A Combined QRS-complex and P-wave Detection in ECG Signal for Ubiquitous Healthcare System

Sachin Bhardwaj, Dae-Seok Lee and Wan-Young Chung, *Member, KIMICS*

Abstract—Long term Electrocardiogram (ECG) [1] analysis plays a key role in heart disease analysis. A combined detection of QRS-complex and P-wave in ECG signal for ubiquitous healthcare system was designed and implemented which can be used as an advanced warning device. The ECG features are used to detect life-threating arrhythmias, with an emphasis on the software for analyzing QRS complex and P-wave in wireless ECG signals at server after receiving data from base station. Based on abnormal ECG activity, the server will transfer alarm conditions to a doctor's Personal Digital Assistant (PDA). Doctor can diagnose the patients who have survived from cardiac arrhythmia diseases.

Index Terms—Ubiquitous Healthcare, Elderly Person ECG, QRS, P-wave, PDA.

I. INTRODUCTION

Population aging has become one of the most significant demographic processes of modern times. An inevitable consequence of the demographic transition and the shift to lower fertility and reduced mortality, the ageing of the world's population has many countries facing unprecedented numbers and proportions of older persons. In much of the world, populations are ageing at an extremely rapid pace. The proportion of elderly persons, that is those aged 65 years and over, currently comprises around 10 per cent of the world's population, and is projected to increase to 22 percent by 2050 [2].

Owing to continuous economic growth, an increased standard of living, and improvements to healthcare in Korea, the life expectancy of Koreans rose from 69.0 years in 1985 to 71.3 years in 1990. It continued to rise throughout the 1990s, and, by 2002, had reached 76.5 years for the general population and 80.0 years for Korean females. The proportion of the elderly aged 65 and over reached 7.1 per cent in 2000 [3], and the nation is quickly becoming an aged society. According to National Statistical Office projections, it would take only 20 years to double this percentage (that is, to 14 percent) by 2022. Thus, according to this estimate, Korea will have evolved from an "aging society" to an "aged society" in only 22 years. This brief transition period indicates that Korea is ageing much more quickly than are other advanced countries. The societal transition, not only demographic but also socio-economic, has been forcing policy makers to prepare for the challenges of this rapidly ageing society as shown in Fig. 1.

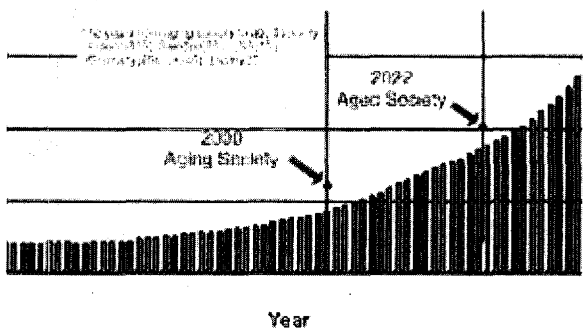

Fig. 1 Trend of population aging in Korea.

Several international projects, which concentrate on using wireless sensors as a framework of a standardized body area network (BAN), are focusing on improving new technology solutions. Though, few of them have possibilities of extended healthcare parameter analysis within the area of ubiquitous healthcare system for elderly person. The European community's MobiHealth System (2002-2004) demonstrates the Body Area Network (BAN) [4]. Code blue [5] is a wireless infrastructure for deployment in emergency medical care. Another health monitoring system is Coach's Companion [6], which allows the monitoring of physical activity and low power, wireless two lead ECG [7]. Gritzali et al. [8] proposed a common approach to the QRS, T and P waves in multichannel ECG signal based upon a transformation they labeled as the "length" transformation. We developed a combined approach of detecting QRS-complex and P-wave from two-Lead ECG digitalized data for ubiquitous healthcare system. Our QRS detection algorithm is based on the originally

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developed QRS detection algorithm by Pan-Tompkins [9] in assembly language for implementation on a Z80 microprocessor and later improved and ported to C by Hamilton and Tompkins [10] and also based on P-wave detection by Hengeveld SJ and van Bemmel JH [11].

