical indexes such as mean and standard derivation are applied to analyze the health data. Abnormal data can be even detected by using the concept of outlier. To suggest a suitable exercise to a patient, the system performs the rule-based checking by considering both **Table 6** and **Table 7**.

4. System Demonstrations

In this section, system function interfaces are presented. At first, a doctor can register a new patient into the system by inputting basic data fields such as age, gender, height, and weight (**Figure 4(a)**). The interface of **Figure 4(b)** is used by a doctor to assign an exercise schedule to a patient, where the kind of exercise, the number of

Table 2. BMI standards.

Category	BMI range-kg/m^2
Very severely underweight	less than 15
Severely underweight	5.0 to 6.0
Underweight	16.0 to 18.5
Normal (healthy weight)	18.5 to 25
Overweight	25 to 30
Obese Class I (Moderately obese)	30 to 35
Obese Class II (Severely obese)	35 to 40
Obese Class III (Very severely obese)	over 40

Table 3. Body fat standards.

Description	Women	Men
Essential fat	10% to13%	2% to 5%
Athletes	14% to 20%	3% to 13%
Fitness	21% to 24%	14% to 17%
Average	25% to 31%	18% to 24%
Obese	over 32%	over 25%

Table 4. Blood pressure standards.

Category	systolic, mm Hg	diastolic, mm Hg
Hypotension	less than 90	less than 60
Desired	90 to 119	60 to 79
Prehypertension	120 to 139	80 to 89
Stage 1 hypertension	140 to 159	90 to 99
Stage 2 hypertension	160 to 179	100 to 109
Hypertensive emergency	over 180	over 110

Table 5. Blood sugar standards.

Target Levels	Pre-prandial	Post-prandial
Non-diabetic	72 to 106.2 mg/dL	under 140.4 mg/dL
Type 2 diabetes	72 to 126 mg/dL	under 153 mg/dL
Type 1 diabetes	72 to 126 mg/dL	under 171 mg/dL
Children w/ type 1 diabetes	72 to 144 mg/dL	under 180 mg/dL

Table 6. Lists of exercises under different BMI conditions.

Conditions	Suitable exercises
BMI: 18.5 - 24.9	swimming, jogging, running, cycling
BMI: > 27 (female)	swimming, jogging
BMI: > 23 (male)	swimming, jogging

Table 7. Lists of exercises for different diseases.

Disease	Suitable exercises
Diabetes	swimming, jogging, running, cycling
Heart disease	swimming, jogging, cycling
Hypertension	swimming, jogging, cycling

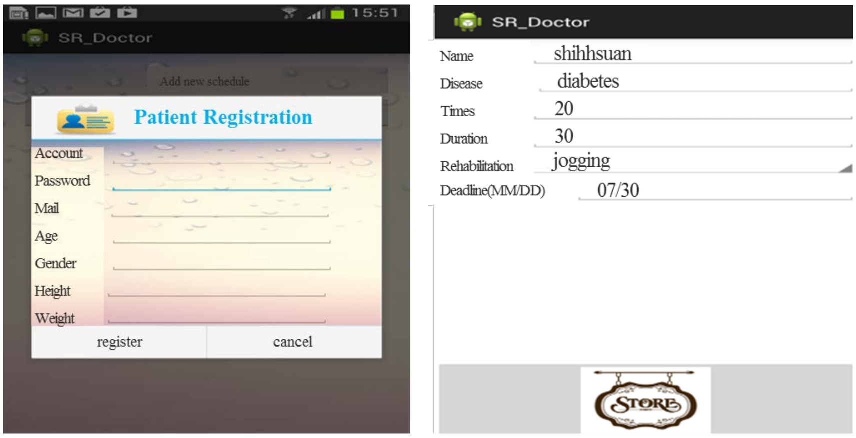
times, and the deadline are specified.

A doctor can view the historical health data of a certain patient by selecting the patient name (**Figure 5(a)**), before or after exercise (**Figure 5(b)**), time interval (**Figure 5(c)**), and item type (**Figure 5(d)**). An example to display the change of blood pressure during the past one week is shown in **Figure 6**.

