Portable Photoplethysmography Sensor: Precursor to Noninvasive Blood Glucose Concentration Measurement

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***Abstract*— Currently the most accurate and easily accessible method to check the blood glucose levels is to prick the finger for blood samples. This method is painful and unpleasant as multiple finger pricks may be required for adequate blood supply for the detection unit. There is also a chance of infections occurring with the current method and the long-term costs are very high. This project is aimed to create a photoplethysmography (PPG) device to be further used for blood glucose monitoring that will mitigate the issues that arise due to the current methods. The primary objective is to create a non-invasive sensor that would ensure accurate monitoring of a PPG signal. The secondary objective was to relate the features of the PPG signals to estimate blood glucose levels however was not able to be done due to covid-19 restrictions at this time. Due to this the project involved generating a low-cost PPG sensor and to extract the features related to the signal that was acquired.**

Keywords-component; PPG signal, Glucose, Non-Invasive

I. INTRODUCTION

The development of this instrument based on Photoplethysmography technology will revolutionize blood glucose detection. As current methods are expensive, messy, and generally unsanitary, this is not an ideal method for test for blood glucose levels. Currently, the most accurate and easily accessible method to check the blood glucose levels is to prick the finger for blood samples. This method is painful and might require the individual to prick their finger multiple times to ensure adequate blood is supplied to the device. Also, as the finger is being pricked, there is a chance for infections to occur if the needle is not sanitized. Infections can also occur at the prick site if the needles penetrate too deep in the skin and wound does not heal in a timely manner. Furthermore, an individual is required check his or her blood sugar levels multiple times a day to ensure proper steps can be taken which leads to a high quantity of needles and testing strips being required. Diabetes test strips cost on average of $50 a month and can cost up to $100 a month. Needles also need to be regularly replaced adding to that relatively high monthly cost. Due to this, the long-term monetary cost for the current method is very high. However, with the proposed non-invasive blood glucometer, users will have access to a cheaper and more sanitary method that can consistently deliver accurate results.

II. PURPOSE

The goal of this project is to decrease the need to invasively find blood glucose levels and create a cheap, accurate, and more healthy way to read those levels from a PPG signal. This project is aimed to create a PPG device to be further used for blood glucose monitoring that will mitigate the issues that arise due to the current methods. The primary objective is to create a non-invasive sensor that would ensure accurate monitoring of a PPG signal to be later used for blood glucose monitoring.

III. MATERIALS AND METHODS

Designing the circuit that would be used to generate a PPG signal was researched intensely to determine what would provide the best results. The schematic of the circuit used is shown below.

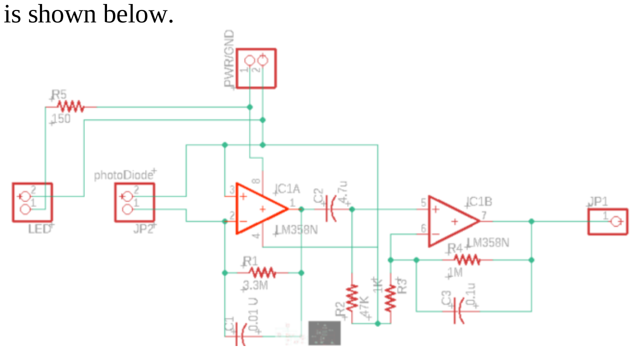

Figure 1: CIRCUIT SCHEMATIC

This circuit is a combination of using a high pass filter and a low pass filter to provide frequencies above .48 Hz and below 4.98 Hz. The average heart beats between frequencies of 1-2 Hz. Using that we determined what would be the best cut off frequencies to use to filter out unwanted noise from the signal. The circuit is composed of:

- Five Resistors
  - One 150Ω
  - One 1KΩ
  - One 47KΩ

- One 330KΩ
- One 1MΩ

- Two .1µ Farad Capacitors
- One 4.7µ Farad Capacitor
- One LM358 Operational Amplifier
- One NONIN Finger Probe

The NONIN finger probe is composed of an LED light that emits wavelengths around 940 nm to probably pass through the finger to a photodiode installed within the probe.

The casing that was used for this project was made in SolidWorks and 3d printed. The size of this casing is 150mm (length) x 80mm (width) x 80 mm (height). The material used for the casing was polylactic acid due to its durability and strength.

Figure 2 : IMPLEMENTATION OF SYSTEM

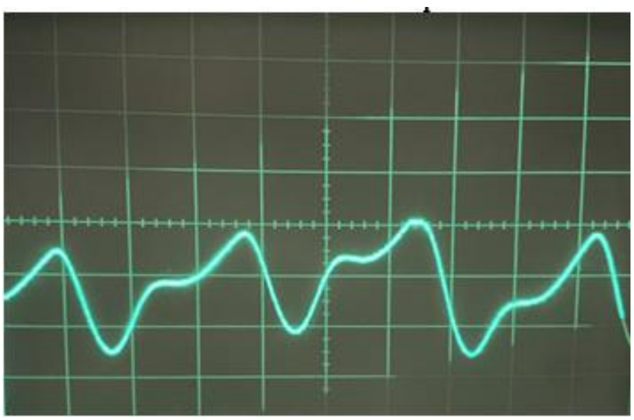

Figure 3: RAW PPG DATA. VOLTAGE VS. TIME

IV. Analysis and Discussion

The raw data obtained from the PPG sensor is shown below. This comes directly from the circuit before being processed through the MATLAB code. The signal that is shown in Figure 1, shows the diastolic arch coming before the systolic arch. Once the signal is processed through an Arduino UNO, the signal will be shown correctly through MATLAB. Once this data is digitally filtered, features will be extracted to develop patterns throughout that will analyze the PPG for future development of blood glucose concentrations.

