Heart Abnormality Detection Technique using PPG Signal

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***Abstract*—Cardiovascular disease (CVD) is the major cause of death in the world. Previous works have been performed to overcome this issue, however, a simple yet effective detection technique scarce. Thus, in this study, photoplethysmogram (PPG) signal which are easily acquired from the fingertip, low cost, and requires low power consumption, is used. These biosignals were obtained from MIMIC II Waveform Database, Version 3 Part 1 with sampling frequency of 200 Hz with the duration of 10 seconds each. The feature of the PPG signals were then extracted using MATLAB and the peak-to-peak intervals (PPI) of PPG signals were calculated and evaluated to differentiate between the normal and abnormal PPG signals. Based on the experimentation results, PPI values between the systolic peaks of abnormal PPG signals are larger than the normal PPG signals. The significant difference between the PPI values of normal and abnormal signals indicates the reliability of the proposed method as a technique to detect heart abnormalities.**

***Index Terms*—Heart Abnormality; Photoplethysmogram; Peak-to-Peak Interval.**

I. Introduction

Cardiovascular disease (CVD) is listed among the major cause of mortality across the globe. It happens mostly because of some factors such as the use of tobacco and alcohol, unbalanced diet, obesity, and physical inactivity. Globally, an estimation of 17.5 million deaths is reported because of CVD in 2012 which represents 31% of total death across the globe [1]. In 2013, 43,602 patients were diagnosed with CVD in Australia alone. CVD keeps on forcing a substantial burden on the Australian community when the country has to pay $1.6 billion for CVD medicine or prescriptions through the Pharmaceutical Benefit Scheme (PBS) in 2013[2].

World Health Organization (WHO) had anticipated that 23.3 million people will die from CVD every year by the year 2030 and this high mortality rate will affect the economic growth of a particular country [3]. Therefore, it shows that a better and reliable method of detecting heart abnormality is needed to overcome this problem. This paper will propose a technique of heart abnormality detection using PPG signal.

The remaining sections of this paper are divided into four sections. Section II consists of the discussion about the related works of heart abnormality detection technique. Section III elaborates more on the method of study of the PPG based heart abnormality detection techniques which comprises of data collection, pre-processing, feature extraction and classification. Then, in Section IV, results of the experimentation are discussed. Lastly, based on the results, conclusion is drawn in Section V.

II. Literature Review

A. Fundamentals of PPG Signals

PPG signal is acquired using pulse oximeter as shown in Figure 1 which is an invasive medical device that is usually used in hospitals to monitor blood oxygen saturation of patients.

Figure 1: Pulse oximeter attached to patient's fingertip [4].

The LED from the pulse oximeter emits light with wavelength of around 900 nm that illuminates the tissue of the fingertips and the photodetector will measure the variation of light intensity which indicated the changes in blood volume in that area. A decrease in light intensity interprets an increase in blood volume in the vessels and an increase in light intensity interprets a decrease in blood volume in the vessels [3]. Figure 2 shows the PPG signal obtained from the pulse oximeter which consists of systolic and diastolic regions.

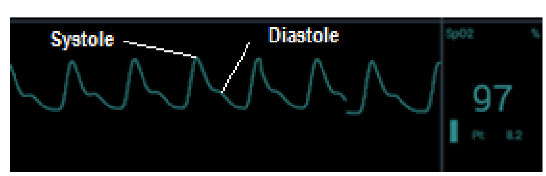

Figure 2: PPG signal obtained from the pulse oximeter [5].

B. Related Works

Nowadays, there are many techniques which exist to determine the heart activity of a patient. The most broadly utilized strategy is by evaluating the ECG signal where a medical expert can recognize irregularities in the heart waveform easily.