A patient when logs into the system would find the notification about any new exercise schedules (**Figure 7**). If a patient would like to measure body conditions, several medical devices are provided (**Figure 8(a)**). After using these medical devices, the measured values are automatically filled and can be uploaded to the cloud server (**Figure 8(b)**). The connection to a medical device is via the discovery process of a Bluetooth device as shown in **Figure 9**. A patient can observe the change of body conditions in different health dimensions between the before and the after exercise (**Figure 10**). The system will also indicate whether the body conditions are health or not. A patient can understand his/her suitable exercises through the system suggestion (**Figure 11(a)**), and can learn the correct way to do exercising through the instructional texts and videos (**Figure 11(b)**).

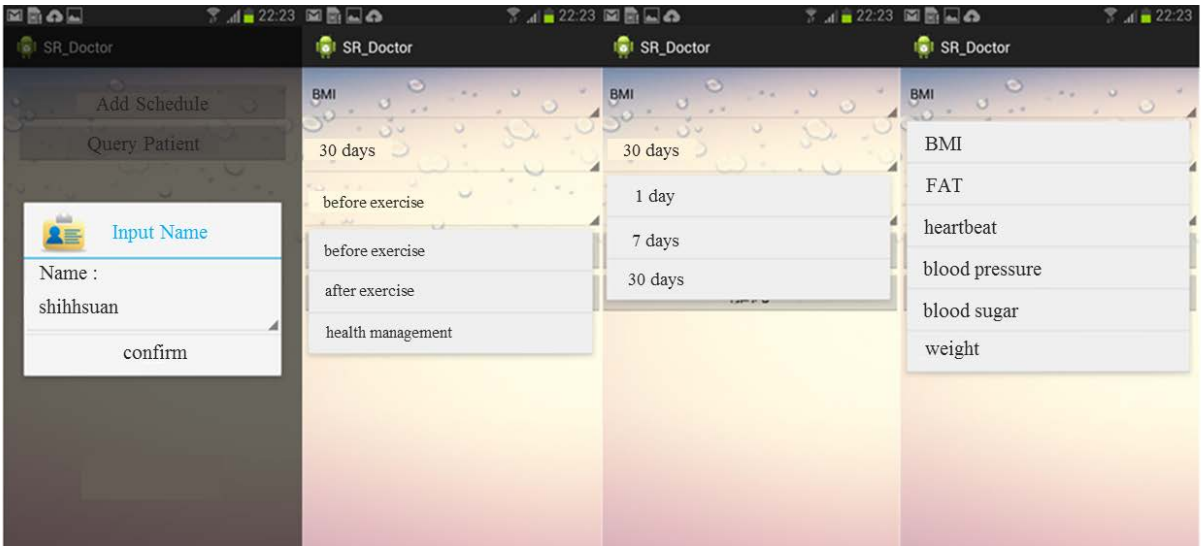
5. Conclusions

For keeping healthy, prevention is better than cure. If the body conditions are known anytime, we can take more care of ourselves. In this paper, a smart homecare system involved with a smartphone is mentioned. One potential function of this system is to collect health related data by using the smartphone. We present this application



(a) (b)

Figure 4. Doctor side function: (a) patient registration and (b) exercise assignment.



(a) (b) (c) (d)

Figure 5. Doctor side function: a series of interfaces to view the historical health records of a patient.

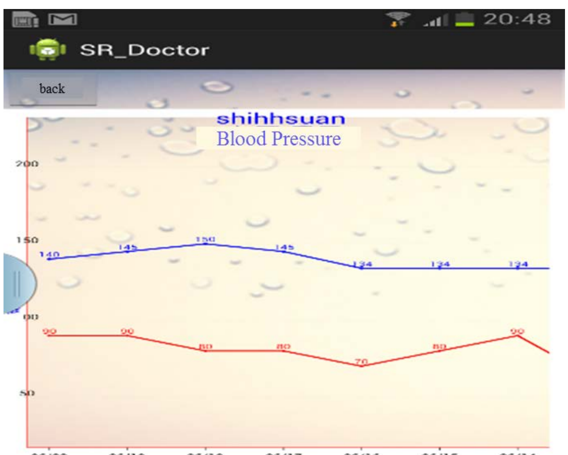


Figure 6. Doctor side function: display the change of blood pressure during the past one week.

