노인 헬스케어를 위한 ECG분석 및 활동량 모니터링 구현

Sachin Bhardwaj* · Amit Purwar* ·이대석* · 정완영**
*동서대학교 디자인 & IT전문대학원,
**동서대학교 컴퓨터정보공학부

A ECG Analysis with Activity Monitrong for Healthcare of Elderly Person

Sachin Bhardwaj* · Amit Purwar* · Dae Seok Lee* · Wan-Young Chung**
*Graduate School of Design & IT, Dongseo University,
**Division of Computer Information Eng., Dongseo University
mail: wychung@dongseo.ac.kr

요 약

본 연구는 무선 센서네트워크를 활용하여 환자 또는 고령자를 위한 ECG, 활동량 모니터링 시스템을 설계 및 구현 하였다. 심전도 변화는 사람의 활동, 뛰거나 걷기 등의 움직임에 따라 조금씩 변화한다. 그래서 종종 자세, 행동에 따른 ECG변화의 기록은 중요시 되며 이를 위해 매일 활동하는 환자의 활동 모니터링 시스템이 필요하다. ECG와 활동량 데이터는 자동 알림기능을 지원하는 시스템에 저장되고 긴급 상황 발생 시 보다 빠르게 초기 활동을 할 수 있게 한다. 몸에서 계측된 ECG 데이터와 활동량 데이터는 무선 센서네트워크를 통해 베이스테이션과 연결된 서버에 전송되며 서버에서 비정상적 상황을 판별 시 발생 의사의 PDA 또는 서버에 데이터를 전송한다.

ABSTRACT

An ECG analysis with activity monitoring for the home care of elderly persons or patients, using wireless sensors technology was design and implemented. The changes in heart rate occur before, during, or following behavior such as posture changes, walking and running. Therefore, it is often very important to record heart rate along with posture and behavior, for continuously monitoring a patient's cardiovascular regulatory system during their daily life activity. The ECG and accelerometer data are continuously recorded with a built-in automatic alarm detection system, for giving early alarm signals even if the patient is unconscious or unaware of cardiac arrhythmias. The hardware allows data to be transmitted wirelessly from on-body sensors to a base station attached to server PC using IEEE802.15.4. If any abnormality occurs at server then the alarm condition sends to the doctor' PDA (Personal Digital Assistant).

Keyword
ECG, Accelerometer, Healthcare, Elderly Person, QRS-complex, P and T-wave, Norm, Orientation, Fall

I. INTRODUCTION

Recent advances in sensor technology allow continuous, real-time ambulatory monitoring of multiple patient physiological signals including: electrocardiogram (ECG), body temperature, respiration, blood pressure, oxygen levels, and glucose levels [1, 2]. Technology that would allow healthcare providers to deploy, configure, and manage such monitoring systems, would provide a tremendous service to the healthcare industry while at the same time improving the quality of life for thousands of patients.

We are trying to develop a robust platform for real-time monitoring of patients staying in their home and transmitting health data to doctors working at the hospital with extended ECG [5] and acceleration analysis [6, 7]. It has been observed that changes in heart rate occur before, during, or following behavior such as posture changes, walking and running. Therefore, it is often very important to record heart rate along with posture and behavior, for continuously monitoring a patient's cardiovascular regulatory system during their daily life activity. The ECG and accelerometer data are continuously recorded with a built-in automatic alarm detection system, for giving early alarm signals even if the patient is unconscious or unaware of cardiac arrhythmias [8]. The doctor at the hospital uses special remote client software that is installed on a standard PC or PDA as a Clinical Diagnostic Station. Trained personnel will thus be able to evaluate the ECG-recording for diagnosing the conditions detected and follow up the patient accordingly [9]. Figure 1 shows the system architecture of ECG and accelerometer analysis for ubiquitous healthcare system using wireless sensors.

