TOWARD MOBILE HEALTHCARE SERVICES BY USING EVERYDAY MOBILE PHONES

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Keywords: Healthcare, mobile phone, wireless biological sensor, electrocardiograph, skin thermometer, and 3-axis accelerometer.

Abstract: More than two billions people use mobile phones in the world of today. The mobile phones are not just potable telephones but portable computers which have WWW browsers with multi-task OS. In this paper, we specifically examine the possibility of mobile healthcare services by using everyday mobile phones. We describe a prototype system of the mobile healthcare services. It consists of the following components which cooperatively work with mobile phones: wireless biological sensors, mobile sensor routers, and sensor middleware. The service of the system aims to maintain and improve user's condition by monitoring one's biological sensing data, such as ECG, skin temperature, and body movement.

1 INTRODUCTION

Aged people have rapidly increased in most of advanced nations. In such matured societies, mobile and ubiquitous computing technologies which support healthcare services are important. In addition, more than two billions people use mobile phones in the world of today. As popularity of the mobile phones have increased, healthcare services using the mobile phones have drawn match attention from researches (Leijdekkers and Gay, 2006)(Oliver and Flores-Mangas, 2006). Although mobile services have been studied in mobile computing for many years, researches using everyday mobile phones with sensor technologies are very few. Recently, several researches which intended to detect user's contexts by using sensor devices embedded in a mobile phones are proposed in the field of ubiquitous computing (Lester et al., 2006)(Kawahara et al., 2007).

This research specifically examines the possibility of ubiquitous healthcare service by using everyday mobile phones. Although current mobile phones are regarded as portable computers which have various computational facilities, they have limited computational powers. Smartphones which have sufficient computational powers are proposed for several years. However, they have got little popularity for ordinary people.

In this paper, we describe a prototype for the mobile healthcare system by using everyday mobile phones and wireless biological sensors. To compensate the limited abilities of the everyday mobile phones, the prototype system consists of the following components which cooperatively work with mobile phones: *wireless biological sensors*, *mobile sensor router*, and *sensor middleware*. The system provides the healthcare service to maintain and improve user's conditions by monitoring one's biological information, such as heartbeat, posture, and movement. The system uses wearable wireless sensors, e.g., electrocardiograph, skin thermometer, and 3-axis accelerometer.

2 HEALTHCARE SERVICES USING MOBILE PHONES

To develop mobile healthcare systems, we have considered the following two healthcare scenarios.

Self monitoring services for physical exercises
When people are getting physical exercises, such as doing aerobics, it is important to monitor their current physical conditions for keeping appropriate strengths of the exercises. If their everyday mobile phones can show the conditions

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without special self monitoring devices, they can easily control the strength of the exercises. Thus, self monitoring for physical exercises using their mobile phones is an important mobile healthcare service.

Remote and self healthcare services for aged people Aged people and patients of heart diseases require preparing for unexpected health troubles. Their physical conditions should be remotely monitored by their doctors and family members. Thus, monitoring their current physical conditions, such as abnormality of ECG, is an important healthcare service using their mobile phones.

Under the vision of the above scenarios, we have developed a prototype system of the mobile healthcare services. Figure 1 shows an outline of the mobile healthcare system.

The system monitors user's physical conditions using an everyday mobile phone [1] and a wireless biological sensor [2]. To sense electrocardiograph correctly, it requires to be attached to user's chest by sticking electrodes of the sensor on tight with a peel-off sticker. Once it is attached to user's chest, it can detect the inclination and movement of the upper half of user's body by the 3-axis accelerometer.

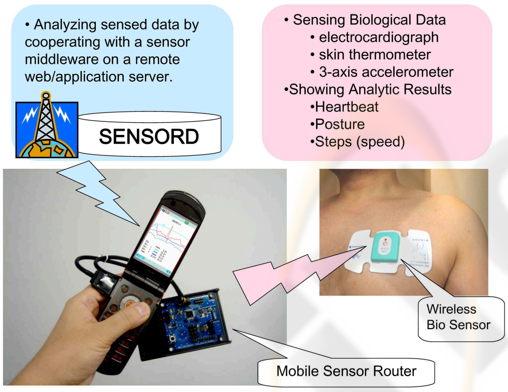

Figure 1: Healthcare services by using everyday mobile phones.

