Wearable Approach of ECG Monitoring System for Wireless Tele-Home Care Application

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ABSTRACT

Wireless tele-home-care application gives new possibilities for ECG (electrocardiogram) monitoring system with wearable biomedical sensors. Thus, continuously development of high convenient ECG monitoring system for high-risk cardiac patients is essential. This paper describes to monitor a person's ECG using wearable approach. A wearable belt-type ECG electrode with integrated electronics has been developed and has proven long-term robustness and monitoring of all electrical components. The measured ECG signal is transmitted via an ultra low power consumption wireless sensor node. ECG signals carry a lot clinical information for a cardiologist especially the R-peak detection in ECG. R-peak detection generally uses the threshold value which is fixed thus it bring errors due to motion artifacts and signal size changes. Variable threshold method is used to detect the R-peak which is more accurate and efficient. In order to evaluate the performance analysis, R-peak detection using MIT-BIH databases and Long Term Real-Time ECG is performed in this research. This concept able to allow patient to follow up critical patients from their home and early detecting rarely occurrences of cardiac arrhythmia.

Keyword

Cardiac Arrhythmia, ECG (electrocardiogram), Wearable biomedical sensors, Variable threshold

Ⅰ. Introduction

Monitoring of biomedical signals from older people who have chronic diseases is getting more popular in medical research field. Chronic diseases are one of the major causes of death around the world. Besides that, world population of older people over age 65 is increasing nowadays. The older population is expected to be tripled from 605 million in year 2000 to 1,963 million in year 2050 [1]. Thus, it is important to increase the research of existing healthcare system in order to deal with current situation.

In current lifestyle of a modern world, developing lifestyle leads to increase the number of high-risk cardiac patients or other related chronic diseases. In the past, healthcare system only focuses on treatment and early detection. This does not sufficient enough for future long term monitoring purpose. Future healthcare monitoring system aim is to reduce the burden and complexity interaction between doctor and patients.

Recently technology advances in sensors, low-power integrated circuits and wireless communications have enabled the design of low-cost, miniature sensor nodes. A new generation of Wireless Sensor Network (WSN) suitable for many applications for example habitat monitoring, machine health monitoring and guidance, traffic pattern monitoring, plant monitoring in agriculture [2] and infrastructure monitoring. One of the most important applications is health monitoring. There are a few numbers of physiological sensors that monitor vital signs, environmental sensors and location sensor where all can be integrated into

a wearable wireless area network.

Wearable health monitoring systems allow ones to closely monitor changes in her or his biomedical signal and immediately sack feedback from medical professional. Thus, it is important to integrate into tele-medical system where the systems able to alert medical professional when emergency case or life-threatening occur. Besides that, patients able to have continuous long-term monitoring which is important to achieve optimal maintenance of any heart related diseases. Continuous long-term monitoring can capture the diurnal and circadian variations in physiological signals.

II. ECG Monitoring System

Ubiquitous healthcare component consists of sensing, monitoring, analyzing, disease classification and emergency alert. In this system, emphasis is placed on sensing, monitoring and analyzing.

Recording of ECG signal using wearable approach is non-invasive procedures, where no penetration of the body with external devices such as needle electrode, transducers and etc. This wearable approach of ECG monitoring system can reduce the risk to subject.

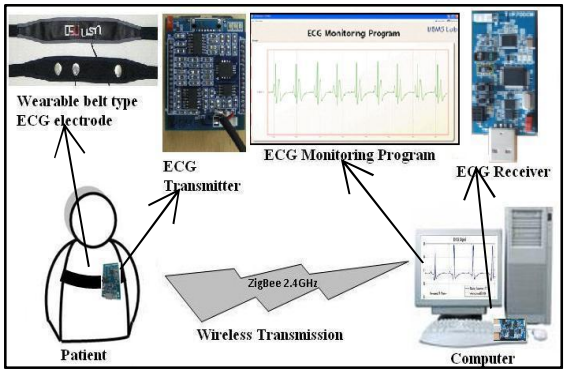


Figure 1. Wireless Tele-Home Care.

This paper discuss the wearable approach of ECG monitoring system for wireless tele-home care applications. Figure 1 show the overall system architecture of wireless tele-home care applications. A ECG analysis with activity monitoring for Wireless Tele-Home care using wireless sensor network technology was design and implemented.

The ECG signal is measured at the surface of the skin using electrode is approximately 1mV. The signal measured is not only from ECG signal as a parts of the muscle tissue that occur in the excited biological signal, but also from stray capacitance of the surrounding environment and various electronic equipments from the unwanted noise signal. Thus, the ECG signal processing circuit is designed to amplify the signal and to extracts the only desired ECG signals.

