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ORIGINAL ARTICLE

A wearable mobihealth care system supporting real-time diagnosis and alarm

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Abstract This paper describes a wearable mobihealth care system aiming at providing long-term continuous monitoring of vital signs for high-risk cardiovascular patients. We use a portable patient unit (PPU) and a wearable shirt (WS) to monitor electrocardiogram (ECG), respiration (acquired with respiratory inductive plethysmography, RIP), and activity. Owing to integrating fabric sensors and electrodes endowed with electro-physical properties into the WS, long-term continuous monitoring can be realized without making patients feel uncomfortable and restricting their mobility. The PPU analyzes physiological signals in real time and determines whether the patient is in danger or needs external help. The PPU will alert the patient and an emergency call will be automatically established with a medical service center (MSC) when life-threatening arrhythmias or falls are detected. With advanced gpsOne technology, the patient can be located and rescued immediately whether he/she is indoors or outdoors in case of emergency.

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1 Introduction

In recent years there has been an increasing interest in wearable telemedicine monitoring system both in research and market areas. Wearable telemedicine, which can provide noninvasive and continuous monitoring of multiple physiological parameters, is expected to be the most important and feasible method under the new generation medical care system. Intelligent wearable electronics and telemedicine are very promising development areas, which will extend monitoring, increase patient's comfort, and improve the living standard of patients [10, 16,18, 24].

Traditional personal medical monitoring systems, such as Holter monitors, have been used to collect data for off-line processing. Systems with multiple sensors typically feature many wires between the electrodes and the monitoring devices. These wires may limit a patient's activity and reduce the level of comfort. Therefore, there has been an increasing interest in healthcare monitoring devices with wearable technology. In recent years, there has been a proliferation of consumer wearable monitoring devices for sports area and recreational market. There are sophisticated devices available today [19] that provide real-time heart rate information and let users store and analyze their physiological data on their home PCs. Bodymedia [3] has developed an armband that can measure galvanic skin response, skin temperature, activity, and heat flux. However, in all cases the physiological data is analyzed on a home PC at a later time.

Monitoring physiological parameters in a mobile environment has been widely studied by many research groups

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and there are many commercial products available. However, the majority of such existing devices are more or less not satisfying. Lifeguard [13] has been successfully used in a number of application domains. But too much disturbing sensors, electrodes, and wires make the device very difficult to use. AMON [1] is a wearable (wrist-worn) medical monitoring and alert system. It includes multiple vital signs monitoring, online analysis, and a cellular connection to a medical center. But the system cannot provide good performance in the detection of ECG. Moreover, the monitoring of ECG is not continuous since that during a measurement the device must touch the left hand, the right hand, and the abdomen of the wearer. Vitalphone [23] with built in global positioning system (GPS) can record ECG with a mobile phone and transmit data to a service center where the diagnosis can be made. But it does not provide online diagnosis and can only locate an outdoor patient with the GPS antenna having an unrestricted view of the sky.

Several research projects consider processing the medical data on a local device. EPI-MEDICS [8] is able to detect standard 12-lead ECG, make online diagnosis, and raise alarms. But it is not a continuous monitor since that the patient turns on the device only when he/she feels uncomfortable. MOLEC [20] provides real-time classification of ECG on a PDA and forward alarms to the hospital in case of high-risk arrhythmias. But the above two devices are both not really wearable devices.

Perhaps the most relevant project to our work is the WEALTHY [17] aiming to design a garment with embedded ECG sensors, respiration sensors, and activity sensor for continuous monitoring of vital signs. WEALTHY is based on a wearable interface implemented by integrating fabric sensors, signal processing, and telecommunication on a textile platform. But the authors report neither experimental results in a real setting nor algorithms for automatic diagnosis and alarm. Effective GPS has not been integrated in the WEALTHY.

Our system aims to provide long-term continuous monitoring of vital signs for high-risk cardiovascular patients. It includes real-time collection, online diagnosis, automatic alarms, secure wireless links, and effective locating mechanism. Given all previous work, the most innovative aspect of our project is the combination of wearable monitoring and real-time diagnosis, our system has following several unique features.