Lim et al. in [6] suggested a bipolar mini-ECG for ubiquitous healthcare (U-ECG) as an alternative method for detecting cardiac irregularities. The difference between ECG and U-ECG is the number of leads used for accessing cardiac diseases. In the study, ECG used 12-lead while U-ECG only requires 2-lead that will be attached to the torso surface. The intention of developing this device was to detect the P, R, and T peaks. The amplitude maps for P, R, and T waves were recorded by using the pseudo-BSPM (Body Surface Potential Mapping) data acquired from the electrophysiological simulation of the heart and torso for specific patients. Then, the time variation in the voltage difference between the two electrodes was obtained and an amplitude map for the wave was plotted. The weakness of using this procedure is that the ECG data showed a clear shape for the target waveforms, but equivocal figure for the other waves which might not be valid for certain diseases. Furthermore, the study stated that the proposed method is currently only suitable to apply for patients who are susceptible to atrial arrhythmia and ventricular arrhythmia.

Nowadays, it is vital to have a system that is able to recognize the heart irregularities faster and reliable as we all agree that arrhythmias have caused serious threats for a quarter of the world population. In [7], Raghavendra et al. had proposed an approach for real-time detection of cardiac abnormalities by using Dynamic Time Wrapping (DTW) technique specifically by using mobile phones. By using this approach, the ECG beats feature are extracted and plugged into the classification algorithm. The amplitude of two ECG beats is normalized and then the DTW distance is computed using time wrapping matrix between query and the training beats. This procedure only measures R peak as the reference and the reading was taken from Lead II. In order to reduce the run-time of DTW algorithm, the subsampling is introduced to produce high accuracy as the unnecessary samples and ambiguity are being classified as other classes.

Bonissi et al. in [8] suggested the continuous identification method based on PPG signals. As mentioned in [9], pulse oximeter is sensitive to the user's movements. Therefore, it is crucial to find a technique which can solve this problem. Bonissi et al. [8] have implemented a basic automated approach to remove unwanted samples which is low in quality. For signal processing, high pass Butterworth filter is applied and the feature were extracted using modified Pan Tompkins algorithms. Based from the study, the experiment shows that, by using specific algorithm that is maximum cross-correlation, the accuracy of the biometric identification can be increased. The results also show the accuracy of the proposed method after being tested within different time period which suggests the PPG signals have sufficient distinctiveness to be applied in biometric recognition techniques. However, according to this study, the feature analysis gives low durability and can be improved if continuous enrolment method is adopted.

Nevertheless, PPG signal has been utilized as a part of hospital's facilities to screen and analyse the wellbeing status of patients. From the PPG signal collected blood pressure estimation, blood oxygen level, pulse rate and breathing rate can be checked effortlessly.

III. Methodology

Figure 3 shows the proposed abnormality detection technique which comprises of four sequential steps which are data collection, pre-processing, feature extraction and classification.

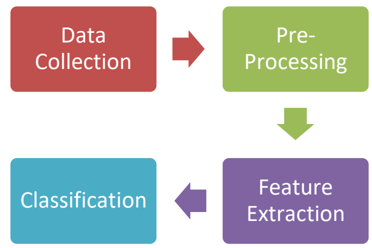

Figure 3: The proposed method used for PPG based heart abnormality detection technique.

A. Data Collection

In this paper, the PPG signals were obtained from the Physionet Database with sampling rate of 200 Hz each. A total of 10 PPG samples were taken from MIMIC II Waveform Database, Version 3, Part 1 which compromises of both normal and abnormal segments of PPG signals from ICU patients with different types of heart abnormalities.

B. Pre-Processing

In a freshly acquired PPG signal, there are a lot of unwanted signals such as noise and baseline wandering which comes from the outside environment for instance, the movement of patient's body. Therefore, to remove the undesirable signal, Butterworth filter, which is a type of low pass filter, is used. Butterworth filter is a type of signal processing technique to get a frequency response as flat as possible in the pass band. This type of filter is used because of its advantages, which it will results in smooth, monotonically decreasing frequency response.

C. Feature Extraction

In this stage, PPG signal goes through segmentation process which is very essential to determine the peaks or systole point of PPG signal. In this study, peak-to-peak interval (PPI) is used as the unique and discriminative features to differentiate signals abnormalities. Figure 4 shows four cycles of PPG signals with the peaks value identified.

