DESIGN OF A WEARABLE SENSING DEVICE FOR HEALTHCARE MONITORING USING WIRELESS TECHNOLOGY

J. H. Kang, S. H. Kim, S. C. Shin, T. G. Yim, S. H. Nam

IT-BT Fusion Technology Research Department,
Electronics and Telecommunications Research Institute, Daejeon, Korea.

{mephisto, skim}@etri.re.kr

Abstract: Development of new wearable biomedical sensors within a wireless infrastructure opened up possibilities for new telemedical applications to significant improvements in continuous monitoring and thereby to better quality of patient care.
In this paper, we introduced a new wearable device system based on wireless technology which has been developed to monitor patient's cardiovascular regulatory system and to detect emergency situation like heart attack, stroke, apnea during their daily life activity. For successful implementation of e-Health system, we have developed a wearable sensing device (called Bioshirt) that looks like T-shirt and a PBM (Personal Biosignal Monitor) unit to acquire patient's vital signal and to transmit data to PC or PDA for analysis via Bluetooth wireless technology.

Introduction

Healthcare industry is one of the most challenging and frequently regulated industries, undergoing major changes in the mode of healthcare delivery. And the advances in healthcare systems have been driven by the developments in wireless communications, pervasive and wearable technologies.

A wearable health-monitoring device using a personal area network (PAN) or body area network (BAN) could be integrated into a user's clothing which provides an excellent platform for the incorporation of sensors to create sensor network and embedded systems.
Much effort is currently devoted to design smart wearable devices capable vital signs while the subject is at work, during sport activities, at home or in a clinical environment without interfering with his/her spontaneous behavior nor limiting his/her comfort. There are some projects that have been worked in this way.

VivoMetrics company have produced a continuous ambulatory monitoring system, LifeShirt [1]. The Lifeshirt can collect data on pulmonary, cardiac and other physiological data by connected recorder. And Liftguard has been developed by the NASA [2]. This system is capable of logging physiological data as well as wirelessly transmitting it to a portable base station for display purpose and further processing. It was originally developed for astronauts, but has many potential uses in clinical, home-health monitoring and military applications as well.

Some projects have constructed a medical center for providing healthcare service related to chronic disease, especially heart attack that is leading causes of making emergent situations on a person.

When an emergency occurs, the most important factors are to transport the patient to a medical center or hospital. In this paper, we presented an emergent monitoring system that connects a patient in an urgent situation with his medical assistants or an emergency call center as soon as possible.

The system consists of four major parts: Bioshirt, PBM, Base or Mobile Station and ECMR. The Bioshirt is composed of several sensors, electrodes for measuring user's vital sign and shielded cables for transmitting signal to the PBM which means personal biosignal monitor.

PBM performs signal conditioning, data acquisition, analog-to-digital conversion, encoding and data transmission to PC or PDA via bluetooth.
The analysis algorithm of the vital signal was implemented on PC (base station) and PDA (mobile station). The received signals from PBM were displayed on station LCD and analyzed in quasi real-time.

Methods

1. Bioshirt

A T-shirt type sensing device (Bioshirt) integrated 6 ECG electrodes, 2 bands for RIP (respiratory inductive plethymograph), 2-axis accelerometer sensors and 1 body temperature sensor. The shielded cable position could be chosen according to personal comfort preferences.

ECG signal was acquired with 6 disposable stick-on button electrodes which were adhered by cushion pouch and placed on the position of mapped right arm (RA), left arm (LA), right foot (RF), left foot (LF) and chest electrode C_1, C_6 (same position as standard resting ECG).

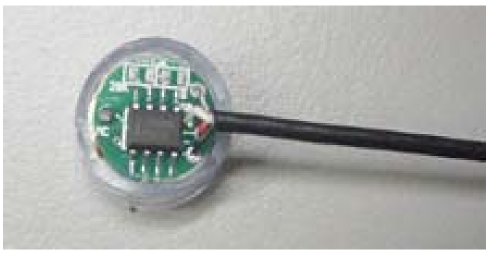

Figure 1: Active ECG electrode

ISSN: 1727-1983

From these electrodes, ECGs of lead I, II were recorded and another bipolar lead signal lead III and ECGs of augmented lead signal aVR, aVL, aVF were automatically obtained by numerical operation.