1. Highly integrated wearable system: Sensors and electrodes had been designed to be non-intrusive for health status monitoring.
2. User friendly designs: Since that the hardware of the WS are designed to be removable from the WS and the tracks embedded in the WS are made of special textile materials resistant to be twist, the washability and reusage of the WS had been realized. Moreover, since that the connection between the PPU and the WS is designed to be wireless, the hardware size of the WS is greatly reduced, therefore patients will feel more comfortable.
3. Online diagnosis and automatic alarms: The system provides online diagnosis and three degrees alarm on local portable device (PPU). This will reduce communication costs because only anomalous physiological signals are transmitted to the MSC.
4. Advanced locating mechanism: Applying with gpsOne technology, the patient can be located whether he/she is indoors or outdoors.

This paper describes a wearable mobihealth care system composed of three parts: the WS, the PPU and the MSC. Figure 1 shows a schematic overview of the system. The fabric sensors and electrodes endowed with electro-physical properties enable the realization of wearable shirt capable of continuously recording a full 12-Lead ECG, respiration, and activity. The physiological signals measured by the WS are transferred to the PPU via short-range wireless communication. The PPU provides real-time visualization, memorizing, analysis, diagnosis, and three degrees of alarm. In case of emergency, an emergency call will be automatically initiated and an immediate act of rescue will be taken according to the location information of the patient acquired through gpsOne. Moreover, the PPU also has three manually activated buttons for summoning helps. The MSC is composed of a medical data server (MDS) and many monitoring terminals (MTs), where the doctors and medical assistants will provide around-the-clock medical helps. The physiological data received from the PPU will be processed by specialized software running on the MT and more detailed diagnosis information would be provided.

2 Methods

2.1 Development of the WS

The WS mainly woven with cotton and lycra materials is comfortable like a common article of T-shirt. The position of the electrodes and sensors is fixed and the elasticity of the WS allows a good fitting to the body. The WS consists of electrodes, sensors, and a small-size printed circuit board (PCB) (Fig. 2). The PCB includes four blocks: power supply (a 3.7 V 14500 size cylindrical Li-Ion cell with a capacity of 750 mAh), MCU (Cygnal C8051F330), analog circuit, and short-range communication unit. To reduce the power consumption of the WS, the physiological signals are

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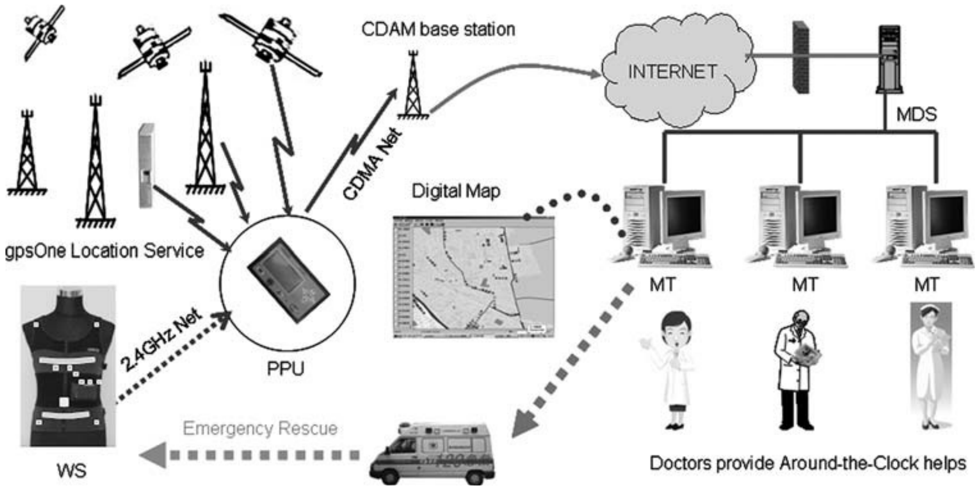

