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Development of High Blood Pressure Device based on Pulse Transit Time Measurement for Hypertension Disease

Muhamad Akmal Hafiz Hishamuddin[1], Mohamad Nazib Adon[1]*

[1] Faculty of Electrical and Electronic Engineering,
Universiti Tun Hussein Onn Malaysia, 86400 Johor, MALAYSIA

*Corresponding Author Designation

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Abstract: High blood pressure, often known as hypertension, is a major health concern for people all over the world, including in Malaysia. Hypertensive individuals should visit their doctor for blood pressure monitoring on a regular basis, and some have complained that the arm cuff produces numbness all over their arm after numerous readings due to its pressure. As a result, this project was formed in order to address all of these issues. It used a Photoplethysmography (PPG) sensor with signal processing within the MATLAB R2020a program to monitor blood pressure using the Pulse Transit Time (PTT) method, and it was embedded with ThingSpeak and ThingView Internet of Things (IoT) applications. Blood pressure readings in systolic and diastolic pressure are displayed on a ThingSpeak webpage for a physician on a desktop computer and a ThingView application for an Android user in this project. Before and after 20 minutes of continuous exercise, the PPG signals of a healthy 23-year-old volunteer were measured ten times. The result shows that there is a link between PTT and blood pressure, with the standard error computed at 0.006 and growing proportionately in the presence of motion artefact, based on the regression equations constructed. Finally, this project is projected to be able to assess blood pressure in a remote monitoring system and develop Malaysian healthcare technology.

Keywords: Hypertension, Blood Pressure, Pulse Transit Time

1. Introduction

High blood pressure is called Hypertension disease in medical terms. It is a very common and very dangerous illness that can lead to many health problems also can worsen it [1]. Due to a variety of factors, including economic growth and population ageing, hypertension has become more prevalent globally, even in developing nations, in recent decades [2]. Modern health systems have come up with a solution to deal with the increasing number of patients with Hypertension disease. There are four

**Corresponding author: nazib@uthm.edu.my*

stages of hypertension which are prehypertension, mild hypertension, moderate hypertension, and severe hypertension. Patients will be evaluated under these stages by acquiring their blood pressure readings. The force exerted by blood against the walls of blood vessels is referred to as blood pressure, and the heart's pumping activity is used to determine the blood pressure value. The blood pressure readings need measurements in both systolic and diastolic pressures, both of which are measured in millimeters of mercury (mmHg) [3]. Systolic pressure refers to the greatest arterial pressure in the left ventricle of the heart during contraction, whereas diastolic pressure refers to the lowest arterial pressure in the ventricles when they are filled with blood during dilatation and relaxation [4]. A typical person's blood pressure reading is 120 mmHg for systolic pressure and 80 mmHg for diastolic pressure [5]. According to the American Heart Association (AHA), high blood pressure is defined as a measurement of 130 mmHg per 80 mmHg [6]. This case has four phases: prehypertension or known as stage 1, mild hypertension (stage 2), moderate hypertension (stage 3), and severe hypertension (stage 4). Individuals with stages 2 to 4 of high blood pressure condition must see their doctor once every six months, once every two months, and once every two days for blood pressure monitoring in order to avoid chronic diseases such as heart attack and stroke, which can be deadly [7]. Due to life's requirements, individuals nowadays are more industrious than previous generations, and this results in them having limited time to drive to the hospital just to take a blood pressure measurement for monitoring purposes.

Thus, the Photoplethysmography Technique for Blood Pressure Measurement with the Internet of Things (IoT) Application had been developed after observing the entire current issues that are related to this case. This project employs a system that helps patients in terms of measuring their own blood pressure everywhere without the need to regularly go to the hospital for blood pressure monitoring purposes.

