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A Novel Low-Cost Method for Acquisition of Photo Plethysmograph (PPG) Signal for Experimental Analysis and Review of Its Applications

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Abstract

Photo plethysmography (PPG) is a technique of acquiring the information of our cardiovascular system using optical sensing technology. This can be commonly observed in fitness watches and is extensively reliable to comment on heart health. PPG data carries a lot of significant information but unfortunately it is not readily available for experimental analysis. This paper aims to create an PPG signals acquisition setup and make the data available for experimental purpose.

Keywords: Signal acquisition, Photoplethysmography, Heart Rate Variability, Digital Signal Processing, USB Powered Device.

1. Introduction

PPG sensors generally acquire the information of the blood flow from the tip of the figure by transmitting the infrared light and acquiring the reflected light using a photodiode. Due to its non-invasive acquisition it is extensively used as a vital biomedical signal marker [1].

With recent advancements in smart watches a built-in pulse sensor module allows to track Heart Rate, not only is this sensor used to track the heart rate but also can be used to track sleep, monitor anxiety, support in guided meditation, provide remote patient monitoring system and many more applications. Its use in diagnostics can also be of great significance [2].

However, this data is never available directly for research purposes and hence this paper aims at acquiring the heart rate pulse signal and making it available for experimental purposes.

The entire process of acquisition of PPG data and its storage is mainly distributed in four parts in the Methodology where a pulse sensor is used for data acquisition the microcontroller ATMEGA328-P is used to convert the analogue signal to the digital signal and transmit the data using serial communication to the PC. This transmitted data is captured using the python interface and stored in the form of a .csv file.

Further the results for this signal acquired are plotted to confirm that the signal is correctly acquired and stored in a .csv file. In the application part we discussed the areas of application for this acquired data and its potential applications concluding with the significance of this signal acquisition tool.

2. Methodology

The complete task of data acquisition can be distributed into three main blocks which are Signals Acquisition, Signal Synthesis and Transmission and Signal Storage. The operation is completely described in Figure 1.

2.1 Signal Acquisition

Physical information related to the blood flow from the body is converted to an analog signal in the electrical form using the PPG sensor. PPG sensor generally operate in the voltage range of 3 – 5 Volt DC and transmit the equivalent analog signal using an IR Led and Photodiode combined with and operational amplifier to transmit signal in range 0-3.3V.

2.2 Signal Synthesis

To be able to store the signal it is important to convert the analog signal generated by the PPG sensor to digital form and then transmit the data in the manner convenient for data storage.

In our case we use ATMEGA328-P microcontroller as it has an inbuilt Analog to Digital converter channel and is compatible with the voltage range of the signal generated by the PPG sensor. The digital data acquired is then transmitted through a digital pin on the microcontroller using serial communication at the Baud rate of 1200.

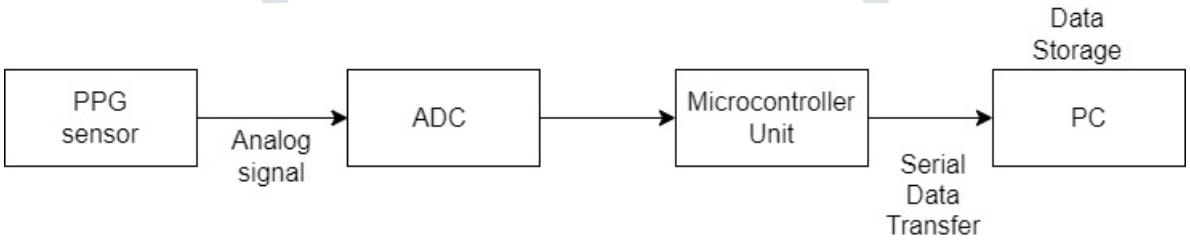

Fig. 1 Block Diagram demonstrating the complete signal acquisition and storage of PPG signal.

2.3 Signal Storage

We have selected a Windows enabled PC with 4GB ram and 500GB storage with python3 to read the signal transmitted by the microcontroller using serial communication. The data is received on one of the communication ports of the computer using python scripting and the received data is then stored in a .csv file along with the user input metadata like the name, age, body weight, size, medical history along with the PPG data. The signal acquisition sampling frequency (fs) is 24 Hz in our case to maintain the data integrity.

The completed setup for the data acquisition and storage is shown in Fig. 2.

