WAITER: A Wearable Personal Healthcare and Emergency Aid System

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Abstract

The emerging pervasive computing is regarded as a promising solution to the systems of personal healthcare and emergency aid, which can monitor personal health status in a real-time manner and automatically issue the alert for medical aids in case of emergency. However, the implementation of such a system is not trivial due to the issues, including 1) the system operations without complicated caregiver aid to reduce cost of human resource, 2) vital sensor deployment for user comfort, 3) on-site vital data process and storage for energy saving in data transmission, and 4) timely communication with healthcare centre for reporting users' health status and seeking urgent medical aids. In this paper, we propose a novel wearable personal healthcare and emergency aid system, namely WAITER. Our system does not require specific caregiver aid. WAITER just employs the tiny wearable sensors to continuously collect user's vital signals and Bluetooth device to transmit the sensory data to a mobile phone, which can perform on-site vital data storage and process. After local data process, the mobile phone can use its GSM module to periodically report users' health status to the healthcare centre and issue alert for medical aids once detecting emergency. We believe that WAITER can satisfy the requirements of real personal healthcare and emergency aid system.

1. Introduction

All Healthcare is one of the most important social issues in the next few decades. As demographics shift and average life-span increases, a larger percentage of elderly will require medical care. Hong Kong Population Projections 2004–2033 [1] predicted that in 2033 about 27% of the Hong Kong population will be over the age of 65. The increasing percentage of elderly, combined with governmental healthcare shortfalls, which is 1230 millions in 2005/06 [2], and the rising cost of medical procedures, will become a heavy burden on Hong Kong healthcare services in the near future. Hospital Authority of Hong Kong estimated that the cumulative shortfalls will reach 7300 million in 2008/09 [3]. In fact, such problems are not only occurring in Hong Kong. In many other developed countries, such as U.S., the medical systems are facing the same problems: How to perform the elderly healthcare in an economical manner in term of both medical human resources and facilities?

Although the development of the traditional hospitals and health centers can alleviate these healthcare problems, the increasing users still cannot be effectively and efficiently served. Fortunately, in the comparison with the traditional approaches, the emerging mobile and pervasive computing technologies can provide more promising solutions to the personal healthcare in a low-cost manner. However, the implementation of a feasible personal healthcare and emergency aid system is not trivial due to the following challenging issues:

1) The healthcare system needs not the aid of specific caregivers to reduce the cost of human resources. The employment of specific nursing or medical person is highly cost, which cannot be afford by most of users.
2) The deployment of the vital sensors should consider the user comfort and not affect the users' behaviors. Although the many cheap and commercial vital sensors can substitute the caregivers to collect the health status data, the vital sensors attached on human body may incur considerable inconveniences to users' life and activities.
3) The raw sensory data need on-site processing and storage. It is widely accepted that the wireless data transmission cost very high energy consumption. The on-site data processing and storage can significantly reduce the amount of raw data to reduce the energy consumption in data transmission.

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4) The collected data should be periodically sent to the healthcare centre to allow medical experts to monitor the health status of users. More important, the system can detect the emergency and send the alert to the healthcare centre for timely medical aid.

In this paper, we propose a novel wearable personal healthcare and emergency aid system, namely WAITER, which can continuously monitor personal body status in a real-time manner and automatically issue the alert for medical aids in case of emergency. First, our system does not need any specific caregivers and is easily used. Second, WAITER employs the heart beat, motion, and body temperature sensors to continuously collect user's vital signals. Also, we use tiny Bluetooth device to transmit the raw sensory data. From the users' point of view, the device attached on the body is just a Bluetooth ear-set. This will not cause inconvenience to the users' life. Third, we use a mobile phone equipped with Bluetooth transceiver to receive the sensory data from the sensors to perform on-site data processing and storage, which avoid the continuous connection to the healthcare centre and reduce transmission cost. The mobile phone can use the attached GSM module to periodically send the health reports to the medical centre and issue timely alerts for medical aid in case of emergency. We believe that WAITER can satisfy the requirements of personal healthcare and emergency aid system in an effective, simple, and low-cost manner.

In the remaining part of our paper is organized as follows. Section 2 discusses the related works; section 3 introduces our hardware devices; section 4 describes the system design; section 5 presents the prototype implementation of WAITER; section 6 concludes the paper and discusses the future works.