Fig. 1 System overview of the Wearable Mobihealth care system

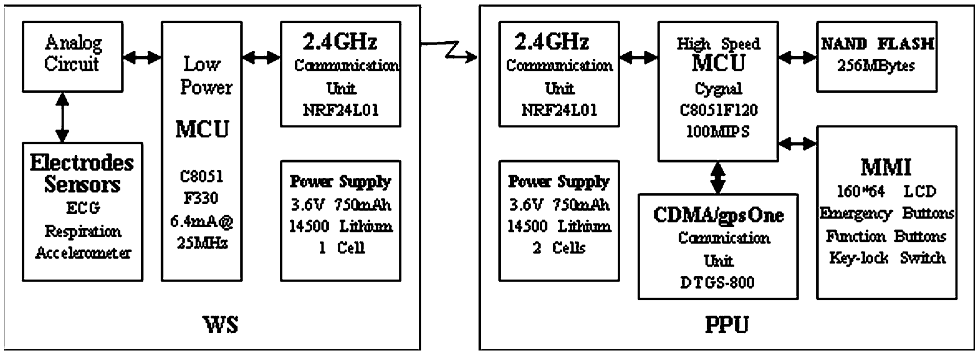

Fig. 2 Block diagram of the hardware of the WS and the PPU

only detected and digitalized in the WS. The processing work will be implemented in the PPU. To facilitate washing, the PCB in the WS is designed to be removable from the shirt. The prototype of the WS is shown in Fig. 3, where the position of the electrodes and sensors is highlighted. In the picture eight ECG electrodes (RA, LA, LL, RL, V1–V6) are shown respectively, while the two respiration sensors and the activity sensor are positioned on the thorax, the abdomen, and the waist, respectively. Three types of sensors and the methods used to develop the WS are described in the following section.

Fabric electrodes used to measure ECG signals substituting for conventional gel electrodes are knitted with stainless steel threads and textile yarns. The advantage of fabric electrodes is nonirritating character and the possibility of integration in a shirt. The major drawback is the inherent high skin-electrode impedance, which leads to a reduced signal-to-noise ratio (SNR). The AC coupled cir-

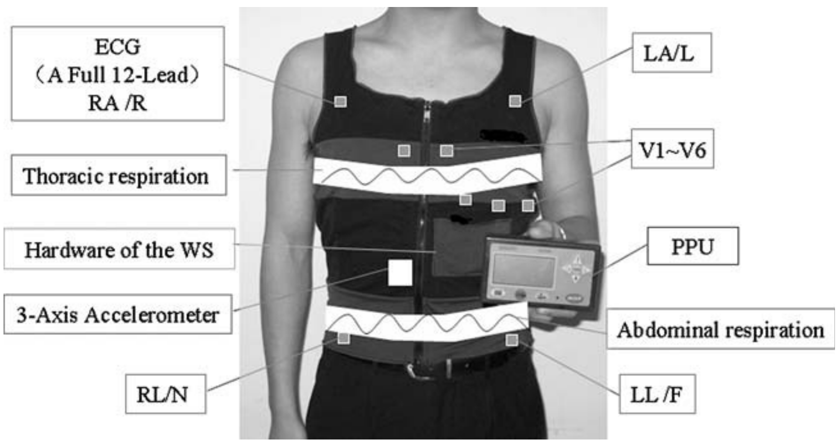

Fig. 3 The prototype of the WS and the PPU

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cuit and the right leg driver were used to improve the common mode rejection [22]. In order to reduce the contact impedance of the skin and improve the electrical signal quality in dynamic condition, the hydrogel membrane has been added to the surface of fabric electrode. The system is able to acquire a full 12-Lead ECG by collecting signals through eight input channels simultaneously. The eight input channels (II, III, V1–V6) sampled at 200 Hz with a 10 bit resolution analog to digital (A/D) converter embedded in the MCU (C8051F330). Each input channel includes a differential preamplifier with a gain of 8, a high-pass filter with 0.05 Hz cutoff frequency, a fourth order Butterworth low-pass filter with 100 Hz cutoff frequency, and a main amplifier with a gain of 125. Figure 4 shows an example of the acquisition of ECG signals with fabric electrodes.