The system consists of *wireless biological sensors*, *mobile sensor router* and *sensor middleware*, and provides following facilities: 1) communicating to a wireless bio sensor via a mobile sensor router attached to user's mobile phone, 2) analyzing the sensed data by cooperating with sensor middleware on a remote server to capture one's conditions, and 3) providing personalized information for the user using GUI on the mobile phone.

Most of mobile phones popularly used in Japan can execute Java programs downloaded from Web sites. Thus, service processes in mobile phones are implemented by multiple threads running on the Java runtime environment. The processes includes collecting surrounding sensor data via a mobile sensor router, sending sensed data to a remote sensor middleware for analyzing them, and graphically showing analytic results of the sensed data.

The wireless biological sensor for sensing user's conditions is a small wearable sensor which integrates three kinds of built-in biological sensors: electrocardiograph, skin thermometer, and 3-axis accelerometer (see Figure 2).

Figure 2: Wireless bio sensor.

Figure 3 shows a mobile sensor router attached to a serial port (UART) of the mobile phones. The router has three main functions: *communicating with sensor networks*, *reducing the number of sensed data*, and *communicating with a mobile phone*.

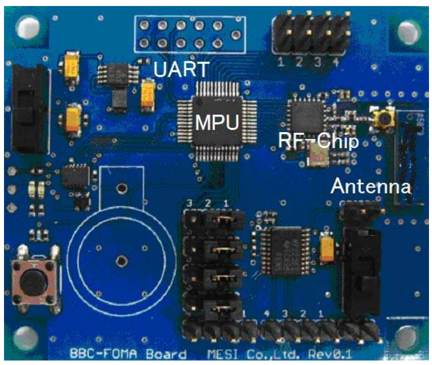

Figure 3: Mobile Sensor Router.

Although the router is able to receive full rates of sensor data stream from the wireless bio sensor, the

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[1] NTT-DoCoMo FOMA N903i: `http://www.nttdocomo.co.jp/english/product/foma/903i/n903i/index.html`

[2] MESI RF-ECG: `http://www.natureinterface.com/index.files/EK_panf.pdf(Japanese)`

mobile phone is not able to receive such amount of data stream. Thus, the router sends not raw data received from the sensors but reduced data of them at the router. It repeats the following processes to reduce the data:

1. clearing a sample buffer;
2. storing obtained sensing data for a certain period of time in the sample buffer;
3. calculating a representative value (e.g., average, maximum, minimum, latest) of the stored data in the sample buffer;

The size of the sample buffer is configurable. If the size is N, the process reduces by one Nth the number of sensed data.

To analyze sensed data for the healthcare service, sensor middleware, called SENSORD (Sashima et al., 2006), performs several signal processing and classification processes based on machine learning techniques, such as Discrete Fourier Transform (DFT), support vector machine (SVM), nearest neighbor learning. Using such algorithms, the sensed data is statistically analyzed or classified to some qualitative categories. The results of the analysis are used for the service to create suitable contents, such as HTML documents to be shown by the mobile phones.

3 USER INTERFACE OF THE SERVICE

User interface of the prototype system has the following three modes: *configuration*, *graph*, and *monitor*. In the rest of this section, we describe outlines of the service at the each mode.

3.1 Configuration Mode

In "configuration mode", users can configure several parameters of the services, such as transmission rates and sensor device id. Considering limited computational power of a mobile phone, we have decided a best transmission rate and a type to reduce the data for each sensor. We have also decided best transmission rates of the router for each sensor. Table 1 shows a default configuration of the sensors and the router for the healthcare service. Notice that all transmission rates of the router are smaller than the rates of sensors. This means that the data sent to the mobile phone is not raw sensor data but reduced sensor data.