2. Related Works

There are existing systems for the personal healthcare. Elite Care[4] is a personal healthcare system based on a smart space, where the sensors and wireless communication devices are deployed unobtrusively. These sensors and devices can monitor the health status and motion of users. Also, these devices can assist users summoning for aids. However, it is different from WAITER that Elite Care can only serve the people living in the specific smart space, which is highly cost and unlikely to be widely used.

CodeBlue is an Ad Hoc Sensor Network Infrastructure for Emergency Medical Care [5]. CodeBlue is designed to provide routing, naming, discovery, and security for wireless medical sensors, PDAs, PCs, and other devices that may be used to monitor and help patients. CodeBlue is designed to scale across a wide range of network densities, ranging from sparse clinic and hospital deployments to very dense, ad hoc deployments at a mass casualty site. CodeBlue is designed just for emergency medical care and cannot contribute to sickness prevention and early diagnosis. However, WAITER can collect the health status data of users and transmit them to the healthcare centre, which can be very helpful to the sickness prevention and early diagnosis.

In Hong Kong, Personal Emergency Link (PEL) system [6], established by Senior Citizen Home Safety Association (SCHSA), can provide emergency medical service for elderly or disabled people. The users of PEL can utilize an advanced communication system in home to contact a 24-hour PEL centre by pressing the main unit device or the portable remote trigger. The users can speak to the operator via the main unit device and the centre operators are able to provide the necessary medical services. However, at present, PEL cannot keep track the patients' health situation and is unable to actively issue an alert if the patient is unconscious. In addition, the effectiveness of PEL completely rely on the users how to understand their own health status. Obviously, WAITER allows the caregivers to more accurately understand the status of the users based on the collected sensory data rather than the users' own oral description. In addition, WAITER can automatically ask for the emergency aid even when the users are unconscious.

AMON [7] is an advanced care and alert portable tele-medical monitor (AMON), targeting at healthcare for high-risk cardiac/respiratory patients. The functions of AMON include continuous collection and evaluation of multiple vital signals, intelligent medical emergency detection, and a cellular connection to a medical centre. AMON integrates all parts into an unobtrusive, wrist-worn enclosure and applies aggressive low-power design techniques. Thus, the patients can wear AMON without the restrictions to daily activities and mobility. However, AMON needs to integrate the GSM module into it, which has not well used the commercial products of mobile phone and caused high cost. Compared with AMON, WAITER just uses Bluetooth to combine the wearable data collection device and mobile phone, which can achieve a lower cost. In addition, this also allows WAITER to have a smaller size compared with AMON, which allows users more convenient to use this device.

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3. Hardware Devices

In this section, we discuss the hardware devices used in our system, which is composed of wearable vital signal collection device, a mobile phone, and a data server deployed at the healthcare centre.

3.1. Wearable Vital Signal Collection Devices

The wearable vital signal collection device (see Fig. 1) mainly includes three different kinds of vital signal sensors and a Bluetooth wireless communication device. The sensors are heart beat sensor, the motion sensor, and the body temperature sensor, respectively. The Bluetooth wireless communication device is used to send out the raw data from sensors. Since the users can conduct the daily activities with this device, all of the components are powered by batteries.

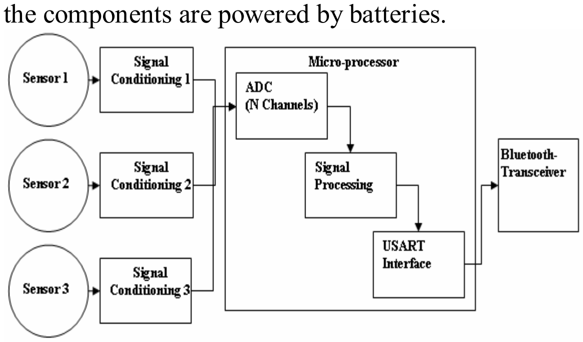

Fig. 1 the architecture of wearable vital signal

The heart beat sensor, also named pulse sensor, can detect the heart pulse non-invasively with the Photoplethysmography (PPG) technique, where a pair of infrared light emitter and detector capture the variations of the reflected light by the body surface. The wavelength of the infrared sensor was around 900 nm to optimize the measurement. This design has adopted reflective sensing instead of penetration method, which can reduce power consumption than human body penetration and be applied on wider parts on body, such as on the wrist and neck.