With regard to the detection of the respiration, we apply an advanced respiratory monitoring method called RIP. By virtue of its design, RIP reduces the signal interference and distortion that is often associated with other monitoring technologies, enabling clinicians to obtain more accurate measurements of respiration. RIP measures changes in the cross sectional area of the rib cage and abdomen over time and applies a series of proprietary algorithms to the data to calculate the amount of air either inhaled or exhaled during respiration [5]. A new type patented RIP was designed to acquire high quality signals and lower system power cost [25]. To measure respiratory function, sensors are woven into the shirt around the patient's chest and abdomen. Two parallel, sinusoidal arrays of insulated wires embedded in elastic bands are woven into the Shirt, surrounding the rib cage and abdominal areas of the torso. Usually a colpitts oscillatory circuit is used to design the RIP by measuring the oscillatory frequency and the changes in cross sectional area that occur during breathing is indirectly measured. As the two body chambers expand and contract, the electrical sensors generate different magnetic fields that are converted into proportional voltage changes over time (i.e., waveforms) [6]. In this new patented RIP, pulse amplitude modulation technology was used. Extremely high electrical current is passed through the wires in extremely short time, in this short time the signal is sampled and held. A high SNR was acquired because of the high input electrical current, but the system power cost was reduced because of the very short exciting time. The electrical current is passed through the wires of the abdomen and rib cage in turn in 100 μs and each wire is excited in 50 Hz. Thus the sample rate of respiration is 50 Hz. Figure 5 shows an example of simultaneous acquisition of respiration and ECG signals from a walking person wearing the WS. It is very evident that high-quality signals could be acquired with the WS.

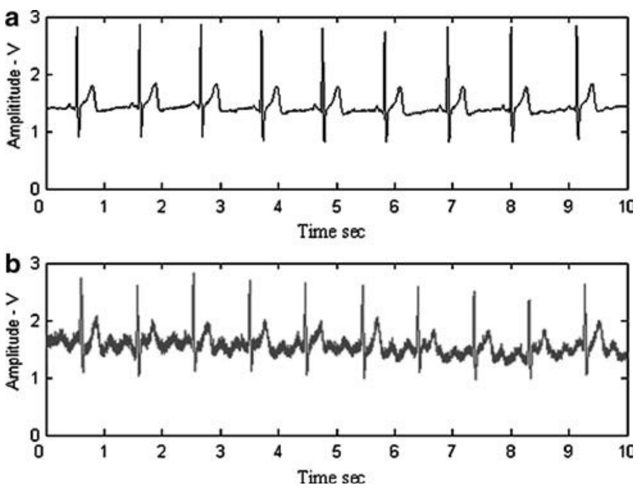

Fig. 4 Example of ECG signals obtained from fabric electrodes: **a** with hydrogel membrane, **b** without hydrogel membrane

Accelerometer has been proposed as being suitable for monitoring human movements and has particular applicability to the monitoring of free-living subjects. It has been used to monitor a range of different movements including gait, sit-to-stand transfers, postural sway, and falls. As for our system, the main purpose is to monitor abnormal events, such as falls or long periods without movement. Falls are very serious risk for the elderly, particularly for those living in the community. It has been proved that a change in orientation from upright to lying that occurs immediately after an abrupt and great negative acceleration (due to impact) is indicative of a fall [14]. In order to assess daily physical activity, accelerometers must be able to measure accelerations up to ±1.5 g when they are attached at waist level (near the centre of mass of the subject). To meet these requirements, a triaxial accelerometer, Freesclae MMA7260, was used to implement human fall detection in our system. The MMA7260 features signal conditioning, low pass filter, and temperature compensation. Figure 6 shows the signals from the MMA7260 sampled at 45 Hz when a subject performing a test.

2.2 Development of the PPU

The PPU includes six blocks (Fig. 2): power supply (two 3.7 V 14500 size cylindrical Li-Ion cells with a capacity of 750 mAh), MCU (Cygnal C8051F120), man–machine interface (MMI), memory, short-range communication unit, and CDMA/gpsOne communication unit. The PPU can display two-channel ECG or respiration signals with a 160 × 64 dot-matrix LCD. Other information, such as heart rate, respiratory rate, and battery status are displayed on the right side of the LCD. To facilitate operation, the PPU provides five functional buttons, three emergency-aid buttons, an on-off button, and a key-lock switch. The three emergency-aid buttons make the patient obtain rapid