II. SYSTEM ARCHITECTURE

Our present ECG analysis algorithm developed for QRS complex, P-wave and T-wave detection using C# based on .NET compiler at server for ubiquitous healthcare system. An ECG analysis is done at server after receiving ECG data from base station. If an abnormal ECG activity is encounter, the Server gives alarm to doctor's PDA and can diagnose the patients who have survived from cardiac arrhythmia diseases [12].

Figure 2 shows the architecture of ECG monitoring system. In our system, continuous real-time ECG is recorded at sensor node which is transferred wirelessly to base station and analysis with automatic event detection is done at server. Detected event can also be recorded at server and transfer to PC/PDA of doctor. The wireless transmission of the sampled data of ECG signal at base station is integrated as a component with server or PC/PDA. It is possible to make an easier and more cost efficient ambulatory ECG recording compared to existing solutions on the market, and patient can be continuously monitored in his home-situation doing daily activities.

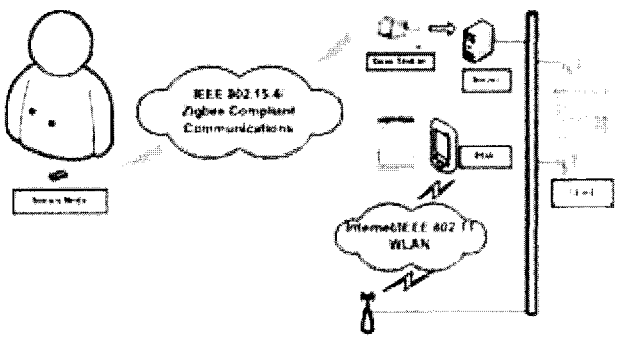


Fig. 2 Architecture of ECG monitoring system.

III. ELECTROCARDIOGRAM

The ECG provides a record of electrical events occurring within the heart and is obtained from electrodes placed on the surface of the body. An ECG is thus a plot of the time-dependence of charging potential differences between electrodes on the body surface. A typical ECG tracing of a normal heartbeat (or cardiac cycle) consists of a P wave, a QRS complex and a T wave as shown in Fig. 3. A small U wave is normally visible in 50 to 75% of ECGs. The baseline voltage of the electrocardiogram is known as the isoelectric line. Typically the isoelectric line is measured as the portion of the tracing following the T wave and preceding the next P wave. There are several typical locations for placing the electrodes on the body. A pair of electrodes provides a view of the heart from a specific angle and is called a lead. All the recordings presented in this report are taken from Lead 2. The positive electrode is placed below the left pectoral muscle and the negative electrode below the right clavicle as shown in Fig. 4 (reproduced from [13]). The ground (G) electrode is commonly located below the right pectoral muscle.

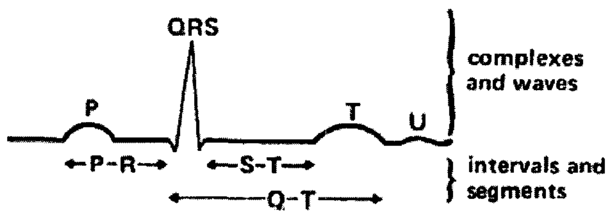


Fig. 3 Typical ECG signal recorded from body surface.

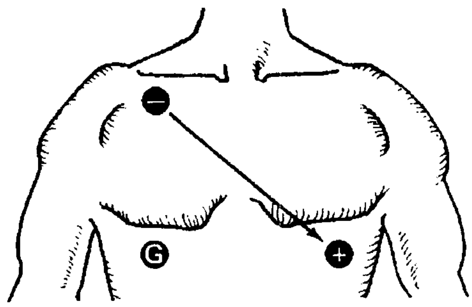


Fig. 4 Location of chest electrode in lead 2.