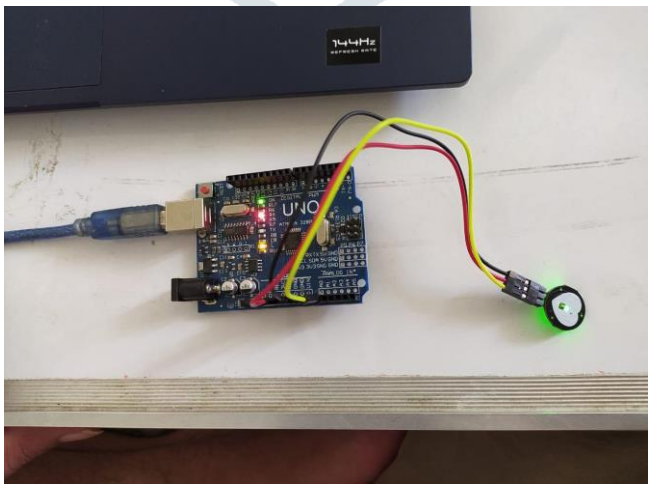

Fig. 2 Hardware Setup For Data Acquisition

A similar approach for acquisition for a different use case can be followed in [3].

3. Results and Discussion

The signal acquired and stored is plotted as shown in Fig. 3. The duration of the signal acquired is kept as 30 sec for all the acquired signals.

The height of the peaks in the PPG waveform represents the magnitude of the blood volume changes during each cardiac cycle.

The raw PPG data plotted in Fig. 3 shows the presence of signal noise and hence we can see the shift in amplitudes in the signal. Hence the raw PPG signal can be mathematically expressed as

$$raw\ PPG[n] = PPG[n] + s[n]$$

where PPG[n] is the actual signal and s[n] as the signal noise. There are various methods to filter the signal noise and estimate the PPG signal however in this paper we have selected the method described in [10] for noise removal and signal filtering. Similarly there are various methods to detect the peaks from the signal but we have implemented the peak detection methodology as described in [11].

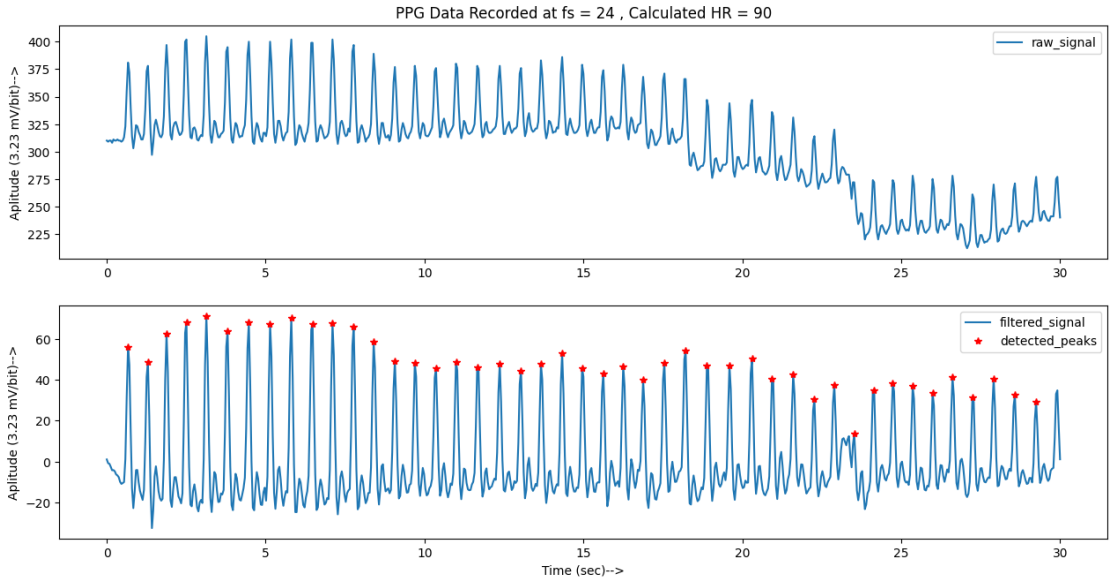

Figure 3. Plot of Raw PPG Signal Acquired Using The Prototype Device.

4. Applications

The acquired PPG data can be used in a wide variety of applications. Feature extraction of different physiological signals and tool creation can be supported as stated in [4]. PPG signal is frequently used to detect heart activity. Since the acquisition of data is possible using small portable devices, a study shows that this data can be used to detect the systolic peaks and used in cardiac emergencies [5]. A detailed study on the impact of exercise on physical health can be done using the acquired PPG data [6]. Recent studies on blood pressure Estimation from the PPG data using Artificial Intelligence are quite popular and show promising results [7]. PPG data is used to guide a person with mediation providing the feedback related to heart beat activity [8]. Heart rate variability (HRV) is the study of correlating between beat-to-beat analysis of the heart activity. PPG data can also be used to comment on the HRV analysis [9].

5. Conclusions

As usage of PPG data in experimental analysis is vital we conclude our methodology to be a novel alternative to acquire and store this data which can be further used in experimental analysis.

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