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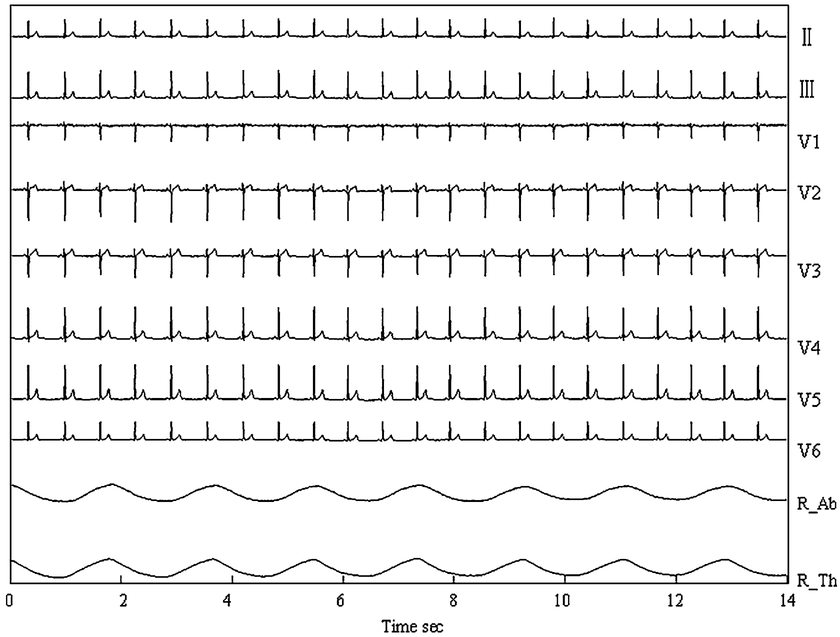

Fig. 5 Simultaneous acquisition of 8-channel ECG, abdominal respiration, and thoracic respiration from a walking person wearing the WS

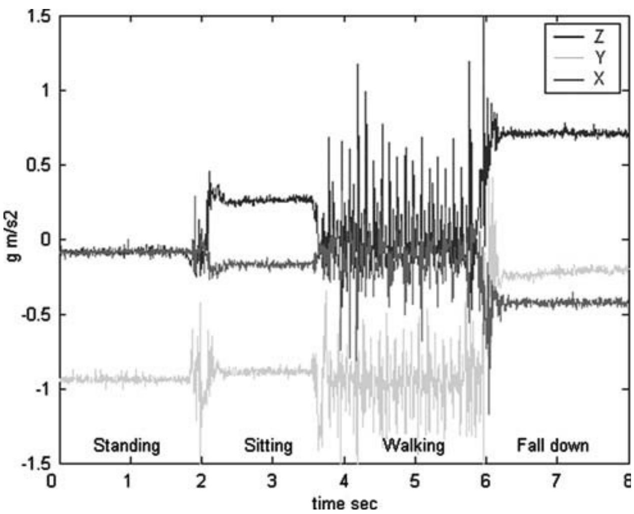

Fig. 6 Triaxial signals acquired from a waist-mounted accelerometer with *Y* axis in reverse gravitational direction during a test

external helps by establishing voice link with the MSC, local first-aid center, or a friend. The key-lock switch can avoid operating wrong.

In order to provide real-time health care for the patient without continuously transmitting medical data to the MSC, the physiological signals will be processed and diagnosed in the PPU. The application in the PPU receives the measurements from the WS and determined whether an abnormal event occurred and raise an alarm through real-time analysis and diagnosis. The PPU has three degrees of alarm. A minor one indicates that a not so important abnormality has been detected and some suggestions will be given to the patient. That includes ST segment (STS) changes and QRS amplitude (QRSA) changes. A medium one indicates life-threatening arrhythmias have been detected. To avoid raising false alarms, the PPU will receive physiological signals for a period of time (currently 10 s) and make a diagnosis. If life-threatening situation is still detected, the PPU will ask the patient for confirmation of an automatic emergency call. The patient can disable the alarm in case of a false alarm. If the patient does not react within a certain time (currently 10 s), an emergency call will be automatically initiated. A major one indicates a fall has been detected and the patient cannot stand up by himself. An emergency call will be automatically initiated.