2. Methodology

The four stages of this project's development are depicted in Figure 1. Stage 1 converts an analog signal to a digital signal using input from PPG sensors. The method for measuring blood pressure was created in stage 2 using the MATLAB R2021a program. The ThingSpeak application and the MATLAB R2021a program must be connected to the internet in stage 3 to allow for real-time monitoring. Stage 4 is used to monitor how the system performs when measuring blood pressure and displaying the results in the ThingSpeak and ThingView applications.

The Arduino Nano microcontroller board and two Photoplethysmography (PPG) sensors help compensate for the project's hardware. One of the PPG sensors is located at the earlobe, and the other sensor, which is at the index fingertip, is situated a little farther out from the heart. The sensor measures the quantity of light reflected by the skin and the body parts from the LED to determine the PPG. To transform the analog signals into digital values, these two PPG signals are transmitted to the Arduino Uno microcontroller circuit. The MATLAB R2021a program was then used to evaluate the data after being transmitted to the computer. In order to calculate PTT, the program is utilised to eliminate PPG signals' unnecessary noise and identify the signal peak. The algorithm to measure the blood pressure is then modified with the received PTT result. Then the ThingSpeak and ThingView applications are used to send the BP readings to the patient and their doctor via an internet platform. For the purpose of establishing internet access for the IoT application, the MATLAB R2021a software is created using the ThingSpeak framework and channel ID. The project's operating flow chart is shown in Figure 2.

