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Measurement of Heart rate from Photoplethysmogram using Savgol filter

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***Abstract*— Our work provides overview of Measuring and monitoring Heart Rate for patients in critical conditions. Variations in heart rate is very important for a patient's physiological condition analysis. Electrocardiogram is the most popular methods of measuring Heart Rate these days for higher efficiency. But measuring Heart rate from ECG may cause discomfort and there is a chance of getting skin allergies to the subject. So, we implement only PPG based system to monitor Heart rate. PPG is smoothed using Savgol filter after extraction from pulse sensor and then processed to get the heart rate. This paper is about the extraction of pulse from fingertip and prediction of heart rate from the extracted pulse (Photoplethysmogram).**

Keywords*— Photoplethysmography(PPG), Heart rate, Electrocardiogram.

I. INTRODUCTION

Heart rate is an dominant factor in every living being . The heart's function is to pass oxygen and blood throughout the body. When the heart stops working correctly, just about everything in one's body will be affected."Cardiac output" directly related to heart rate and the amount of blood pumped out through the arteries and veins of a body with each beat stroke volume.

One of the methods used to evaluate cardiovascular autonomic nervous system activity is HRV analysis (cranial heart rate variability). The autonomic nervous system is responsible for the connection of the central nervous system to the cardiovascular system. The heart rate variability is constantly modulated through complex interactions between branches of the autonomic nervous system, the sympathetic nervous system, and the vagus nerve. Since the activity of the autonomic nervous system and the heart rate are related in a nonlinear manner, the changes in the sympathetic activity or the vagal tone have the ability to change the response of the heart rate to the stimulation of any branch of the system

Using ECG all the time and in all the patient's health conditions is not safe. Since, the electrodes are present in the process of estimating Heart rate through ECG, these electrodes might create irritation to the subject. Also small powered electric signal is passed to the subject's body, which is also not safe.So we introduce a system that involves a single LED based system namely Photoplethysmography to estimate the Heart rate. In this proposed method, only LED is placed on the fingertip of the subject and parallely a photo detector also placed to read the blood volume variations that occured at the finger due to heart's function.

II. LITERATURE REVIEW

On the Analysis of Fingertip Photoplethysmogram Signals [1]. In this research they found that The characteristics of the PPG waveform and its derivatives have been clarified and some features of the PPG signal have been discussed. Taking the first and second derivatives of the PPG signals may help in detecting the informative inflection points more accurately. Different features have been used as indicators for the same physiological variables. Moreover, they didn't found the realistic information about PPG and also failed to extract the most informative parameters from PPG. This

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study gives an idea that a PPG signal can be extracted from fingertip.

Feature Extraction for Photoplethysmographic Signals using PWA: PPG Waveform Analyzer [2]. In this paper they have proposed an algorithm to identify some of the features and patterns present in Photoplethysmographic (PPG) signals for example, dichrotic notches, ectopic beats and apertures, and various techniques for extracting these features are suggested.

Non-contact heart rate monitoring utilizing camera photoplethysmography in the neonatal intensive care unit [3]. In this research they used non-contact, camera based HR monitoring in newborn infants in the NICU using only ambient light.To increase robustness of HR monitoring a combination of improved algorithms, more sensitive cameras and dedicated illumination are used to compensate infant motion and suboptimal illumination conditions. The reason to use ambient light instead of dedicated illumination because it is in line with the unobtrusive, passive nature of this camera based technique

Heart Rate Monitoring Using PPG With Smart phone Camera [4]. In this paper they have proposed a model using videos of fingertip captured with smartphone camera to estimate heart rate (HR) using the photoplethysmography (PPG) technique. It is based on tracking subtle color changes on the skin owing to cardiovascular activities. These color changes are invisible to the human eye but can be detected by digital cameras. The method is divided into three main steps: first, reading the video frames and processing them to obtain the PPG data, next, extracting the Blood Volume Pulse (BVP) signal, and finally, estimating the HR from the signal.

III. EASE OF USE Pulse Sensor

The Pulse sensor is designed as a non-invasive optical technique to detect the PPG signal or pulse wave from human body. Pulse sensor is shown in figure(1). It uses an infrared light source to illuminate the finger and a photodetector is placed in such a way that it can measure the small variations also from the transmitted light intensity. The variations captured in the photodetector are related to changes in blood volume inside the human body. The signal is further processed by the process like filtering, amplifying to obtain a nice and clean PPG waveform. This waveform is nothing but a synchronized heart beat. Since the waveform is synchronous to the heart beat, this technique can be used to calculate the
heart rate.