As for the respiration signals acquired with RIP, we mainly use them to acquire a very accurate non-invasive measurement of ventilation and non-invasive detection of sleep apnea syndrome in the future. In current prototype, the tidal volume has been able to be accurately calculated, but the study of sleep apnea monitoring is still in the development period. In this section, we will focus on the process of the ECG since it is the most important physiological parameter. To realize real-time arrhythmias classification in the PPU, some simple and accurate processing algorithms must be performed. These algorithms include removal of interferences, QRS complex, P wave and T wave detection, arrhythmias classification, and fall detection.

In order to acquire high-quality ECG for arrhythmias classification use, some digital filters must be applied to remove noise and interference. A subtraction procedure was applied to remove power-line interference [7, 12]. The procedure is simple and has good performance in coping with changes in amplitude of the power-line interference. A high-pass filter with QRS complex elimination was applied to remove baseline drift [4]. The procedure applies a fast linear-phase low-pass filter to extract the baseline drift and then subtract it from the original ECG signals. The heart beat classification is the most important part in the software design of the PPU. In the first prototype, we define the minor alarm occurs in the situation that STS > 0.2 mV, STS < –0.1 mV, QRSA > 2.5 mV, or QRSA < 0.5 mV. We apply "So and Chan" QRS detection method to detect QRS complex, P wave, and T wave [21]. It selects the first derivative approach, which had been proven the good performance even though the ECG signal was corrupted by high-level composite noise. The ST segment can be simply acquired by adding about 100 ms to the R point. As for the medium degree of alarm, we focus on two life-threatening arrhythmias: ventricular tachycardia (VT) and ventricular fibrillation (VF). To detect these arrhythmias we used the open source software developed by E.P. Limited, which includes a C implementation of heart beat classifier [9]. This classifier is able to classify the heart beat as NORMAL, premature ventricular contraction (PVC), or UNKNOWN. Since that the open source software cannot recognize VT or VF, we classify the PVC and UNKONWN as VT or VF using the method of sample percentage in the dynamic range (SPDR) and complexity measure (CM) [2]. We use MIT/BIH Arrhythmia Database to test the heart beat classification algorithm. The accuracy percentages for VT and VF are 82.5 and 92.3%, respectively. The result proved the classifier can provide a very good accuracy for arrhythmias detection and classification.

In the design of the major alarm, patient's falls must be detected in real time with high accuracy. Each of the three axis's signal sampled at 45 Hz was pass through a median filter of 13 samples in order to remove noise. Then a high pass finite impulse response (FIR) filter of order 35, with a cutoff frequency at 0.25 Hz was applied to each axis's signal. Finally, a non-overlapping moving window with a length of 0.8 s (36 samples) was applied to each axis signal. The energy expenditure can be acquired [15]:

$$\text{Energy\_expenditure} = \alpha\left(\int |x^2| + \int |y^2| + \int |z^2|\right)$$

where α is a constant of proportionality, in our case α is 1.

The detection of a fall will be performed comparing the energy expenditure value with a specific threshold obtained by experiments.

2.3 Development of wireless communication

The main task of the short-range wireless communication is to transfer physiological signals measured from the WS to the PPU. The two main open standards currently used for medium data rate transfer are Bluetooth and Zigbee, which have advantage in good connectivity between equipments from different manufacturers. But they neither have optimum price nor power consumption. In our system, we used Nordic nRF24L01, which features low-cost, low-power, and high speed, to build short-range communication unit. To avoid the abrupt disconnection of the short-range communication, both the PPU and the WS would alert the wearer with sound and vibration when the PPU is taken too far away from the WS (more than 10 m).

We utilize CDMA data link as air interface. To ensure the reliability of the data transfer, we use TCP/IP protocol to perform error detection and flow control. The gpsOne technology is an advanced positioning solution that utilizes assisted GPS (AGPS) alone or in combination with wireless network measurements to create reliable and accurate location information.

The system uses a CDMA data module, AnyDATA DTGS-800, to establish CDMA communication and acquire the location information. The module supports not only CDMA 2000 1× air interface, but also gpsOne position location capability. It uses QUALCOMM MSM6050 chipset, which provides three modes of operation in gpsOne function (MS-Based, MS-Assisted, and MS-Assisted/Hybrid). Applying with gpsOne technology, we can immediately locate the patient in case of emergency whether he/she is indoors or outdoors. In this way, the patient is able to walk out of room to any place without worrying whether he/she is in familiar surroundings or at a location that he/she does not know. The CDMA module was designed to support four types of communication channels.