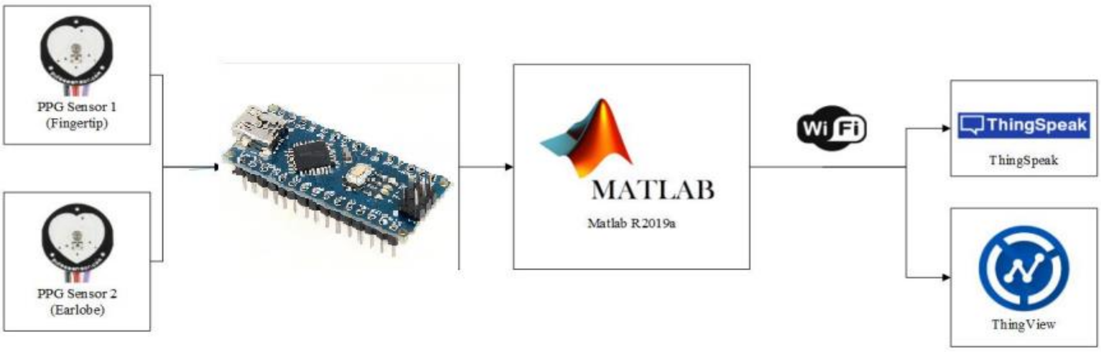


Figure 1: Block diagram of Pulse Transit Time measurement system

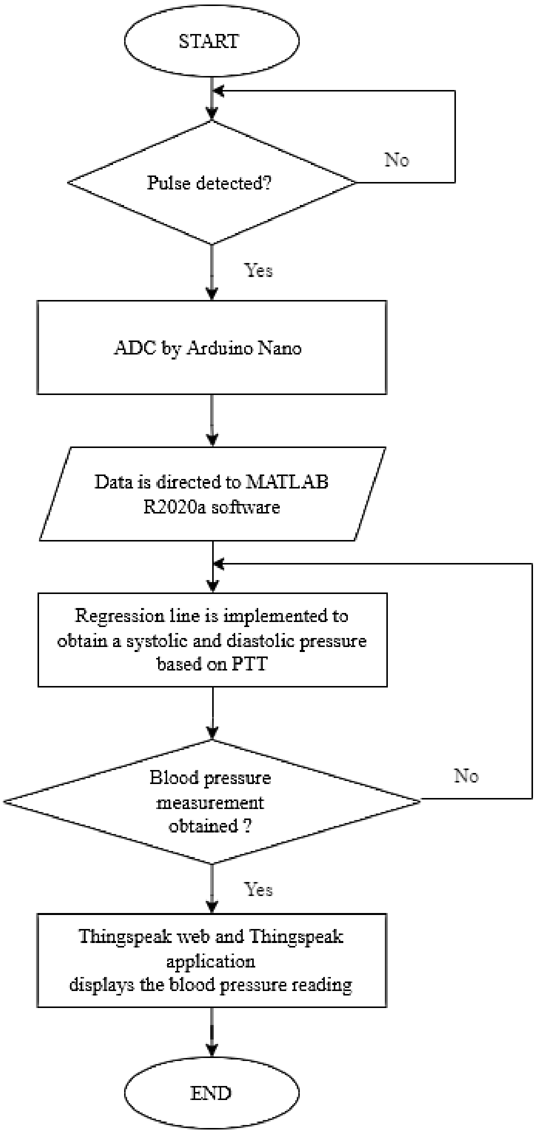


Figure 2: System flowchart

Table 1 shows blood pressure readings before and after the continuous activity is done. A healthy 24-year-old female volunteer has conducted a preliminary trial to confirm the device's functionality. In order to calibrate BP and PTT, the volunteer was asked to wear the developed device prototype together with an OMRON Blood Pressure Digital Monitor (HEM-7120). An exercise bike located at UTHM's electronic medical laboratory is used for the calibration. The volunteer is required to ride the bike for

20 minutes at a speed between 70 and 80 revolutions per minute (RPM). The measurements are taken simultaneously from an OMRON BP monitor and PTT ten times before and ten times after the continuous riding activity.

Table 1: Blood Pressure reading

Before Activity				After Activity			
SBP OMRON (mmHg)	DBP OMRON (mmHg)	SBP Prototype (mmHg)	DBP Prototype (mmHg)	SBP OMRON (mmHg)	DBP OMRON (mmHg)	SBP Prototype (mmHg)	DBP Prototype (mmHg)
120	85	134	81	126	86	143	95
121	79	121	89	127	88	139	91
123	77	137	92	125	84	151	87
122	79	133	87	123	85	137	85
117	81	134	81	125	88	145	91
119	86	131	88	124	89	134	89
121	79	127	95	124	83	155	97
121	76	133	87	126	81	152	89
122	82	126	93	125	86	137	96
119	81	129	84	128	83	141	92

The calibration curve acquired during the activity is then included in MATLAB for blood pressure estimation, and the results are fed into the ThingSpeak and ThingView apps for the purpose of the visualization of the results. Figure 3 illustrates the PTT device prototype that was created.

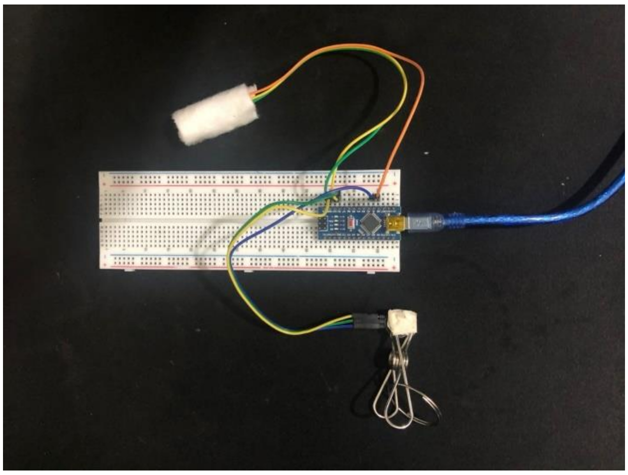


Figure 3: Prototype of Pulse Transit Time (PTT) monitoring device

3. Results and Discussion

The pulse sensor's raw PPG data are susceptible to motion artefacts and noise from 50Hz power line interference. A low-pass filter can often be used to eliminate high-frequency noise, but it might be challenging to eliminate movement noise. Signal morphologies in PPG measurements are distorted by noise, and this distortion leads to incorrect peak detection diagnoses. However, by utilising a denoising approach with a digital filter, the quality of these signals can be enhanced. In order to reduce undesirable noise in PPG signals, a linear phase FIR (Finite Impulse Response) filter is constructed in this project utilising MATLAB software. PPG signals typically have a frequency range of 0.5 to 4 Hz. To eliminate the high-frequency noise on the PPG signals, the filter's cut-off frequency is set at 4 Hz. The filtered

PPG signals are shown in Figure 4. The signal-to-noise ratio (SNR) of filtered signals is often higher than that of unfiltered signals.