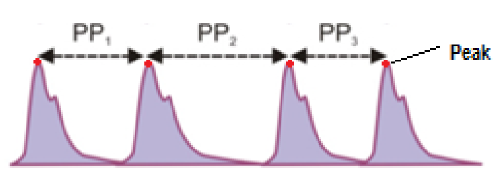

Figure 4: Peak-to-Peak interval of PPG signal [10].

D. Classification

Classification stage is very vital in this experimentation because here is where the normal and abnormal signals are differentiated. In this study, Peak-to-Peak interval (PPI) is used as classification mechanism to discriminate between normal and abnormal PPG signals. As can be observed in Figure 4, the PPI varies which indicates the presence of heart irregularities in the signal. PPI can be computed as in Equation 1.

$$PPI_k = SystolicPeak_{(n+1)} - SystolicPeak_{(n)} \qquad (1)$$

where: k = number of intervals
n = respective systolic peak.

After the segmentation process where peaks of the PPG signal is determined in the previous section, the PPI values are calculated using MATLAB.

IV. Experimentation and Results

In this section, the experimentation using the proposed detection technique as shown in Figure 3 is elaborated further. To briefly recap, the proposed method consists of four stages which are data collection, pre-processing, feature extraction and classification.

Figure 5 shows the raw PPG signal which is acquired from Physionet database with sampling rate of 200 Hz. As can be observed, the signal is inconsistent which indicates the presence of heart irregularities.

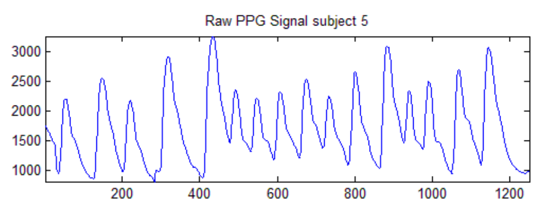

Figure 5: Raw PPG signal

In order to increase the quality and accurateness of the PPG signal as well as to remove noise from the raw PPG signal, Butterworth filter, a type of low pass filter is applied as shown in Figure 6. This filter is also capable to remove the baseline wandering which is caused by the movement of patient's body. This action completes the second stage of this experimentation which is Pre-Processing.

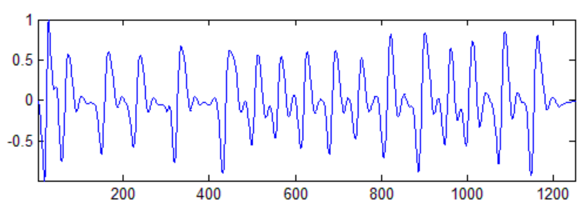

Figure 6: Filtered PPG signal

The third stage of this experimentation is feature extraction. In this stage, the peaks or systole point of the PPG signal is determined using MATLAB as shown in Figure 7. Then, the signal goes through segmentation process which differentiates the normal and abnormal part of the PPG signal. Figures 8 and 9 depict the normal part on PPG signal whereas Figures 10 and 11 depict the abnormal part of the PPG signal.