The first deflection of the ECG, which represents atrial depolarization, is the P wave. Although depolarization of the SA node precedes atrial depolarization, no manifestations of this pacemaker activity are seen in the ECG. This is simply because the SA node is too small to generate electrical potential differences large enough to be recorded from the body surface. The width (or duration) of the P wave reflects the time taken for the wave of depolarization to spread over the atria. The QRS complex records potentials at the body surface generated when the wave of depolarization passes through the ventricles. The amplitude of the QRS complex is greater than that of the P wave because the ventricular mass is greater than that of the atria. Repolarization of the ventricles generates the T wave. The duration of the T wave is considerably longer than that of the QRS complex because, unlike ventricular depolarization, repolarization does not spread as rapidly propagated wave. In some normal ECG's a small deflection is seen after the T wave. This is the U wave, whose origins remain uncertain. Table 1 provides approximate values for the durations of various waves and intervals in the normal adult ECG. Many are age or gender dependant and can vary with heart rate.

Long term ECG analysis plays a key role in heart disease or chronic disease analysis. The long term objective, however, is to automate the ECG event classification in order to further enhance medical treatment. In order to classify the ECG signal, a reliable extraction of the characteristic ECG parameter is needed.

Table 1 Durations of waves and intervals in a normal adult human heart

Parameter	Duration (sec)
P-R Interval	0.12-0.20
Q-T Interval	0.30-0.40
P wave	0.08-0.10
QRS complex	0.06-0.10

IV. SYSTEM DESIGN

The component of Ubiquitous Healthcare system consists of sensing, monitoring, analyzing and the feedback of behavior modification, disease classifi-cation, and Emergency alert which is shown in Fig. 5.

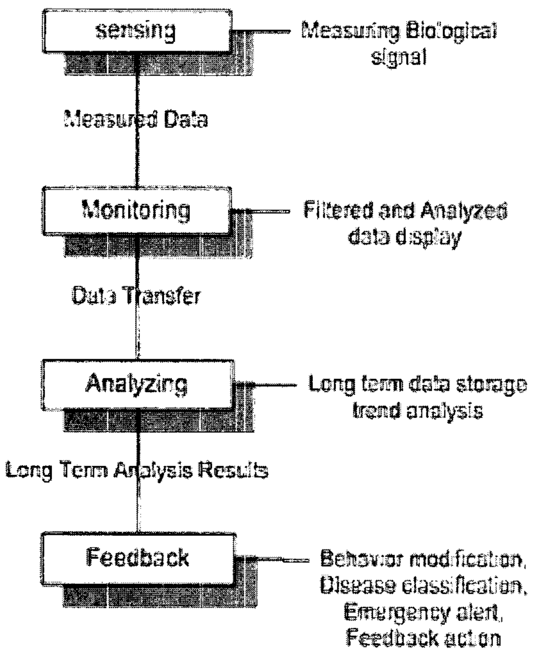


Fig. 5 Component of Ubiquitous healthcare system

Emphasis is placed on recent advances in wireless ECG system for cardiac event monitoring with particular attention to arrhythmia detection in patient. 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. Wireless Sensor nodes are small sized hardware modules which have strong capabilities of sensing, computing and bi-directional communication. These sensor nodes can be programmed using TinyOS [14] and operates on low power batteries. The sensor measures ECG-signals with a sampling frequency of 200 Hz. The signal is digitalized with 10 bits resolution, and continuously transmitted it to a receiver-module attached to PC/PDA, using a modulated RF-radio link of radio chip CC2420 (Chipcon Inc., Norway). The sensors are sticky and attached to the patient's chest. It will continuously measure and wirelessly transmit sampled ECG-recordings using of a built-in-RF-radio transmitter to the base station and then to PC/PDA through a RS-232 connector.

Server/Client software programs were developped in C# based on .Net compiler for monitoring and analyzing the ECG-recordings. For QRS detection in ECG analysis, the variant of Pan-Tompkins algorithm 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 P-wave detection. The flowchart of QRS-complex and P-wave detection in ECG signal is shown in Fig. 6. 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. After differentiation, the ECG samples are squared. This makes all data points positive and does nonlinear amplification of the output of the derivative emphasizing the higher frequencies. The moving window integration extracts more information from the signal to detect a QRS event by averaging a certain number of samples per window. Here for 200 samples per sec, 80ms moving average. The moving window integration process produces a signal wherein the peaks of the signal have been emphasized. 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. After detecting a QRS complex, there is a 200 milliseconds (ms) delay from original signal.