1. SMS: It is used for command messages such as set emergency phone numbers.
2. Voice call: It is used to establish a voice link in case of emergency.
3. Packet data service: It is used to build a data connection with the MSC based on TCP/IP protocol.
4. gpsOne function: It is used to get the location information of wearer through gpsOne function.

The communication protocol has been designed in such a way that short-range wireless communication, the SMS, and the packet data service rely on the same structure: header, raw data, and tail. The header includes the flag explaining the type of the content, the length of the content, and sequence of the current type of data. The raw data includes medical data, the location information, or the command information. The tail is used to check errors.

2.4 Development of the MSC

The MSC composed of a MDS and many MTs can be set in a hospital or a health care provider. The MSC will arrange doctors or medical assistants to keep a 24-h watch and provide around-the-clock medical helps. The MDS is responsible for receiving medical data from the PPU via Internet/GPRS and transferring them to a certain MT. Every MT managed by several doctors and medical assistants is in charge of a certain amount of patients. The authorized doctors have ability to access the patient's archive including personal information, medical history, and medical records. The MSC enables emergency management, medical data processing, database management.

When an emergency call with the MT was established by the PPU, the MT would send alarms to the doctors, and then the doctors will ask the patients about their illness and instruct them to save themselves by phone. Under emergency, rescue will be initiated according to the location information. At the same time, the medical data received from the PPU will be displayed and analyzed in real time in the MT. The specialized software running on the MT enables visualization, archiving, analysis, diagnosis, and printing for the medical data. Had been initially processed in the PPU, the medical data will be father analyzed with the high-level algorithm in the MT. We use Hermite function representation and self-organized neural networks to classify the different types of heart beats. The procedure devised by Lagerholm et al. [11] is based on Hermite-function encoding of QRS complexes. A self-organized feature map is used to cluster the encoded QRS complexes. Decomposing the beats into five Hermite functions turns out to be sufficient for achieving good classification accuracy (98.5%). The procedure also has a good performance in real-time processing. Only less than 1 minute is needed to classify a 30-min one channel ECG signals. With this high-level algorithm, the MSC can provide rapid and accurate analysis and diagnosis.

The medical data will be shared in the MDS. The authorized hospitals with the usernames and the passwords, can access to the medical data via secure Internet.

Different security issues must be taken into account when developing the system. These include data transmission security, data access security, and data storage security. It is implemented by using TCP/IP for encrypted and authenticated data transmission between the PPU and the MDS, using hypertext transfer protocol over secure socket layer (HTTPS) security for other authorized hospitals access to the MDS, and using confidentiality and user access authentication for data storage security in the MDS and other hospitals. In addition, the medical data would not be stored in the "disk", but some data would be stored for buffering for other hospitals.

3 Results

In order to confirm the feasibility of monitoring multiple vital signs with the WS, the reliability of the wireless communication, and the validity of online diagnosis and alarms, a medical experiment was conducted. For the experimental study we recruited 15 healthy volunteers without past histories of cardiovascular disease, mostly male (80%) between 21 and 85 years of age. The experiment includes three steps: Firstly, the device was continuously tested for a period of 5 min on each participant. The tidal volume of the respiration acquired with the WS and the PPU are one by one compared with the results of a pneumotachograph (PNT) by a mouthpiece. The ECG measurements are compared to a MGY-H12 Holter. The comparison elements are heart rate (HR), QRSA, and STS. After that, we select six young volunteers and divide them into three groups (two people in each group) to simulate falls in a foam-rubber cushion. The first group is asked to lie down slowly, the second group to stand up after falling down, while last group to fall down there to play dikkop. Secondly, we met with each participant for about 10 min to teach them how to use the device, and then they took the devices with them and wore them during that night in their homes. All devices had been preset to transmitted 2-min-long measurements at a time to the MSC every 4 h. They returned the devices to us the next morning. Finally, after the experiment, they were asked to fill out a questionnaire focus on rating the experience.