A low cost, low power, complete dual-axis accelerometer has been used as the motion sensor. By measuring and monitoring the body movement of the user, the motion sensor can help to determine where a user has faced any difficulty in movement or fallen at home, hence providing instant aid to the user. Furthermore, the motion information can act as a reference signal to determine whether the measured signals from other sensors have been affected by the motion of users and be used to minimize the impact of motion to other vital signals.

To remain non-invasive, this wearable device would only measure the skin temperature. The temperature sensor used is a precise integrated-circuit semi-conductor, which varies the output voltage with the Celsius (Centigrade) temperature proportionally.

The Bluetooth wireless communication device includes microprocessor, and a Bluetooth wireless transceiver for data communication. This device provides a wireless channel between the wearable vital signal collection devices and the mobile phone. Once the device receives the data from the sensors, it will forward the data immediately to the mobile phone via an established Bluetooth data transfer channel. An implementation prototype is built into a box with a dimension of 2 x 2.5 x 4 cm3, as shown in Fig. 2.

Fig. 2 The prototype of wearable vital signal collection device

3.2. Mobile Phone

In our prototype system, we use a NOKIA8250 (see Fig. 3) as on-site data processing and storage centre. Since NOKIA8250 has already been equipped with a Bluetooth transceiver, it can directly receive the raw data sent by wearable vital signal device. Meanwhile, NOKIA8250 also support J2ME and, based on the Java platform, we develop the software to allow the mobile phone to conduct on-site data filtering and validation, hourly report generation, emergency detection, and the alert issuing. After the data processing, the mobile phone can transmit the data to the data server deployed at the healthcare centre via GSM system.

Fig.3 the mobile phone, NOKIA8250

3.3. Data Server

The data server at the healthcare centre is equipped with a GSM module. Thus, the server can receive the data reports from the mobile phone for different users. The server will store the reports in the local database

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and the caregivers can access the database to learn about the users' health status. Also, the server can receive emergency alert from a specific user and then, immediately ask medical aid for the user.

4. System Design

In this section, we discuss the system design of WAITER. First, we describe the system architecture. Then, we discuss the communication protocols between the wearable vital signal collection device and the mobile phone. Finally, we propose the algorithm used by the mobile phone for data processing.

4.1. System Architecture

As shown in Fig. 4, WAITER is mainly composed of four components, including the wearable vital signal collection devices, the mobile phone, and the server deployed at the healthcare centre. The sensors in the wearable vital signal collection devices will continuously perform a sampling every 0.05 second. Also, the Bluetooth transceiver will continuously transmit the raw sensory data to the mobile phone (see Fig. 5).

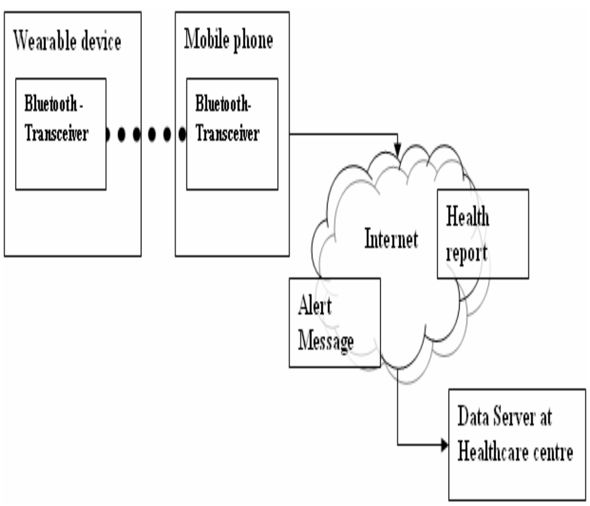

Fig. 4 the system architecture of WAITER

The mobile phone can locally process and store the received sensory data. Based on these data, the mobile phone can generate hourly reports for the user's health status. Also, the mobile phone can detect the emergency of the users and generate an alert for medical aid. Once the mobile phone generates a report or an alert, it uses its GSM module to communicate with the data server at the healthcare centre and transmit the corresponding content to the server, as shown in Fig. 5. In addition, the mobile phone provides interfaces for the users to check and learn about their own health statuses. In addition, the interfaces allow the users to specify the personal preferred parameters, where the system can be easily customized.