So, the further processing needs to search back for 220 ms for QRS complex due to the delay of filters and then it is deleted and replaced with the base-line. The base line is determined by analyzing a few samples preceding the QRS complex. The resulting signal is band pass filtered with -3dB points at 3Hz and 11Hz and the search interval is defined as QTmax = 2RR/9+250ms, where RR is the interval between two successive QRS complexes. The signal is rectified and threshold at 50% and 75% of the maximum to obtain a three level signal. After taking a cross correlation of the result computed with three levels signal and from a representative set of P waves. The peak in the cross-correlation corresponds to the location in the original ECG.

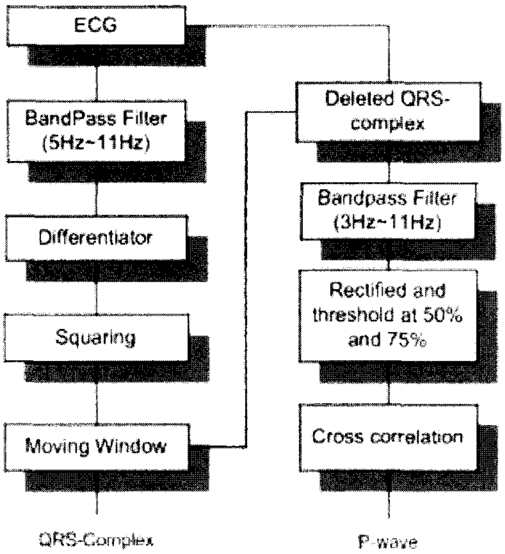
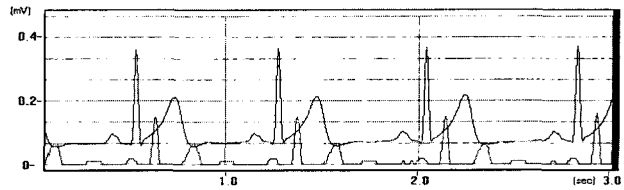


Fig. 6 Flowchart of QRS-complex and P-wave detection in ECG signal.

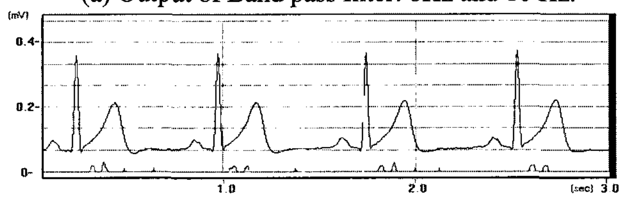
After calculating all parameter of ECG signal then can classify shape and beat of ECG and can diagnose arrhythmia diseases. If any abnormality occur at server then it can transfer alarm condition to doctor's PDA.

V. EXPERIMENTAL RESULTS

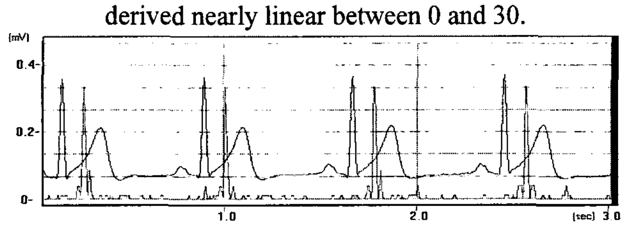
Our experimental set-up obtains the ECG data from the sensors placed on real human body and MIT-BIH arrhythmia database [15]. The normal ECG data is taken from real body of human being by using MIB510 data acquisition board attached to micaZ mote and abnormal ECG data is taken by MIT-BIH arrhythmia database. Figure 7 shows the step results of ECG analysis from band pass filter, differentiator, squaring, moving window, deleted QRS-complex and band pass filter for P-wave detection. The normal ECG analysis Interface with normal status having Heart Rate =77; RR Interval (ms) =775; PR Interval (ms) =198; QT Interval (ms) =422 as shown in Fig. 8.The abnormal status of the patient is shown in Fig. 9 with Heart Rate =157; RR Interval (ms) =380; PR interval (ms) =176; QT Interval (ms) =334. According to abnormal ECG in Fig. 9, the sever sends alarm condition to doctor's PDA.