Firstly, from the displacement amplification, it undergoes low-power amplifier (INA326, Texas Instruments Co., USA). In order to remove power supply noise, a 60 Hz TwinT Notch filter was designed for variable Q value. TwinT Notch filter is usefyl in rejecting unwanted signals that are on a particular frequency. As the input signal move closer to notch frequency, attenuation level will increase this giving the typical notch filter's response.

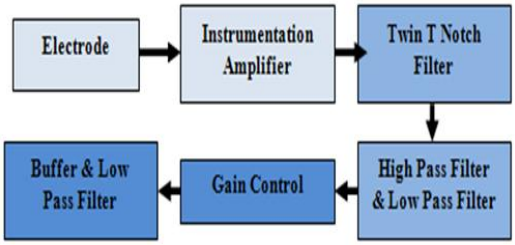


Figure 2. Analog Signal Processing.

In order to minimize the removal and basis line fluctuation, gain control and buffer are used in signal amplification circuit. A secondary 35 Hz low pass filter was used at the final analog ECG signals.

III. Signal Processing Algorithm

ECG signal consists of a P wave, a QRS wave and T waves in ECG signal. Event and wave detection is important to identify the part of the signal related to a specific event of interest.

Signal processing algorithm is used as wave detection method. Firstly, a preamp component which consists of signal amplifier is used to detect the ECG signal induced from wearabel belt-type ECG electrode. Preprocessing method is used to obtain information about signal slope and intensity frequency response curve of derivative. Firstly, differentiation process is perform on ECG signal. By applying the window in differential ECG, the maximum amount of points with the slope, the derivate

procedure to determine the R-peak.

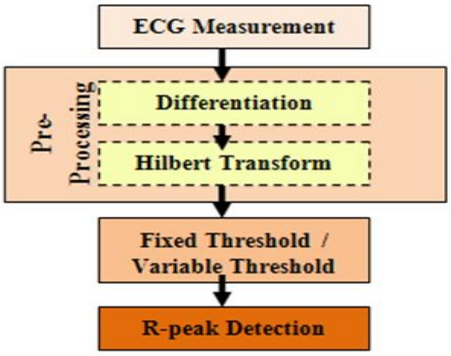


Figure 3. Signal Processing Algorithm.

In differential part, the derivative operation is specified as below.

$$y(n)=\frac{1}{8}[2x(n)+x(n-1)-x(n-3)-2x(n-4)] \quad (1)$$

Differentiating the ECG signal for the purpose of modified its phase, creating zero-crossing in the location of R-peaks. The derivative based operator is used to remove baseline drift in ECG signal and low frequency artifacts. The derivative procedure cancels the low frequency components of P and T wave. Besides that, it provides a large gain to the high frequency components from the high slopes of the QRS complex.

After differentiation process, Hilbert transform is required to rectify the phase in order to create a signal with outstanding peaks in the location of R-peaks. Hilbert transform corresponding to R-peaks, is an odd filter, the zero-crossing of the differentiated ECG signal. Hilbert transform is expressed as below.

$$y(t)=\frac{1}{\Pi}\int_{-\infty}^{\infty} V_r(\alpha)\frac{1}{t-\alpha}d\alpha \quad (2)$$

where is the input ECG signal after differentiation process. For the frequency domain part, the signal is transformed as

$$H(j^{j\omega})=\begin{cases}-j, & 0<\omega<\Pi\\ j, & -\Pi<\omega<0\end{cases} \quad (3)$$

The input signal will processed with all pass filter with -90 shift for positive frequencies and +90 shift for negative frequencies. The imaginary part of Hilbert transfrm is analytic signal and real part is its input.

After the pre-processing method, variable threshold is used to further detect the R-peak. The formula for variable threshold is define as

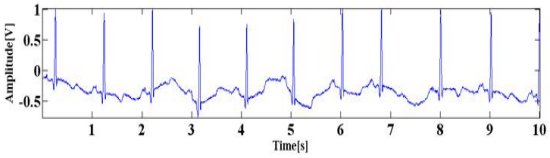
$$V_{TH}=\frac{\sum_{t=t-4}^{t}(Rpeak_t)-Max(Rpeak)}{4}\times 55\% \quad (4)$$

The value corresponding to 55% of the data average 4 except a highest from 5 R-peak detection from ECG is detected variably first.