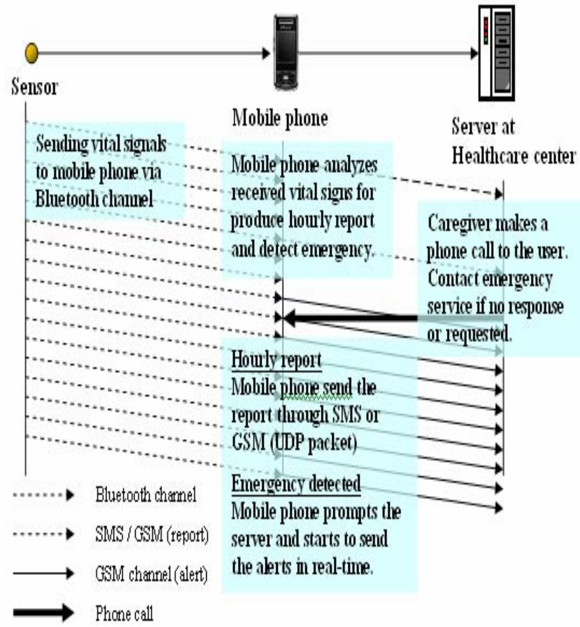

Fig. 5 the functionalities of the WAITER system

The data server located at the Healthcare Centre mainly has the four functions, including 1) receiving the users' hourly reports from the users and storing them in the back-end database, 2) authorizing login request of the caregivers, 3) allowing authorized users accessing the data, and 4) asking for the medical aid of suitable caregivers or directly call for the emergency services once receiving alerts.

4.2. Protocol Design for Sensory Data Transmission

The wearable device needs continuously collect the vital signal and transmit the sensory data to the mobile phone. Obviously, this will consume a large amount of energy because the sensor will perform 20 times of sampling in every second. On the other hand, a packet of Bluetooth protocol has about 16 bytes for control and header message and about 383 bytes for payload. After every sampling, the sensors can generate only 8 bytes raw data. If the wearable device just sends a packet for the sensory data of every sampling, the utility of the packet will be very low. Thus, we allow the wearable device to cache the sensory data temporarily. When the device obtain sufficiently large amount of sensory data, it can send all the cached raw data in one packet to the mobile phone.

Another problem in the protocol design is that J2ME platform has not provided any synchronization

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mechanism for the communication participants. This can cause the packet loss, since the mobile phone cannot determine when the packet will be sent. Thus, we propose a simple, yet effective mechanism to synchronize the mobile phone and the wearable device.

As shown in Fig. 6, the mobile phone periodically sends a control message, namely "sending start", to the wearable device. Once the wearable device receives the "sending start" packet, the device continuously sends out a specified number of sensory data packets. Then, the mobile phone can receive the packets properly and detect the packet loss.

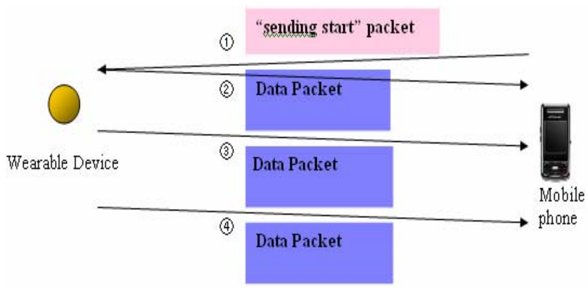

Fig. 6 the protocol for sensory data transmission

In addition, using the "sending start" packet, the mobile phone can modify the data sending frequency in case of emergency. When the mobile phone detects the emergency from the received data, it will more frequently send out the "sending start" packet to obtain the sensory data more quickly. Thus, the mobile phone can more accurately identify the emergency of users in a shorter time.

4.2. Protocol Design for Sensory Data Transmission

Recall that a mobile phone has two mainly functions, including hourly report and emergency detection and alerting. In this sub-section, we mainly describe the emergency detection on mobile phone in details. The system will detect the emergency by following the steps shown in Fig. 7. In addition, we provide a flowchart to present the details (see Fig. 8).