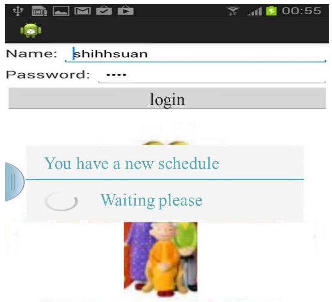
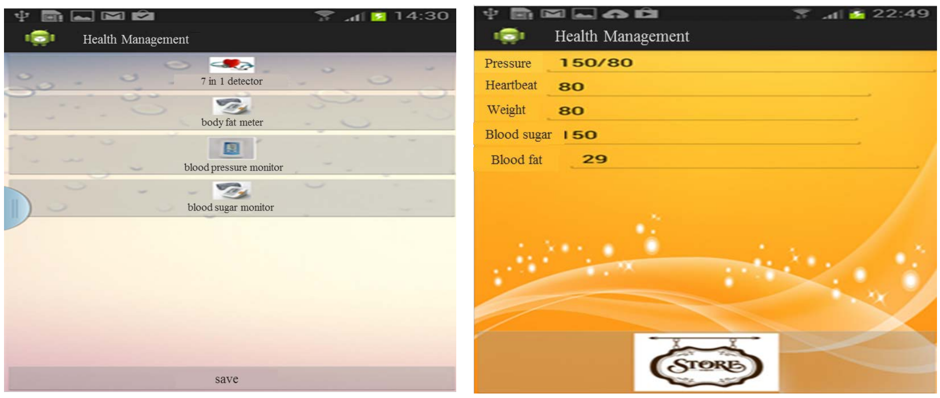


Figure 7. Patient side function: notification about a new exercise schedule from the system.



(a) (b)

Figure 8. Patient side function: (a) connect to a medical device and (b) upload the health record.

Figure 9. Patient side function: a real example to measure the body condition via a multi-function medical device.

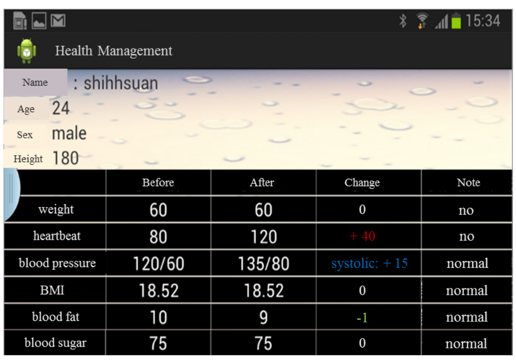
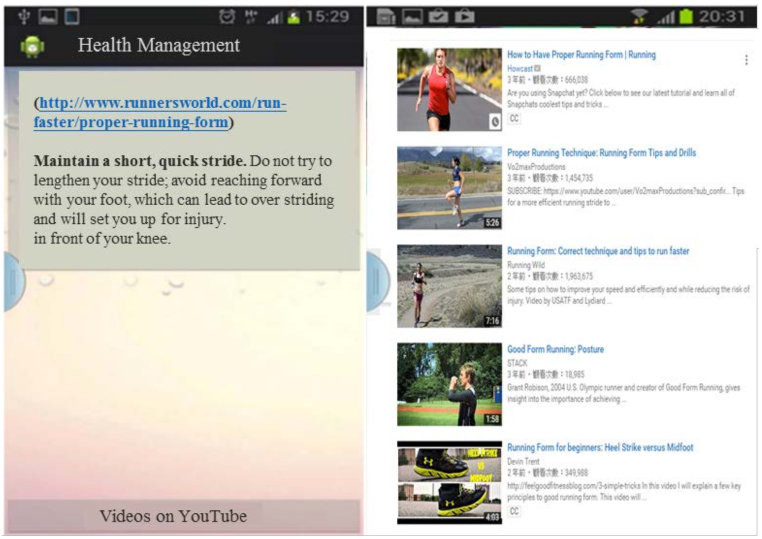


Figure 10. Patient side function: show the change results in terms of different measurement factors between the before and the after exercise.

(a)



(b)

Figure 11. Patient side function: (a) display the summary of suitable exercises and (b) show the correct way to perform a certain exercise in both text and video.

by developing a mobile application in the cloud. A user can easily connect some medical devices that support Bluetooth connection to the smartphone. The patient-doctor interaction is provided for performing regular body rehabilitations in home. A doctor can remotely monitor the patient's condition. Also, a patient can clearly understand his/her physical condition. The system can analyze the measured data to suggest suitable exercises to the user. In the future, a more complex data mining technique would be applied to precisely conclude or predict the body condition.

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