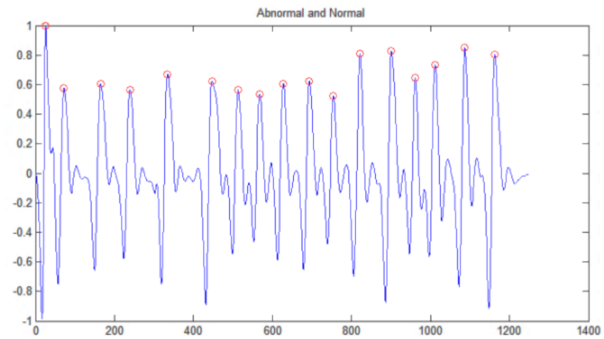

Figure 7: Determined peaks of PPG signal

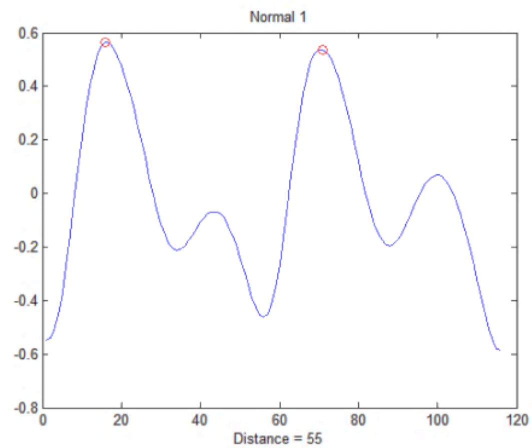

Figure 8: Normal PPG signal

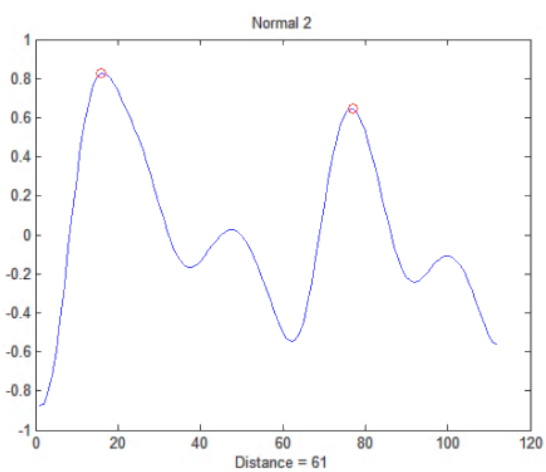

Figure 9: Normal PPG signal

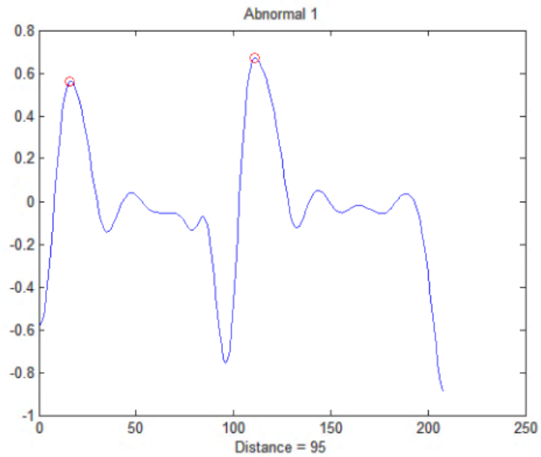

Figure 10: Abnormal PPG signal

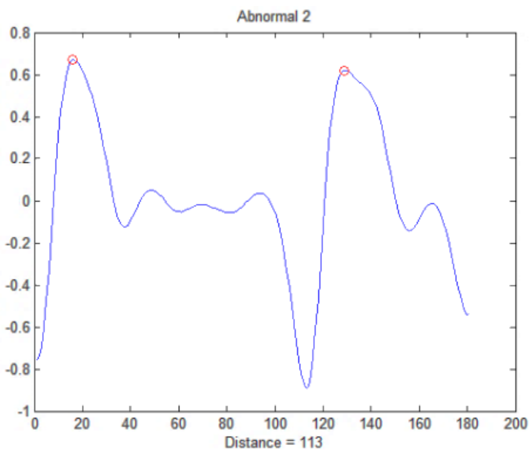

Figure 11: Abnormal PPG signal

To see the difference clearly, all four segmented signals are overlapped in Figure 12 where the blue lines indicate normal signals and the red lines indicate abnormal signals.