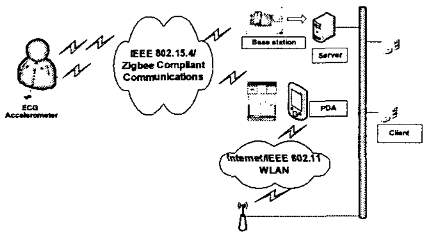

Fig. 1. System architecture of ECG and accelerometer analysis.

II. SYSTEM DESIGN

Emphasis is placed on recent advances in wireless ECG system for cardiac event monitoring with particular attention to arrhythmia detection and behavior monitoring such as walking, running of patient. An accelerometer data for supporting the ECG analysis gives some detail about the effects of motion while the person is in the motion. The system also provides an application for recording activities, events and potentially important medical symptoms. The hardware allows data to be transmitted wirelessly from on-body sensor to the base system and then to PC/PDA.

Accelerometer data is received by sensor unit which consist of 3-axes accelerometer and data acquisition board (AD5893, 12 bit ADC-MUX) connected to to Micaz motes (Crossbow Technology Inc.) as a platform for processing and radio communication. Micaz mote has Atmel Atmega 128L microcontroller, 4 KB of RAM and a CC2420 (Chipcon, Zigbee Compliant) 2.4 GHz ISM band radio capable of data transfer at 250 kb/s. The firmware for sensor unit is developed in nesC using Tinyos [10]. As for the abnormal case, ECG data is taken from MIT-BIH arrhythmia database [11].

After receiving the serial data received from the base station node attached to server, ECG and accelerometer data are analyzed, which includes searching the R-peak, ST-segment, P-wave, T-wave and calculating the norm and orientation angle, in real time.

Server/Client software programs were developed in C# based on .Net compiler for monitoring and analyzing the ECG and Accelerometer recordings. Figure 2 shows the flow chat for ECG and accelerometer parameter analysis.

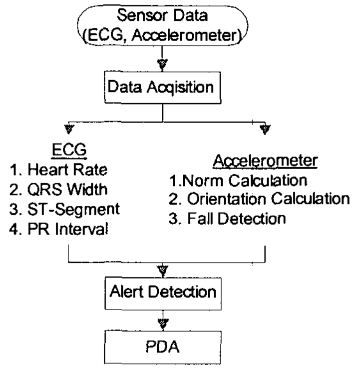

Figure 2. Flowchart of ECG analysis.

For ECG analysis, the variant of Pan-Tompkins algorithm [12, 13] is used for signal processing. This algorithm is improved according to our software analysis requirement and is developed in C#.net language to comfort with accelerometer analysis. The algorithm proposes a real-time QRS detection based on analysis of slope, amplitude, and width of QRS complexes. It includes a series of filters and methods that perform low pass, high pass, derivative, squaring and integration procedures. Filtering reduces false detection caused by the various types of interference present in the ECG signal. This filtering permits the use of low thresholds, thereby increase the detection sensitivity. The algorithm adjusts the thresholds automatically and parameters periodically to adapt to changes in QRS morphology and heart rate.

Moving window integration extracts more information from the signal to detect a QRS event by averaging a certain number of samples per window. In such cases, the window must be same as the widest possible QRS complex, and the length of the window must be selected carefully.

Here for 200 samples per sec, the window's length is 30. By using moving window integration process, we can calculate R-peaks, R-R intervals, width of QRS complex and heart rate variability. Heart rate is computed by measuring the length of the R-R interval, or a full period of the waveform. These parameters are used to detect abnormality in patients. For the abnormal condition, Server will store the 1 minute ECG-recording and calculate the heart rate, variation in RR-interval and width of QRS complexes.

ST-segment is derived 80ms after the endpoint of the QRS complex, if the R-R interval is greater than 0.7s. If the RR interval is smaller than 0.7s; the amplitude is measured 60ms after the QRS complex has ended. The slope is calculated for the following 20 ms.

P-wave and T-wave detection algorithm searches for the T-wave first, after a QRS-complex has been detected. The wave is expected within a specific time window. The start and duration of window depends on the R-R interval:

If the R-R interval>0.7s:

T-wave Window begin = 0.08s after QRS end.