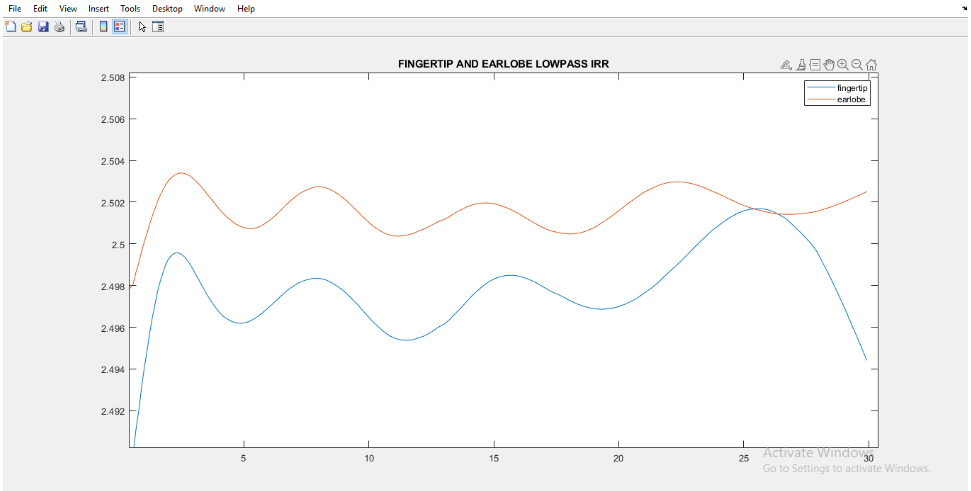
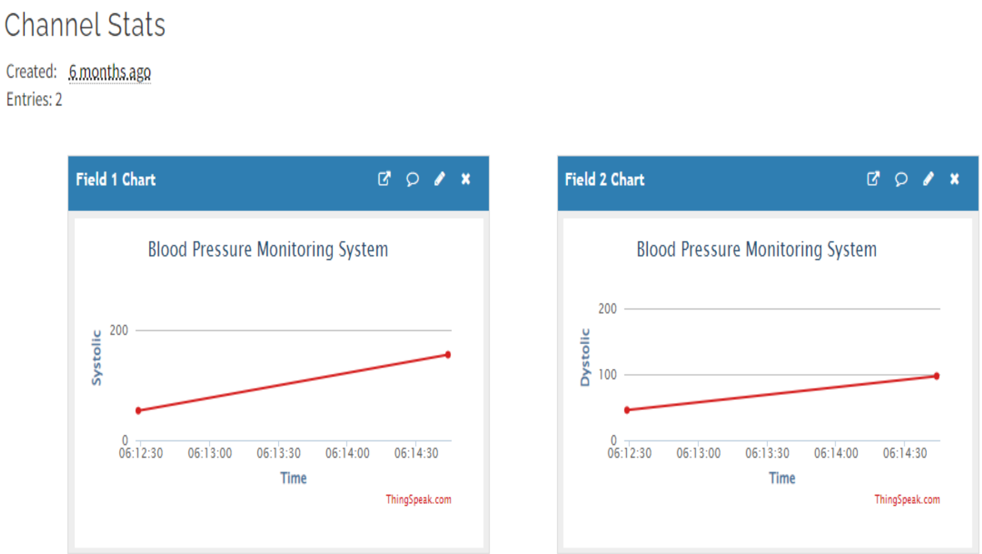


