

Photoplethysmographic Heart-rate estimation using LabVIEW

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Abstract : Photoplethysmography (PPG) signal has often used to estimate the heart rate, respiratory rate, blood pressure. Accurate heart rate (HR) estimation using photoplethysmogram is a challenging task due to motion artifacts. This article provides a heart rate estimation from the PPG signals which is interfaced with Arduino and LabVIEW. Software development is done using LabVIEW i.e., VIs are developed to calculate the peaks of PPG signals, the time at which peaks are occurred and hence the heart rate. Arduino microcontroller is used to collect PPG sensor data.

Keywords – Pulse sensor, Heart rate monitoring, Arduino, LabVIEW, Signal peak tracking.

I. INTRODUCTION

Heart rate is the number of heartbeats per unit of time. Usually, heart rate is expressed as beats per minute (BPM). The heart beats to supply oxygenated clean blood from the left ventricle to the blood vessels of the body via the aorta[7]. As the need for oxygen changes in various situations, like exercise, sleep and so forth, the heart rate changes accordingly. Heart rate measurement is used by healthcare professionals to aid in diagnosis, follow up of several medical conditions including heart diseases. Heart rate variability (HRV) analysis is a common practice for assessment of the cardiovascular autonomic nervous system[1].

Normally humans have their heart rate between 70 to 90 beats per minute. The American Heart Association states the normal resting adult human heart rate is 60–100 bpm[7]. Athletes have a lower basal heart rate while stress, exercise, and anxiety in normal persons often raises the heart rate. Heart rate is usually measured by finding the pulse in the body. The pulse is felt by the pads of the index and middle fingers of the examiner. At each beat, the heart pumps blood into the blood vessels. As the blood flows into the blood vessels the blood vessels expand and this is felt as a pulse. This pulse rate is felt at any part of the body where the arterial pulsation is transmitted to the skin surface especially when it is compressed against an underlying structure like bone. Pulse rate or heart rate can also be determined and using an electrocardiograph, or ECG or heart rate monitors. Heart rate monitors allow accurate measurements of the heart rate during exercise as well as during rest.

Photoplethysmography (PPG) is a non-invasive optical technique for monitoring beat-to-beat relative blood volume changes in the microvascular bed of peripheral tissues[1].

The PPG signal is obtained from pulse oximeters and its periodicity corresponds to the cardiac rhythm[2].

II. METHODOLOGY

1. Hardware -

In this experiment, PPG sensor module, Arduino UNO microcontroller are used to acquire data to estimate heart rate. We will see the functioning of each device/module one by one:

1.1. Pulse sensor –

A photoplethysmograph is a device used to optically obtain a volumetric measurement of an organ. A photoplethysmogram (PPG) is an optically obtained plethysmogram(waveform). A PPG is often obtained by using a pulse oximeter or PPG sensor which illuminates the skin and measures changes in light absorption or reflection.

In this paper, a Pulse sensor is used in reflection mode as shown in fig. (1). In the reflection mode of photoplethysmography, light source and photodetector both are placed on the same side of finger or body part[3]. The light source generally used is an infrared light emitting diode and phototransistor is used to detect the light. When fingertip placed on the sensor, three main things are happened depending on the volume of the blood present in the finger at that time: some amount of light will be absorbed, some will be transmitted and remaining will be reflected[3]. The intensity of reflected light depends on the volume of blood in the fingertip.

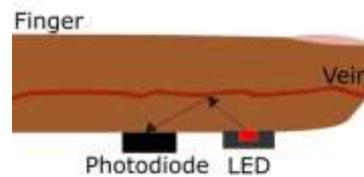


Fig. (1). Placement of Light source and detector in reflectance photoplethysmography

1.2. Arduino UNO –

The Arduino UNO is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc[8]. The board has 14 Digital pins, 6 Analog pins, and programmable with the Arduino IDE (Integrated Development Environment) via a type B USB cable[8]. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX)[8].

In this project, Arduino UNO is used for data acquisition. The output from the PPG sensor consists of AC and DC component. The AC component shows the pulsatile nature of blood and DC component shows the absorption of light by skin, tissues, and blood. AC component plays the main role to estimate heart rate. The signal pin of the PPG sensor is connected to an analog A0 pin of Arduino UNO board to receive the PPG signal.