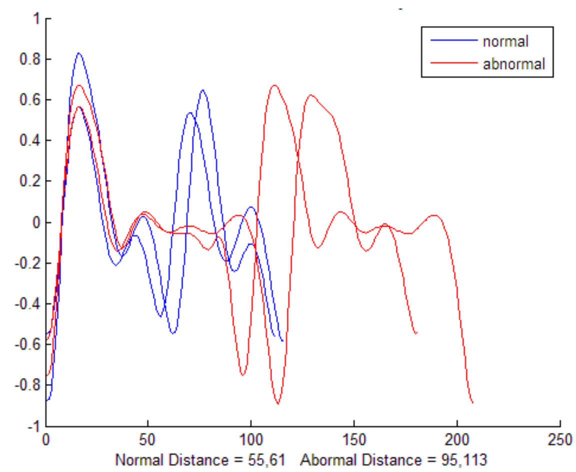

Figure 12: Segmented PPG Signals

Table 1 reflects the results of PPI for all 10 subjects tested in this experimentation. As we can observe, there are significant difference between the PPI of normal and abnormal signals. The PPI values of normal heartbeats are much smaller than the abnormal heartbeats. The range of differences varies between 19 and 75.5. To see the results more clearly, Table 1 is interpreted in histogram representation as shown in Figure 13.

Table 1
Peak-to-Peak Intervals of normal and abnormal signals

Subject	Normal 1	Normal 2	Abnormal 1	Abnormal 2	Difference between normal and normal	Difference between abnormal and abnormal	Average differences between normal and abnormal
Subject 1	82	76	98	98	6	0	19
Subject 2	62	51	118	143	11	25	74
Subject 3	69	61	107	106	8	1	41.5
Subject 4	61	55	155	112	6	43	75.5
Subject 5	55	61	95	113	6	18	46
Subject 6	58	50	112	92	8	20	48
Subject 7	76	73	101	94	3	7	23
Subject 8	55	53	93	86	2	7	35.5
Subject 9	53	58	148	82	5	66	59.5
Subject 10	53	50	105	86	3	19	44

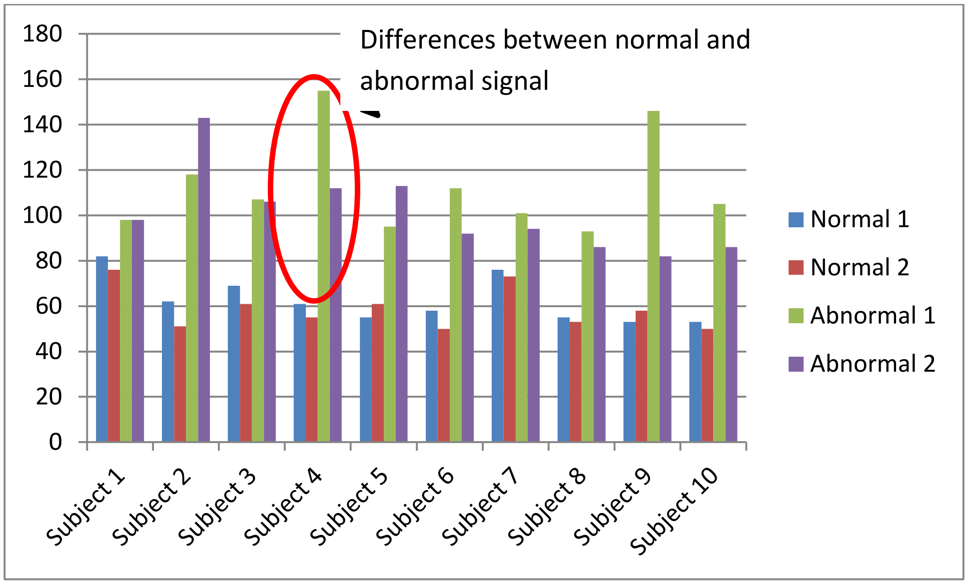

Figure 13: Peak-to-Peak Intervals of normal and abnormal signal

V. Conclusion

As a conclusion, we managed to validate the proposed method as one of the techniques of differentiating the normal and abnormal heartbeats. From the results, we can see that the normal heartbeats have smaller PPI values than the abnormal heartbeats. The significant difference between the PPI values normal and abnormal signal indicates the reliability of the proposed method as a technique the detect heart abnormities. For future works, we would like to devise this proposed method by using real PPG data to improve the accuracy of this method.

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