In our implementation, the default configuration shows best results about processing the data. For example, when the transmission rates are more than the configuration values, the response time of the system is slow down, and showing classification results becomes delayed for several dozen seconds.

Table 1: Default configuration of the data transmission for the mobile healthcare service.

Sensing Data	Transmission Rate		Reduction Type
	From Sensor to Router	From Router to Phone	
Skin temp.	204 Hz	2 Hz	latest
ECG.	204 Hz	8 Hz	maximum
3-axis acc.	204 Hz	8 Hz	average

3.2 Graph Mode

In "graph mode", the system graphically shows user's biological statuses, such as ECG, in real time (see left side of Figure 4). The user can know their current physical conditions graphically, and control the strength of the exercise. In this mode, the received data from the router is directly shown on the display without data processing by the sensor middleware.

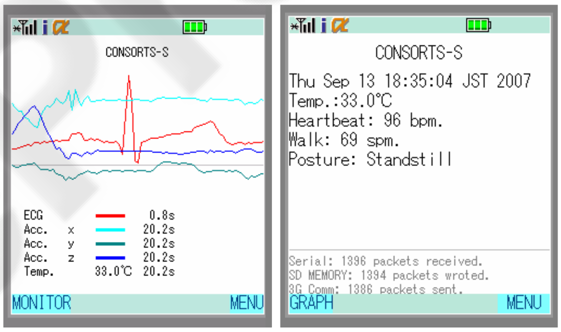

Figure 4: GUI of the healthcare service: graph mode (left side) and monitor mode (right side).

3.3 Monitor Mode

In "monitor mode", the system shows analytical results of user's sensing data. The results include numerical values representing the user's conditions, such as heartbeat. It also categorizes user's conditions into some qualitative statuses: running, walking, standing-still, etc. (see left side of Figure 4). The following analytical results are shown in this mode.

3.3.1 Posture Recognition

This process analyzes the sensed data to categorize user's postures into three categories: *standing-still, facing downward, and facing upward*. The postures are determined by calculating inclination of the upper half of user's body based on the values of the 3-axis accelerometer.

3.3.2 Movement Recognition

This process analyzes the sensed data to monitor user's movements, such as step speeds. The steps are recognized by calculating Discrete Fourier Transform (DFT) of finite length time series of sensed data of the y-axis accelerometer. In the current implementation, the length of the time series is 8 seconds (64 samples). When the middleware is asked to calculate the current steps, it retrieves the latest 64 samples from the data storage of the middleware, and calculate it. Then, it classifies user's statuses into three categories: *staying*, *walking*, *running* based on the results of DFT. When user's status is "walking" or "running," it also shows an average speed of user's movements as Steps Per Minute (SPM). The user can control his/her movements based on the information.

3.3.3 Heartbeat Monitoring

This process analyzes the sensed data to monitor the user's current status of heartbeat as beat per minute (BPM). The heartbeats are calculated by DFT of finite length time series of sensed data of the electrocardiograph. In the current implementation, the length of the time series is about 16 seconds (128 samples). When the sensor middleware is asked to calculate the heart beat, it retrieves the latest 128 samples from the data storage of the middleware, and calculates it.

As a prototype implementation of the remote healthcare scenario, emergency messages (email) are sent to a doctor and family members when the abnormality of the heartbeat and the posture are recognized.

3.3.4 Skin Temperature Monitoring

The biological sensor is able to monitor user's skin temperature. If the temperature is lower than 31 ℃, the system recognizes that the sensor is not attached to a human body.

4 CONCLUSIONS

In this paper, we have focused on implementing a prototype system of the mobile healthcare service by using not smart-phones but mobile phones with attachments, namely mobile sensor routers. Smartphones are still special devices for limited types of persons, such as businesspersons. By using the existing mobile phones, we have aimed to enable ordinary people to always collect and analyze their health information derived from wireless biological sensors. We have confirmed that cooperations between the current mobile phones, the mobile sensor routers, and the sensor middleware is able to provide the mobile healthcare service for the ordinary people. In future work, we plan to examine possibility of a general-purpose service platform for various mobile healthcare services by using everyday mobile phones.

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