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Real Time PPG Data Acquisition with GUI based Application for HRV Measurement

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Abstract

This paper presents a study of Photoplethysmography (PPG) for Heart Rate Variability (HRV) measurement. PPG is a non-invasive device which is used to measure the blood volume changes in the veins. Using optical based method, the PPG signal gives such reliable information regarding to the person's body condition. One of the information that could be extracted from PPG signals is the measurement of HRV. In this research, PPG data acquisition is done in real time where it is directly processed using Graphical User Interface (GUI) based application. The main purpose of this research is to design a prototype for acquiring real time PPG signal for HRV measurement. Raw PPG data is extracted from HRM2511e and filtered using Easy Pulse circuit. Then, a software prototype is built for feature extraction and classification. The result is based on 6 different subjects. Each subject will provide PPG signal and HRV measurement in two different physical conditions which are sitting and standing.

Keywords: Data Acquisition, Easy Pulse, GUI, Heart Rate Variability, PPG

1. Introduction

Nowadays, the development of biomedical technology is blooming throughout most countries in the world. Technology transfer between countries allowed researcher to study and experiment on few aspects that could improve their productivity and innovation related to the biomedical technology. According to a report done by California Healthcare Institute (CHI) regarding biomedical industry in 2014, the employment of biopharmaceutical and medical device grew by 2% from 2008 to 2012[1]. Biomedical industry continues to be significant toward people around the world. Numerous biomedical signals were introduced such as Electrocardiogram (ECG), Electroencephalogram (EEG) and PPG. Some biomedical signals may have similar function, such as to measure the heartbeat. However, each signal uses different approach in acquisition process.

In addition, there are a number of methods that can be applied to measure blood flow rate through organs. One of the techniques to record the changes in the volume of an organ is by using plethysmography. It is operated based on optical method called Photoplethysmography (PPG) which can be used to measure HRV. However, previous works on PPG exclude the real time HRV calculation from PPG signal. Furthermore, this research is focusing on the establishment of hardware and software of the project development.

The circuit of PPG consists of a suitable photodetector which is able to collect a continuous measurement of the light intensity scattered from a given source by the tissues. The scattering of the light intensity is emitted by using a light source such as LED. There are two types of PPG probes mode which is transillumination and reflection mode as shown in Figure 1. In transillumination mode, the PPG is positioned adjacent to each other, whereas in the reflection mode, PPG is positioned opposite sides of the particular areas[2]. Figure 2 shows a distinctive waveform of the PPG and its characteristic parameters.

HRV is defined as the changes in physiological phenomenon in the time interval between heartbeats where it contains hidden health problems. This measurement

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is very significant in medical field. The information contained in HRV can be crucial for doctors to determine their patients' body condition[4]. Therefore, in this research, we will use PPG based method to measure the HRV.

Figure 1. PPG Probes. (a) Transillumination mode. (b) Reflection mode.

Figure 2. A typical waveform of the PPG and its characteristic parameters[3]

The remaining of the paper is organized as follow. In Section 2, some explications of literature review relevant to the topic of this research are discussed. Section 3 elucidates the proposedmethodology used in this study which includes the signal processing of the data together with the hardware and software implementation. Then, Section 4 lace out the experimentation results. Finally, Section 5 briefly maps the conclusion of the research.

2. Related Works

Research in PPG becomes the interception area between engineers, doctors, physicians and physiologist. Whenever one of them requires studying the performance of bodily function, they need a device that is helpful and accurate to pursue their research. Engineers are responsible to build that bridge for them as engineers are trained to solve problems. In this research, the application of PPG can be extended toward the measurement of HRV. This may become one of the methods that other people may use in any application that is suitable for them. Therefore, in this section, related works on PPG and HRV are discussed.

2.1 Related Works on PPG Device

The basic construction of PPG device consists of three elements which are light source, a detector and signal processing system. There exist previous works in developing a PPG device. In[5] had established a research which is focusing on the investigation of PPG signals and blood oxygen saturation values using a multimode PPG/SpO_2 sensor. The study discussed about the effective level of different type of PPG probe mode which are transmittance and transreflectance mode. The procedure of the research began with selecting suitable electronic equipment for constructing a multimode finger PPG probe as shown in Figure 3. There were four LEDs used in the device. Matlab software was used to calculate the oxygen saturation (SpO_2) values. Besides that, the study applies the formula as shown in Equation (1) to obtain the SpO_2.