A. *Data Acquisition*

The data is acquired by an Arduino Uno and is processed in a MATLAB script. 500 samples are collected and stored in a 500x1 matrix file. This file is then used for extracting features that can be used to determine blood glucose levels non-invasively like finding the average waveform, the beats per minute, the width at various heights of the peak, and the peak to peak distance. The sections below will highlight the results of the MATLAB script with sample data

B. *Averaging*

The MATLAB script takes all the PPG waveforms and segments them into individual pulsatile waveforms and averages all the waveforms into a single waveform for increasing the accuracy of the feature extraction functions.

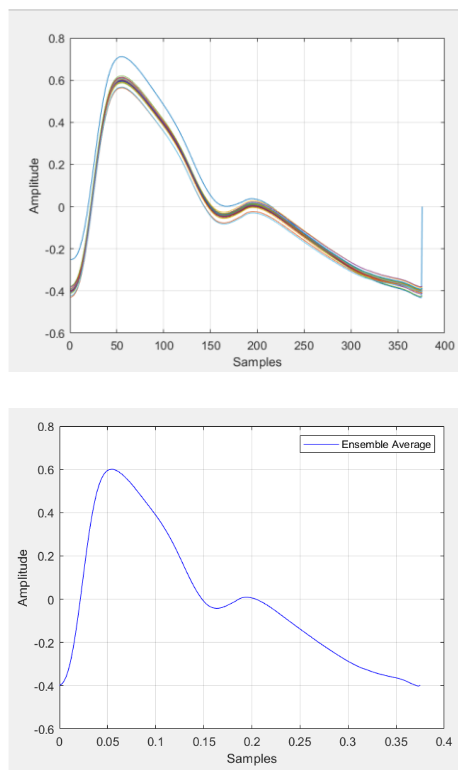

Figure 4a (top): SEGMENTED WAVEFORMS PLACED ON TOP OF EACH OTHER
Figure 4b (bottom): SINGULAR WAVEFORM

C. *Calculating Beats per Minute*

To calculate the beats per minute (BPM), the total number of peaks found in the 500 sample is recorded. Then this value is divided by the signal duration to find the pulse rate. This is a key factor to identifying blood glucose levels as it allows the machine learning algorithm another artifact to track to increase the accuracy of the model.

D. *Peak Width*

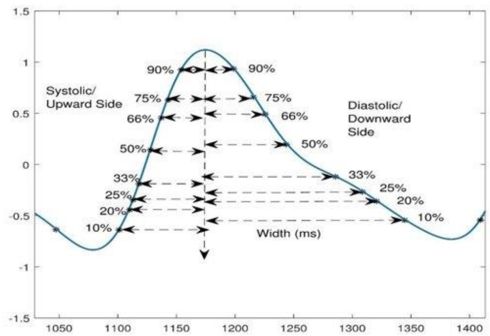

Figure 5: PEAK WIDTH

The peak width allows for extracting more accurate information of the pulsatile waveform as any baseline shift is ignored. This ensures that features that is fed into any machine learning algorithm is as accurate as possible and closely related to just the PPG signal rather than any variations that may arise. These variables could be the user's arm movement, the baseline signal of the user, and the powerline shift of the adapter. This feature also creates a more accurate picture of any changes in the pulsatile volume (aka blood flow) which can be due to changes in blood glucose concentrations.

E. *Peak to Peak Distance*

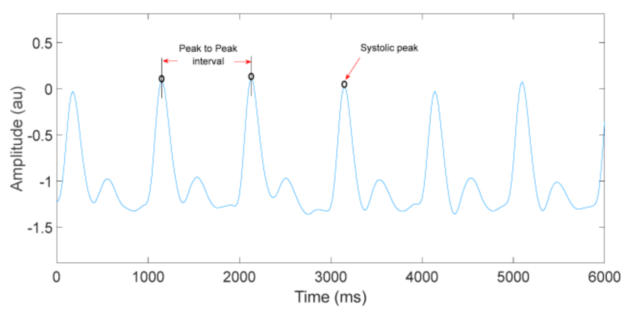

Figure 6: PEAK TO PEAK DISTANCE

The peak to peak interval is an important feature to store as variations in peak to peak voltage of photoplethysmography signals are closely related to changes in pulsatile volume. This allows the machine learning algorithm to have another feature that is closely related to direct changes in the flow of blood. This helps create a more accurate model and strengthen the connection between PPG waveforms and variations in blood glucose concentrations.

V. Conclusion

This project provides a cheap and accurate measurement of a PPG signal generated through the index finger. The features extracted allow for future pattern recognition to develop measurements for blood glucose concentration and many other possibilities.

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