2. Software –

Two software is used in this project: Arduino IDE and LabVIEW.

2.1. Arduino IDE –

The Arduino integrated development environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in the programming language Java. It is used to write and upload programs to the Arduino board. The Arduino IDE supports the languages C and C++ using special rules of code structuring.

The Arduino IDE plays the main role to interface Arduino UNO board with LabVIEW software.

2.2. LabVIEW –

LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a system-design platform and development environment for a visual programming language from National Instruments. LabVIEW is commonly used for data acquisition, instrument control, and industrial automation on a variety of operating systems (OSs), including Microsoft Windows, various versions of Unix, Linux, and macOS.

LabVIEW integrates the creation of user interfaces (termed front panels) into the development cycle. LabVIEW programs-subroutines are termed virtual instruments (VIs). Each VI has three components: a block diagram, a front panel, and a connector panel. The last is used to represent the VI in the block diagrams of other, calling VIs. The front panel is built using controls and indicators. Controls are inputs: they allow a user to supply information to the VI. Indicators are outputs: they indicate, or display, the results based on the inputs given to the VI. The back panel, which is a block diagram, contains the graphical source code. All of the objects placed on the front panel will appear on the back panel as terminals. The back panel also contains structures and functions which perform operations on controls and supply data to indicators. The structures and functions are found on the Functions palette and can be placed on the back panel. Collectively controls, indicators, structures, and functions are referred to as nodes. Nodes are connected to one another using wires, e.g., two controls and an indicator can be wired to the addition function so that the indicator displays the sum of the two controls. Thus a virtual instrument can be run as either a program, with the front panel serving as a user interface, or, when dropped as a node onto the block diagram, the front panel defines the inputs and outputs for the node through the connector panel. This implies each VI can be easily tested before being embedded as a subroutine into a larger program.

3. Algorithm –

To interface Arduino microcontroller with LabVIEW, we used LINX. LINX is an open source software and is designed to develop embedded applications using LabVIEW.

We developed a system:

- i. to interface Arduino with LabVIEW,
- ii. to acquire the signal of pulse sensor through Arduino,
- iii. to detect the peaks of the acquired signal and
- iv. to calculate heart rate using the peaks and time at which peaks occurred.

Heart rate calculated as follows:

N = Total number of peaks

t_2 = time at which the last peak occurred

t_1 = time at which the first peak occurred.

The duration between these two peaks: $T = (t_2 - t_1) * 10$ sec.

Heart beats in one min :

$$\text{BPM} = (N * 60) / T$$

III. RESULTS

Figure 2 shows the output waveform and the heart rate in beats per minute.

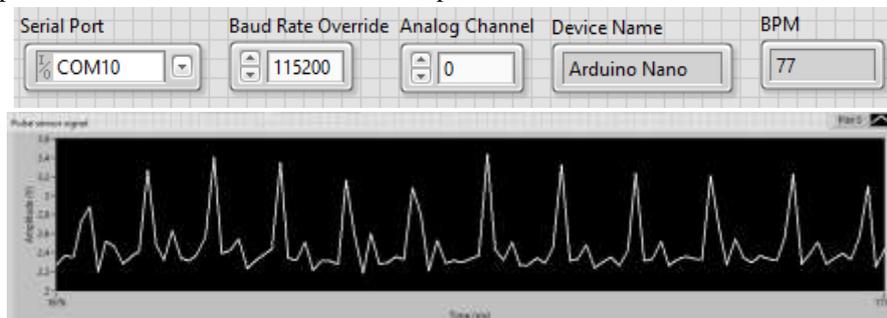


Fig. (2). Output waveform and heart rate on the front panel of LabVIEW

The subjects were told to be in a relaxed position to get a stable reading.

We measured the heart rate of 10 subjects using the proposed system and compared with the previously recorded samples. We found that the average error between two data sets is around ± 2 BPM.

IV. CONCLUSION

Heart rate has been calculated using the developed system. LabVIEW platform is used for software development – GUI(Graphical User Interface) and monitoring.

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