Figure 3. Diagram of the multimode PPG finger probe identifying the configuration (placement) of all optical devices (LEDs and Photodiodes).

$$SpO_2 = 110 - 3\ (R) \quad (1)$$

where R is the ratio of AC PPG (pulsatile PPG) and DC PPG (total detected intensity) as shown in Equation (2).

$$R = \frac{AC_{red}}{DC_{red}} = \frac{AC_{ired}}{DC_{ired}} \quad (2)$$

The result of the research shows that the transmittance mode only failed in 17 volunteers whereas transreflectance mode only failed in 3 volunteers. This suggest that transreflectance mode generate better performance as compared to transmittance mode. In conclusion, the outcomes are considered as a reliable output information. Researchers who focus their work on PPG signal analysis may reconsider the suitability the type of probe that they want to use.

In another study done by[6], the application of a smartphone PPG for measuring various physiological indices were developed. The research design a technology that is able to perform PPG and calculate the heart rate and normalized pulse volume based on the PPG signal collected using smartphone. The concept of the device construction is based on the transreflection mode. Therefore, the outcome shows that the PPG signals is successfully measured by using CMOS camera implemented in the smartphone. This research proves that PPG signal is possible to be merged in a smartphone system. This application may ease the implementation of a portable and smart PPG system. However, the system only works in certain smartphone such as Iphone 4s, 5 and 5c. This shows that the research needs to be improved parallel with the development of smartphone system.

In a different research performed by[7] where the investigation is focusing on the developing a driver's physiological monitoring system based on PPG sensor and a smartphone. The research designed a wearable PPG sensor module based on a Programmable System on Chip (PSoC). The PPG signal is processed using method shown in Figure 4.

Figure 4. PPG signal process[7]

Based on the developed system; the project is fit to be applied in the real life situation. However, in another perspective, the result may be strengthen and fortified by adding another parameter to increase the dependability of the results.

2.2 Related Works on PPG Variability

There are several issues in studying the effect that may fluctuate the PPG signals. Human physiological conditions may have a tendency to influence the PPG signals. In[8] perform a comparison PPG Variability (PPGV) with HRV in the sitting position during paced respiration. The first approached used in the study is by searching the Pulse Transit Time (PTT) and followed by performing PPG component detection algorithm. Then, the signals will be measured. In the signal processing, the method used is denoising, peak detection, and calculation for PTT. The result shows that the variation of PTT will give effect to the internal part of PPG. However, the experimentation does not consider the analysis in frequency domain which considers more reliable parameters.

Another research done by[9] presents a real time acquisition and analysis of Phonocardiogram (PCG) and PPG waveforms which mainly focuses on signals processing. In the result analysis, it had been stated that the equation used to calculate the HRV is shown as in Equation (3).

$$HRV = \frac{NoOfPeaks}{(T / fs)/60} \quad (3)$$

where *No Of Peaks* is referred to the number of adjacent systolic peaks, *T* is the total length of the signal and *fs* is the sampling frequency. This equation is the basis of the HRV measurement in this study.

2.3 Open Issue

Despite of all research done by previous researchers, most of the PPG signal acquisition were not measured in real time. A system design that includes a real time PPG signal measurement can be process for further usage. Therefore, in this research, we proposed a prototype that will assist the process of PPG data acquisition which is done in a real time and includes the HRV measurement.

3. Methodology

This research will be based on the methodology shown in Figure 5 which consists of data acquisition, pre-processing, feature extraction and classification.

Figure 5. Proposed methodology.

3.1 Signal Acquisition

In this study, a total of 6 subjects were acquired with age range of 22–25 years old. The recorded data is obtained separately in two different conditions which are sitting and standing.

3.3.1 Hardware Block Diagram

This project is done by using HRM2511e which contains photodetector and IR LED, Easy Pulse sensor V1.1, Z-duino microcontroller for interfacing and data processing machine for measurement as shown in Figure 6. This device establishment is important as the data acquired is in real time.

Figure 6. Hardware block diagram.