In addition to the above-mentioned six ECG signals, it was possible to get all the precordial ECG signals (V_1-V_6) by using a transform matrix conversion method [3]. As a result, we could obtain and analyze this derived 12-ch standard ECG signals.

The respiratory signal was obtained by indirect measurement method, RIP (respiratory inductive plethysmograph), which was used to changes of RC (rib cage) and AB (abdoment) volume during a patient's breathing.

A 2-axis acceleration sensor and a circuit for detection of his/her falling down were implemented in PBM which was positioned into pocket inside the Bioshirt.

Temperature sensor was positioned under the arms and it measures his/her body temperature periodically.

Figure 2: The Bioshirt was devided into inner and outer clothes for comfortable preferences

We replaced the six ECG electrodes and shielded cable with conductive yarn rubber electrode cable which was made form the disposable ECG electrode cable and conductive rubber [4]. The filler material of conductive rubber is nickel-coated graphite (Ni/C) and an elastomer is silicone. We used the conductive yarn, Bekinox VN 12/2x275/175S/316/ L/HT which is manufactured by Bekaert Corporation of Belgium. The average linear resistivity of this yarn is 0.14 ohm-cm and elongation is 1%.

2. PBM (personal biosignal monitor)

The PBM is a compact unit with the size of 72 mm ∗ 43 mm ∗ 18 mm, the weight of 43.8g and being powered by 4.2V Li-Ion battery which currently can perform for more six hours of continuous operations.

It was designed to have a simple user interface with 5 LEDs to check the PBM status and event button for triggering an alarm manually.

The simultaneous recording of vital signals obtained by sensors in the Bioshirt is sent to the PBM. It performs signal conditioning, data acquisition and data transmission to a PDA or PC (base station) in quasi real-time.

Figure 3: A signal acquisition device, PBM

To eliminate the noises from body motion and environment, we have implemented active filters based on an output feedback method.

By means of a 10-bit analog-to-digital converter, the analog biosignals were converted into digital data. And the converted signals were transmitted to the PDA (or PC in the phase of development) via a wireless bluetooth communication module which integrated Bluecore2 chip manufactured by CSR and SSP (serial port profile) service firmware for communicating PBM with Universal asynchronous receiver-transmitter (UART) was adopted for the serial interface, because most microcontrollers have built in support for it. Two bytes represents one data packet (Figure 4). Each channel has its own channel number. And this bluetooth module was realized for a Class II Bluetooth device with output power of 2.5mV (4dBm) has a range of ten meters enough to communicate with mobile device on the body or PC at home.

MSB ... LSB

0	C0	C1	C2	N/A	D9	D8	D7

1	D6	D5	D4	D3	D2	D1	D0

MSB: 0 if first part, 1 if second part
C0-C2: channel number bit (0 to 7)
D0-D9: data bit (0 to 1023)
N/A: No Use (Reserved)

Figure 4: The data packet structure for the PBM

There are two methods to send the alarm message to a healthcare management system. The first case is that the user perceives his/her abnormal condition. The user can press the 'event button' to alarm the emergency service center and to send his/her biological signal to the emergency service center. And the second case is that the automated diagnostic algorithm perceives the user's abnormal condition by monitoring the signals and sends an alarm to emergency service center. In this case, the user may have been faint or unconscious. The emergency service center can take appropriate actions immediately. Event button of the first case is located at on the front of PBM.

ISSN: 1727-1983 © 2005 IFMBE

3. PC (base station) and PDA (mobile station)

PBM has a supported SPP (serial port profile) bluetooth module that allows to communicate with PC or PDA. The vital signal which was measured by the Bioshirt and acquired by the PBM, was processed by some procedure. The data packet structure for wireless communication was decoded to original 10 bits-stream data and it was filtered LPF or BPF and was converted into physical unit vital signal and then used to monitor his/her health.