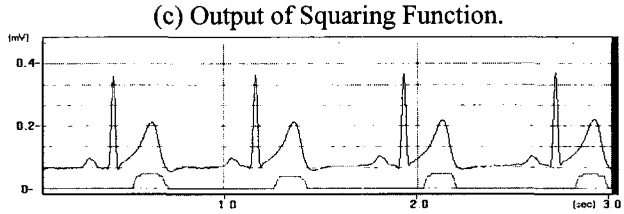
(a) Output of Band pass filter: 8Hz and 16 Hz.



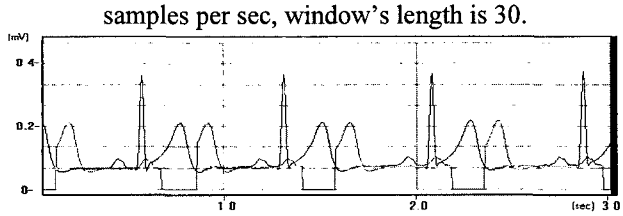
(b) Output of Differentiator: Five point derivatives derived nearly linear between 0 and 30.



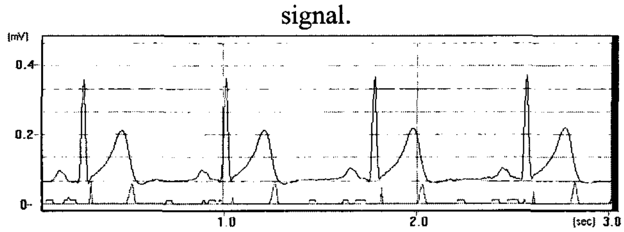
(c) Output of Squaring Function.



(d) Output of Moving window Integration: For 200 samples per sec, window's length is 30.



(e) Output of Deleted QRS complex from the original signal.



(f) Output of Band pass filter: 3Hz and 11 Hz.

Fig. 7 Step results of ECG analysis

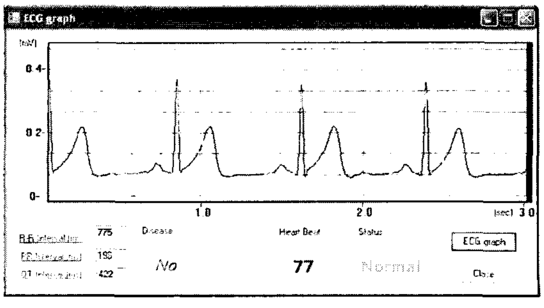


Fig. 8 ECG analysis Interface with normal status.

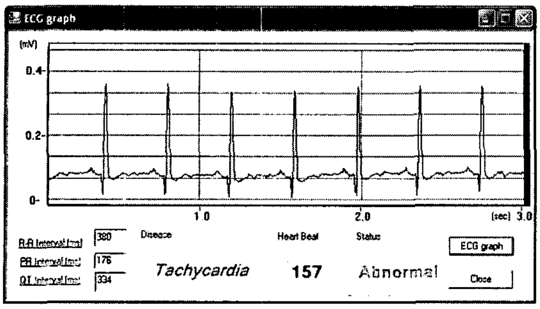


Fig. 9 ECG analysis Interface with abnormal status.

VI. CONCLUSIONS

A combined QRS-complex and p-wave detection algorithm was developed for the advanced ubiquitous healthcare system. It therefore reasonable to assume that our combined QRS-complex and p-wave detection algorithm is able to, reliably, detect rarely occurrences of cardiac arrhythmias. Thus, the developed algorithm makes correct diagnosis even under situations where the patient is unconscious or unaware of cardiac arrhythmias and provides a capability for real time (software) analysis of ECG signal at server. Needed information of abnormal ECG from the server can also be transferred to the doctor's PDA for further diagnostics. Doctor can diagnose the patients who have survived from cardiac arrhythmia diseases.

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