Table 1. Data Collected from 6 Subjects

Subject	HRV Measurement (bpm)	
	Sitting	Standing
1	141.36	133.51
2	94.24	117.80
3	94.24	133.51
4	70.68	151.07
5	133.51	125.65
6	133.51	141.36

3.3.2 Software Block Diagram

GUI developed in this project is based on Figure 7. Firstly, the GUI will display the main menu. User will enter the file name to save the subject. Then, the recording of PPG signal in a real time is initiated. The time taken for a person to record his/her PPG data is 10 seconds. After the measurement is complete, a file will automatically save in the same directory where the software is located. This step is done for future reference. The HRV computation is performed once the user clicks on the HRV calculation button.

Figure 7. Software flowchart.

The real software appearance is shown in Figure 8. The GUI consists of several buttons to assist the user in acquiring the PPG signals.

Figure 8. Software GUI display.

3.2 Pre-Processing

Figure 9. Pre-processing technique.

PPG signal measured from HRM2511e sensor contains noise. In order to eliminate the noise and obtain a smooth PPG signal, the raw PPG data is passed through two filtering stages in Easy Pulse sensor as shown in Figure 9. High Pass Filter (HPF) and active Low Pass Filter (LPF)

is used in the first stage for filtering and amplification of the signal. In the second stage, passive HPF and active LPF were used for controlling the gain. While the device is operated, the amplitude of the signal can be adjusted by tuning up or down the gain (in second stage). The non-inverting buffer is fed with two-step amplified and filtered signal. Therefore, the required analog PPG signal is obtained from the buffer stage[10].

3.3 Feature Extraction

The PPG signal obtained from the device is used to measure the HRV. The formula is based on the calculation between two peaks derived from the PPG signal. In this study, the sampling frequency used is 25 Hz and Equation (3) is applied for the HRV measurement.

3.4 Classification

In the final stage, the GUI application will show the analog PPG signal, the file name saved by the user and the measured HRV. In this study, our calculation is based on Equation (3). In the GUI application, we will use the flowchart as shown in Figure 10 to compute the HRV.

Assume that in Figure 10, *s[n]* is the input PPG signal and *n* is the number of sample. If the value *s[n-1]* is less than *s[n]* and the value of *s[n+1]* is larger than *s[n]*, the number of beat which is initially 0 will increase by 1. At the end of the signal measurement, *beat* in Figure 10 will represent the number of total beat and that value will be plugged into Equation (3). Finally, the HRV measurement will be obtained.

Figure 10. HRV flowchart calculation.

4. Results and Discussions

In this research, the results obtained from the software that had been developed are analyzed. Figure 11 shows the PPG graphs and calculated HRV of all 6 subjects in sitting and standing positions.

Figure 11. PPG signal of 6 subject (sitting and standing position).

Based on the developed prototype, data is collected and taken while the subject is sitting and standing as shown in Table 1.

According to the observation from the experimentation results, hardware prototype is functioning well during PPG signal acquisition. It is advisable to use a high performance computer during signal acquisition to avoid complications when the application is used. It has been shown that the PPG signal is affected when each subject stays in different position. In most cases, HRV of a person increases when they are standing. However, based on the results in Table 1, Subject 1 and Subject 5 experienced HRV declinations when changing from sitting to standing position. This may be due to the initial state of that person where during the first data acquisition interval (which is sitting), a lot of body movements were involved which require them a longer time to be in resting condition. In addition, PPG waveforms of subjects in sitting conditions are more stable. This is true as the subjects are in a calm and relax state which reflects the stability of the resultant PPG waveforms.

5. Conclusion

As a conclusion, the main objectives of this research which is to develop a prototype that can assist user to obtain PPG signal as well as to measure HRV in a real time are achieved. Moreover, HRV measurements in sitting and standing conditions of a person changes when their physiological condition varies. Sitting position of a person resulted in more stable PPG waveforms as compared to standing. This is because when a person is sitting, his/her body movement is minimal which make them more relax and calm.

Therefore, there are several considerations that can be included for future works such as by implementing biometric identification. Several parameters such as physiological variability contributes to changes in PPG signals. Therefore, a better algorithm that can identify current physical states of human body have a potential in developing PPG technology into other application such as wireless health monitoring device and etc.

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