In the first step of the experiment, the statistical results are shown in the Table 1. From the table, we can see that the experiment has received satisfactory results both in the measurements of the respiration and the ECG. The tidal volume calibrated and calculated with the RIP has remarkable consistency with that measured with the PNT. In the 11437 times of respiration, the absolute percentage error (APE) of 93.9% (10,734) of the measurements are within the 10%. It is enough to prove the validity of the RIP of the WS. Regarding the ECG, the WS is able to acquire high-quality signals. The HR, QRSA, and STS provided by the PPU almost meet the results of the Holter. As a result of the simulated falls test, the PPU does not raise alarm in the first two groups because what they act are

Table 1 Statistical data of the experiment

ECG: 5655 QRS complexes, 99.4% (5620) was detected			
APE	<5%	<10%	<15%
HR	97.1% (5457)	98.9% (5558)	99.4% (5586)
QRSA	96.5% (5423)	97.6% (5485)	98.8% (5551)
STS	96.1% (5401)	97.2% (5463)	98.6% (5541)
Respiration: 11,437 times of respiration			
APE	<10%	<15%	<20%
Tidal volume	93.9% (10734)	98.1% (11220)	99.0% (11326)

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in normal range. Major alarm generates in the last group since the volunteers have fallen down and could not stand up by themselves.

In the second step of the experiment, both the short-range communication and the CDMA link can work well during the experiment. All measurements of the 15 participants have been successfully transmitted to the MSC. Concerning the quality of the signals, about 17% of the ECG signals provides poor results due to the motion artifacts resulting from the movement of the electrodes when the participants are lying down. But the results of respiration signals are very good during the experiment. By the way, there are four participants experiencing receiving minor alarms and two participants receiving false medium alarms due to noise ECG signals (when lying in bed, they turn on their sides, and that results in the movement of the electrodes).

Finally, the result of the usability questionnaire was very positive: None of our participants experienced any technical problem. All participants were willing to use the WS to get better control of their physical conditions. They replied wearing the WS would give them a feeling of security if they were suffering high-risk chronic diseases, and they would recommend the system to their friends.

4 Discussion

This paper described a wearable mobihealth care system with real-time monitoring, diagnosis, alarm, telecommunication, and advanced GPS. The system is able to provide real-time analysis and diagnosis on a portable device and raise three degrees of alarm. In abnormal situations, an emergency call will be automatically initiated. In particular, the system provides three manual emergency-aid buttons aiming to acquire rapid external helps. The related studies point out that if receiving immediate treatment most of the cardiovascular would survive. By implementing online diagnosis and alarms locally on the PPU, we can supervise the patient in real time without being continuously connected to the MSC. This would reduce the workload of medical staff and communication costs. The WS makes the wearer feel increasingly comfortable and convenient by integrating fabric electrodes and sensors into the shirt. The small-size PPU is can be easily worn without connecting disturbing sensors and electrodes due to applying short-range wireless communication.

A working prototype of the system has been developed, and a medical experiment on 15 healthy volunteers had been taken. There are several advantages using the WS: A full 12-lead ECG, respiration, and activity can be acquired; Electrodes and the sensors are always in the right place; A mix-up of electrode leads is impossible; There are no skin irritations even on long term use. Regarding the ECG signals measured with the WS, although fabric electrodes can cause baseline drift owing to the high skin-electrode impedance and the variation in pressure of the electrode to the skin, high-quality signals with remarkable stabilities have been acquired during the most the time of the daily life. However, the WS provides poor ECG signals as the participant is lying down. This may be related to the lack of adherence of fabric electrodes to the skin during body movement. To reduce the motion artifacts, we attempt to change the shape of the WS to fit the body of the wearer without any influences on comfort. Additionally, some algorithms, such as restraining the motion artifact with the help of activity information will be implemented in the next prototype of the system. Nevertheless, to our exciting is the respiration signals measured with RIP are very stable and free from the motion artifacts. As for the online diagnosis and alarm, the result of the experiment is satisfying. The falls suffered by patients could be detected with high accuracy and sensitivity. Although several false medium alarms are raised, we are assured this problem will be solved if the high-quality ECG signals can be acquired.

Finally, some additional areas that we would like to explore in the future: Providing many more physiological parameters monitoring, such as galvanic skin response (GSR), blood pressure, and saturation of pulse oximeter (SPO2); Carrying out a study on sleep apnea syndrome.

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