Data processing algorithms on the both station derive heart rate from the received ECG waveform were used by QRS detection method based on Pan and Tompkin's algorithm[5] but modified on the many parts of routine.

Using a detected R point as reference of ECG beat, we could make ECG beat sequence sets which were used to process beat analysis for detecting an ectopic beat like PVC (premature ventricular contraction) beat.

There are also a respiratory signal analysis routine which performs a complete respiratory tidal volume derived from RC/AB volume change in RIP and extracts indirectly respiratory features from ECG (EDR method) [6].

We have embodied the PDA application upon the Pocket PC 2002 Platform using EVC4.0 and have used the BTAccess Bluetooth Stack for the bluetooth wireless communication. The PDA application runs on being inputted the appropriate communication setting and the patient's information. Then it begins to receive the signal from the PBM unit and the several diagnostic algorithm works for each signal which have been received from the PBM. The user can select the 1-channel signal to be displayed on the PDA windows. The PDA application displays the selected signal and the diagnostic figures in real time.

It was possible to communicate between PBM and PC using Bluetooth USB/Serial Dongle (hardware) and Broadcomm Bluetooth Stack (software). We have made the PC application for displaying data from the PBM. It was programmed by Microsoft Visual C++ 6.0.

The PBM sends all the signals have been detected by sensors. The signals and the diagnostic figures are displayed on the PC monitor in real time. The current version of the Bioshirt doesn't include the respiratory sensor. Instead of using the respiratory sensor, we deduced the breathing rate using the EDR (ECG derived respiration) method [6].

We used the bluetooth wireless technology to translate the biological data from the PBM unit to PDA or PC. The PDA or PC application decodes the biological signals and converts it into physical unit signal.

As mentioned above, from 4-channel ECG signal, we derived the bipolor/augmented ECG signal by simple numerical operation and calculated the precordial ECG signal by transform matrix conversion. So we could get the derived 12-ch ECG signals totally. Then we applied the diagnostic algorithms such as QRS detection, arrithythmia, ectopic beat detection and HRV analysis for monitoring the condition of the heart. In the emergency, the emergency service center can take actions.

We used the 2-axis acceleration signal (x, y-axis) from accelometer positioned into PBM for falling detection algorithm by calculating his/her activity level.

Conclusions and Perspectives

In this paper we have outlined solutions for real-time healthcare monitoring and the Bioshirt, PBM and management system on PC or PDA. In the future this system will support more effective algorithms of ECG, acceleration and other kinds of vital signal, such as non-invasive blood pressure, and SpO_2, will be considered as important factors to detect emergencies in the next version. In addition, The conductive rubber electrode is capable for our wearable monitoring system to be able to take off and put on. Moreover, if the conductive rubber electrode is added more viscosity, it will get a good contact and not slide from skin.

Figure 5: PDA application

Figure 6: Management application on PC

ISSN: 1727-1983

References

[1] LIFESHIRT, URL: http://www.viometrics.com
[2] LIFEGUARD, URL: http://www.lifeguard.stanford.edu
[3] D. WEI, "Deriving the 12-lead electrocardiogram from four standard leads based on the Frank Torso model," Proc. 23rd Annual EMBS Intl. Conf. IEEE EMBS2001, Istanbul, Turkey, pp. 381-383, 2001.
[4] CHANG YONG RYU, "Conductive rubber electrode for wearable health monitoring," Proc. 27th Annual EMBS Intl. Conf. IEEE EMBS2005, Shanhai, China. pp 942-944, 2005.
[5] J. PAN AND W.J. TOMPKINS, "A real-time QRS detection algorithm," IEEE Trans. Biomed. Eng, vol. BME-32, pp. 230-236, 1985.
[6] S. H. NAM, "The Preliminary Study of Unobstrusive respiratory monitoring for e-health," Proc.27th Annual EMBS Intl. Conf. IEEE EMBS2005, Shanhai, China, pp 956-958, 2005.

ISSN: 1727-1983 © 2005 IFMBE