Arduino

The arduino UNO is designed as follow. It consists of
14 digital input/output pins of which 6 are analog inputs and 6 can be used as outputs, a USB connection, a power jack, a reset button and more. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to- DC adapter or battery to get started.

Out of all these 14 pins shown in figure 3, we used the following pins for PPG extraction using a pulse sensor.

- **GND (3)**: Short for 'Ground'. There are several GND pins on the Arduino, any of which can be used to ground your circuit.
- **5V (4) & 3.3V (5)**: As you might guess, the 5V pin supplies 5 volts of power, and the 3.3V pin supplies 3.3 volts of power. Most of the simple components used with the Arduino run happily off of 5 or 3.3 volts.
- **Analog (6)**: The area of pins under the 'Analog In' label (A0 through A5 on the UNO) are Analog In pins. These pins can read the signal from an analog sensor and convert it into a digital value that we can read.

Pseudo Code

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The Pulse sensor design which is in reflectance approach, TCRT1000 IR device is used as sensor. It will detect the pulse signal when an user places his/her fingertip on the top of the sensor. While this sensor performed well, it was susceptible to a very small movement of the finger. So, the user should keep the finger very steady to obtain the accurate pulse signal.

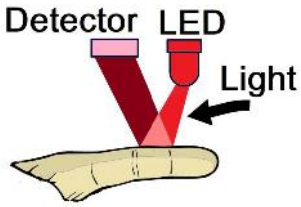

Figure : Pulse sensor working

1. Connect the pins as shown in table 1
2. Create a function to read the pulse from pulse sensor
3. Initialize baud rate to 1600
4. Fix Threshold value to reduce noise
5. Fix delay variable
6. Start serial monitor
7. Acquire PPG signal and filter the Noise after extraction using
8. Read the Saw detection module in Arduino to count the peaks in pulse generated.
9. Calculate and display heart rate (BPM)

BPM= 6 × no.of peaks generated in 10 sec BPM=Beats Per Minute [its mutable])

Methodology

The Table below gives the overview of PINs that we configured from pulse sensor to the arduino UNO board to extract the pulse from fingertip.

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Table 1 : PIN CONFIGURATION

Pulse sensor pin	Arduino Pin
Signal	6 - **A_0**
VCC	5 - **3.3V**
GND	3 - **GND**

The snap shown below (figure 4) depicts the real time monitor of heart rate from fingertip using pulse sensor and samsung wrist watch at the same time. The heart rate from the pulse sensor is generated using the pulse generated at fingertip and it is measured in Beats Per Minute.

Figure 4 : pulse sensor vs samsung watch

The pulse generated from the pulse sensor using the serial input is displayed in figure 5a. Eventhough, the threshold is set to minimize the noise, we can see some inequalities in the pulse generated. In order to get a perfect Photoplethysmogram, this signal will be further processed and smoothened

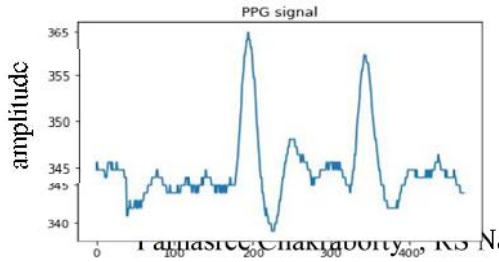

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Figure 5a : PPG signal before smoothening

A digital filter named **Savitzky-Golay** (SAVGOL) filter is used to smooth the PPG signal extracted from the Pulse sensor. The output of the smoothened signal is shown in figure 5b

number of samples

Anyhow, while measuring the heart rate from the pulse generated at the fingertip using photoplethysmography have an error while compared with samsung wrist watch. The output of heart rate generated from pulse sensor is displayed in figure 6 and the output of heart rate from samsung wrist watch is displayed in figure 4 (wrist watch).

```
22:37:03.440 -> ♥  A HeartBeat Happened !
22:37:03.488 -> BPM: 75
22:37:03.852 -> ♥  A HeartBeat Happened !
22:37:03.852 -> BPM: 74
22:37:04.090 -> ♥  A HeartBeat Happened !
22:37:04.139 -> BPM: 78
```

IV. CONCLUSION

In this study, we established a connection from arduino using a pulse sensor to extract the features of pulse or the blood volume changes occured due to heart beat. These changes can be called as Heart rate since these are directly related to the heart beat occured by the body. This Ppg based heart rate monitoring is accurate enough to measure the Heart rate of human body from fingertip. This method is also said to be Non invasive method of Heart rate estimation since we measured heart rate without passing any electric current to the human body. Our method measures heart rate with an accuracy of 97%.

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