T-wave window end = 0.004s.

If R-R interval<0.7s:

T wave window begin = 0.04s.

T wave window end = (0.7R-R interval -0.06) s.

Within this window, the minimum, maximum and order of the slope of the derived function are important for detecting the T-wave. Bi-phase T-wave can be identified in the same way. The change of slope, as well as the end of the T-wave, is detected based on thresholds. The slope must include positive and negative values and the slope magnitude needs to be at least 0.006mV/s for a T-wave to be detected. The detection rule for a P-wave is a positive slope followed by a negative slope. The magnitudes of both slopes have to be greater than 0.004mV/s. The algorithm searches for this combination, until the beginning of a new QRS complex is detected. The algorithm searches for this combination, until the beginning of a new QRS complex is detected. If SlopePwave[p-1]> SlopePwave[p] then the slope is negative and if SlopePwave[p-1]<SlopePwave[p] then the slope is positive. It will check for five consecutive slopes then can decide finally positive and negative slope. Where p is the number of slope encounter and SlopePwave is the calculated slope during P-wave detection. Initially, the value set as p=1 and SlopePwave[0]=0. Estimated P-R interval should be less than 0.02sec for normal ECG, which extends from the beginning of the P wave to the first deflection of the QRS complex.

If Xi, Yi and Zi are the acceleration values at a particular instant of time then acceleration norm An is given as

$$An = \sqrt{(Xi2+Yi2+Zi2)}$$

and the orientation is calculated using the dot product of the the norm and the vertical axes

$$\cos\Theta = Zi/An$$

The data collected at the base station attached to PC are the sample level values in the range [0, 4096] of the voltage signal from sensor unit. So for calculating the acceleration from these samples first voltage level is calculated and checks weather this voltage level is for positive acceleration or negative acceleration. The formula used for calculating using the exact acceleration values is given as

$$V.L.=\frac{[(VDD\ (mV)^{*}\ Sample\ Level)/4096\ -\ 1500(mV)]}{200(mV)}$$

Where 1500 mV is the reference voltage level of the accelerometer, above this level is positive acceleration and below is negative acceleration and 200 mV/g is the sensitivity of the accelerometer. After calculating all parameter of ECG signal then can classify shape and beat of ECG. For example, in rest if the heart rate is greater then 100 then is called sinus tachycardia disease and if the heart rate is lees then 60 then it is called a sinus bradycardia disease. If the heart rate is in between 60 and 100 then it is a normal sinus rhythm. But it is not sure during moving activity of patient. The moving activities (walking and running) of patient is recorded in experiments up to acceleration norm value 3g (where g = 9.8m/s2). If the orientation angle is near by 90 degree and if constant after few seconds then indicates patient fall down . Further software will search for wide QRS complex, P-wave, T-wave, ST- segment then we can classify the types of arrhythmia disease. If any abnormal ECG encounter then the server will send alert condition with ECG parameter and behavior status to doctor's PDA.

III. EXPERIMENTAL RESULTS

In our experimental results, we can diagnose arrhythmia diseases and can give information about activity of patient. An ECG and tri-axial accelerometer graph with their analysis result shown in fig 3. Tri-axial Accelerometer data is received by sensor as a real time streaming and the abnormal ECG data is taken by MIT-BIH arrhythmia database for testing.

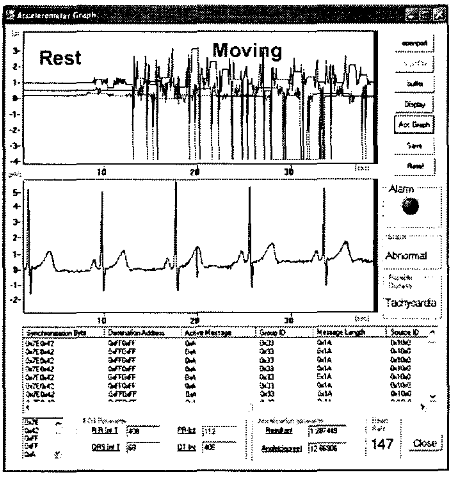

Fig. 3. An ECG and accelerometer analysis interface.