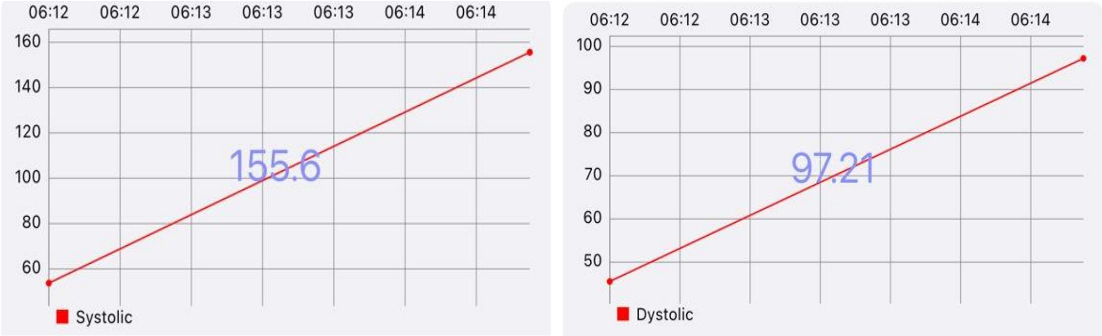
Figure 4. Filtered Photoplethysmography (PPG) signals.

The MATLAB Signal Processing toolboxes locate peaks function served as a basis for the peak identification technique. Based on a data sample that was greater than its two neighbouring samples, the locate peaks calculate the maximum point. Only the point with the lowest index was returned if the peak was flat. To make sure the highest point observed is related to the PPG signal peak, a threshold level was established. Following that, the difference between the peak PPG signal values at the earlobe and the fingertip in the temporal domain is used to calculate the PTT value.

Through bike exercise, a calibration curve for BP and PTT was obtained for this study. The technique was then put into practise in the MATLAB program to convert the PTT value to the BP measurement and communicate the data over the IoT platform. Figures 5(a) and 5(b) for the ThingSpeak and ThingView applications, respectively, illustrate how the systolic and diastolic pressure values were concurrently shown in two graphs. Once the user has taken their blood pressure, the data is automatically updated every second and is immediately stored and presented.



(a)



(b)

Figure 5: Visualization of blood pressure using (a) ThingSpeak application, (b) ThingView application

For the visualization of the blood pressure data through ThingSpeak and ThingView applications, it is noted that the transmission process happens in just one minute starting from the time of the blood pressure measurement taken from the volunteer. This transmission of blood pressure data is considered to be much faster compared to other online applications. This is due to the fact that the ThingSpeak application has its own cloud while the ThingView application has the ability to refresh the data for each second automatically. Not to mention that the application also has a private channel mode which will ensure the safety and confidentiality of the measurement process for patients as only those with the channel ID could view the measurement. The BP measured with an OMRON BP monitor is compared to the results of the cuffless BP device. For estimated SBP, the mean error and standard deviation (SD) are 22.6 ± 20.6 mmHg, while for estimated DBP, they are 1.6 ± 1.2 mmHg. The American Association for the Advancement of Medical Instrumentation (AAMI) standard states that both SBP and DBP blood pressure estimates must have an absolute mean error value of less than 5 mmHg and an error standard deviation of less than 8 mmHg [8].

4. Conclusion

This project is extremely important and must be adopted in health care technology all over the world owing to its power to show blood pressure reading at a distance using a non-invasive procedure that deploys a little cuff around the fingertip and earlobe. Since the oscillometric cuff, which after multiple measures produced arm numbness, was no longer utilised, this is convenient for all hypertension patients. Additionally, because all blood pressure measurements are safely saved in the ThingSpeak cloud, this project allows patients to test their blood pressure anywhere without traveling to the hospital and may lessen the workload of the doctor. More volunteers are required to confirm the effectiveness of IoT-based cuffless BP measurement, but the preliminary results for the cuffless BP monitoring appear promising.

Acknowledgement

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