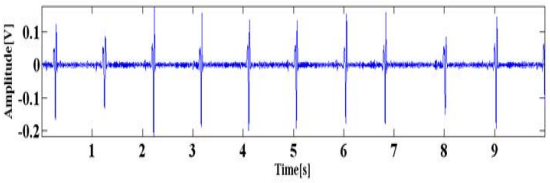
The signal processing algorithm was implemented in MATLAB.

Ⅳ. Experimental Results and Discussion

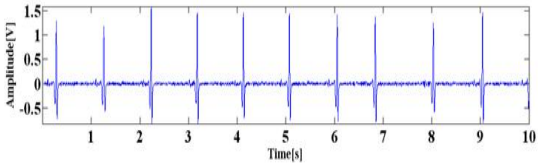
In preprocessing part, the input ECG signal undergoes differentiation process, then Hilbert Transform. The experimental performance of the ECG preprocessing is performed. Firstly, ECG signals of MIT-BIH Arrhythma Database 100 in the range of 0 to 10 second are used as shown Figure 4(a). Then, the signal undergoes differentiation process in Figure 4(b). The final part of preprocessing process is Hilbert Transform process in Figure 4(c).



(a) Original MIT-BIH 100 ECG.



(b) After Differentiation Process.



(c) After Hilbert Transform Process.

Figure 4. ECG Signal Preprocessing.

In R-peak detection of ECG signal, variable threshold value are used in this paper. To

apply the threshold value which corresponding to 55% of the data average, 4 out of the 5 R-peak of ECG is firstly detected.

For performance analysis purpose, R-peak detection with variable threshold method using MIT-BIH Long Term ECG Database 14184 was used. MIT-BIH database is a long-term ECG recording with time range of 14 to 22 hours and manually reviewed beat annotations.

After applied signal preprocessing technique on MIT-BIH Long Term ECG Database 14184, the result is shown in Figure 5(a). Figure 5(b) show the R-peak of ECG which is successfully detected using variable threshold value method.

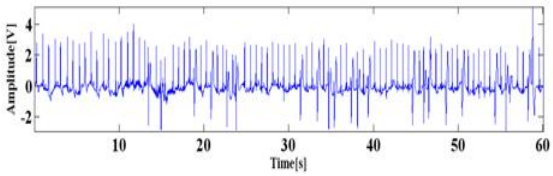


Figure 5(a). MIT-BIH Long Term ECG Database 14184.

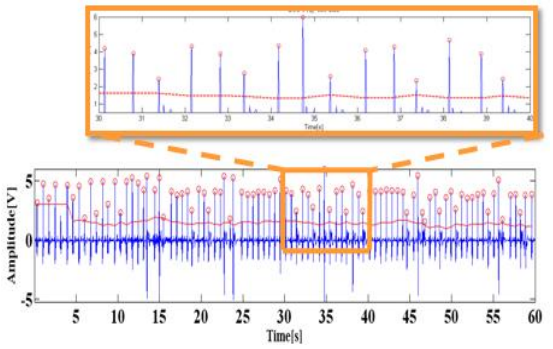


Figure 5(b). R-peak Detection using Variable Threshold value method.

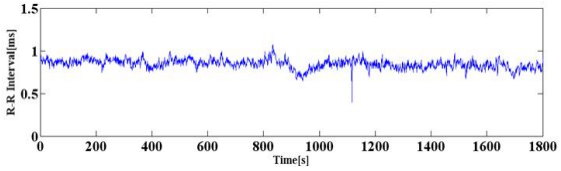


Figure 6. R-R Interval.

From the R-peak, R-R Interval can be calculated easily as shown in Figure 6. The R-R Interval is also known as inter-beat intervals. R-R interval is useful in providing information of HRV (Hear Rate Variability). HRV is the measurement of beat-to-beat variations in heart rate and is useful in analyzing cardiovascular autonomic control [3].

Ⅴ. Conclusion

A wearable approach of ECG monitoring system for wireless tele-home care application was developed using sensors technologies. The wearable belt-type electrode able to transmit ECG signal to PC monitoring via wirelessly and a Zigbee-compatible wireless sensor node. A signal processing algorithm is implemented where preprocessing process is the first step which includes differentiation method and Hilbert Transform. In order to detect the R-peak of ECG, variable threshold method is used. From the R-peak, R-R interval can be easily obtain and is useful information for HRV.

With the recent advanced in technology that allow healthcare providers to deploy, configure, and manage such monitoring system, it improve the quality of life for thousands of patients while providing tremendous service to ubiquitous healthcare industry.

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