In first half of figure shows x-, y-, z-axis graph as a blue , red , green lines from channel-0, channel-1, channel-2 respectively of accelerometer data. An ECG parameter box shows the values of R-R interval= 408 ms, QRS interval= 68 ms, PR interval= 112 ms and QT interval = 406 ms. An accelerometer parameter shows the resultant (norm) = 0.8984118 and orientation angle (in degree) = 75.84344. According to analysis results the patient status goes abnormal with possible disease tachycardia which is shown in status and possible disease box. Activities of patient following by the rest position and start moving after 13 seconds and falls after 26 seconds. After ECG and accelerometer analysis, if there is any abnormality then send alarm condition to the doctor's PDA.

IV. CONCLUSION

A prototype of ECG analysis with activity monitoring was developed for the advanced ubiquitous healthcare system using sensors technologies. Our system acts as a continuous event recorder, which can be used to follow up patients who have survived arrhythmia diseases in both ambulatory settings and in hospitals. The use of an affordable device for monitoring activities and analyzing ECG signals of patient at home can provide informative details to the doctors using PDA/PC, and simultaneously alert the doctor of any emergencies.

REFERENCES

[1] Marculescuetal., "Ready to Wear," IEEE Spectrum. Vol. 40, No. 10, Oct. 2003, pp.28-32.

[2] A. F. Cardenas, R. K. Pon and Robert B. Cameron, "Management of Streaming Body Sensor Data for Medical Information Systems," in Proc. METMBS 2003, Las Vegas, NV, pp. 186-91.

[3] B. G. Cellar, N. H. Lovell and J. Basilakis, "Using information technology to improve the management of chronic disease. Med. J. of Australia, 2003; 179 (5): 242-246.

[4] N. Maglaveras, I. Lekka et al., "Congestive Heart Failure Management in a Home-Care System through the CHS Contact Center," IEEE Computers in Cardiology 2003, vol. 30, pp.189-192.

[5] M. H. Crawford, ACC/AHA Guidelines for ambulatory electrocardiography, Journal of the American College of Cardiology, vol. 34, pp. 912-48, 1999

[6] J. Chen., K. Kwong, D. Chang, J. Luk, Ruzena Bajcsy, "Wearable Sensors for Reliable Fall Detection", Proceedings of Engineering in Medicine and Biology, IEEE vol 27, September 1-4, 2005.

[7] D.M. Karantonis, M. R. Narayanan, M. Mathie, N. H. Lovell, and Branko G. Celler, "Implementation of a Real-Time Human Movement Classifier Using a Triaxial Accelerometer for Ambulatory Monitoring", IEEE Trasactions on Information Technology in Biomedicine, vol.10, no. 1, January 2006

[8] R. Fensli, E. Gunnarson, and O. Hejlesen, A Wireless ECG System for Continuous Event Recording and Communication to a Clinical Alarm Station, 26th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, pp 2208-1,2004.

[9] Y. H. Nam, Z. Halm, Y. J. Chee, and K. S. Park, Development of remote diagnosis system integrating digital telemetry for medicine, presented at Proceedings of the 20th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 1998.

[10] David Gay, Philip Levis, David Culler and Eric Brewer. "nesC 1.1 Language Reference Manual" May 2003.

[11]MIT-BIH Arrhythmia Database CD-ROM.Available from the Harvard-MIT Division of Health Science and Technology, 1992.

[12] J.Pan and W.J. Tompkins, "A real-time QRS detection algorithm", BME-32, pp.230-236, 1985.

[13] Hamilton PS, Tompkins WJ. "Quantitative investigation of QRS detection rules using the MIT/BIH arrhythmia database".IEEE Trans. Biomed Eng. 1986;33:1157-65.