5. Prototype Implementation

In this section, we show the prototype implementation of WAITER. The prototype of the wearable vital signal collection device has been shown in sub-section 3.B. Due to the limit in space, we can only show the prototype implementation on the mobile phone. We have developed the software on J2ME platform on NOKIA8250 for data processing and storage. Also, our implementation provides the interfaces for users to check and learn about their own

1. The mobile phone is waiting for the new packet;
2. When the mobile phone receives a new packet of vital signal, it begins to analyze the newly arrived data and determines the occurrence of emergency;
3. If the newly received data is laid in the normal range, the danger level will be decreased. User situation is "Normal". The system goes to 1;
4. If the received sensory data is not stay in the normal range, the danger level will be increased;
5. The system checks whether the danger level is within acceptable range. If the level is within the acceptable range, it means that such abnormal situation has not existed sufficiently long time and the system still need more time and data to determine the occurrence of emergency. The system goes to 1;
6. If the danger level is higher than the acceptable range, an alert will be created and invoke the sending emergency alert function;
7. The system goes to 1.

Fig. 7 the mechanism of emergency detection

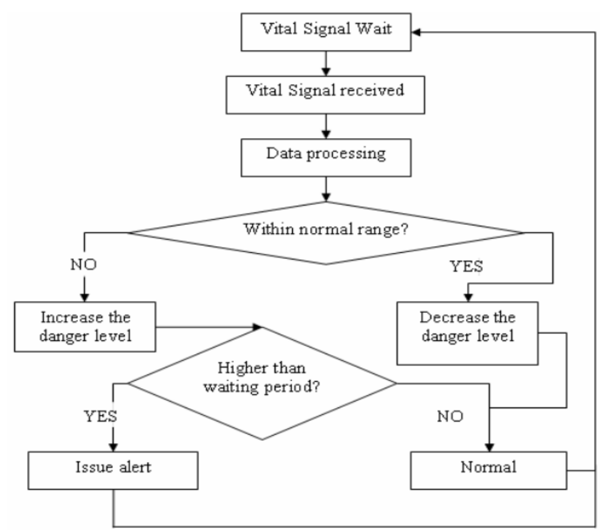

Fig. 8 the flowchart for emergency detection

health status. In addition, we provide the interfaces for users to specify the personal preferring parameters and customize the system. We mainly show the user interfaces for the visualized presentation of collected vital signals and the threshold specifying for different vital signals for emergency detection. As shown in Fig. 9, when the mobile phone receives the sensory data, it presents three different vital signals, including heart beat rate, the body temperature and motion acceleration from up to down. Also in Fig. 9, we show

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the thresholds of vital signals specified by the users. The alert will be issued once the received sensory data beyond the specified range.

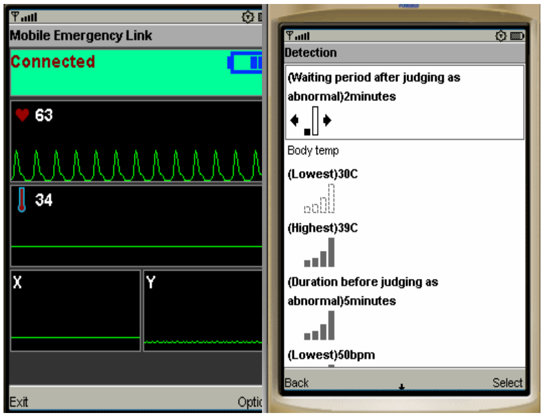

Fig. 9 the prototype implemented on the mobile phone

6. Conclusion and Future Works

In this paper, we have proposed a novel wearable personal healthcare and emergency aid system, namely WAITER, which can continuously collect personal health status, periodically send the status reports to healthcare centre, and rapidly issue the alerts for medical aid in case of emergency. WAITER can be easily used without any specific aid from caregivers. Taking advantages of wearable devices, the system can be attached on human body but will not affect the users' daily life and activities. Employing Bluetooth devices and on-site data processing and storage on a mobile phone, WAITER can effectively reduce the product cost and communication energy consumption.

However, still some problems need to be investigated in future. At the present, our system is equipped with three different kinds of sensors, including heart beat sensor, motion sensor, and body temperature sensor. We are still working on integrating more sensors, such as blood pressure sensors, to the system. Using more sensors, the health status of a user can be more comprehensively learned by the caregivers and then, they can make more accurate medical decision. Also, we are considering how to enhance the security of our system. Since the health status of a user is a private issue, the corresponding information should be protected from the eavesdropping on wireless channels.

Acknowledgement

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