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Non-invasive Blood Pressure Monitoring using Pulse Transition Time

[I]Karanjeet Singh, [II]Parminder Singh
[I]M-Tech Scholar, Dept. of ECE DIET, Kharar, India.
[II]Astt.Prof, Dept. of ECE DIET, Kharar, India.

Abstract
Blood pressure (BP) is one of the important vital signs that need to be monitored for personal healthcare. This paper attempts to present the Blood Pressure (BP) estimation using the Pulse Transit Time (PTT) cuff-less method. PTT is measured by synchronous electrocardiogram and photoplethysmography (PPG) registration and the difference time is the basis parameter for blood pressure estimation. Pulse transit time is the time taken for the arterial pulse Pressure wave to travel from the aortic valve to a peripheral site. It is usually measured from the R wave on the electrocardiogram to a photoplethysmography signal. PTT is inversely proportional to blood pressure.

Keywords
Blood Pressure, Pulse Transition time

I. Introduction

Blood is being carried from heart to all parts in the body by blood vessels called arteries. Blood pressure is the force of blood pushing against the wall of the arteries. Each time the heart beats, it pumps out blood to arteries. Systolic Pressure which is the highest blood pressure occurs when the heart is pumping. Diastolic pressure is lowest blood pressure when the heart is resting. Normal blood pressure is around 120/80 mm of Hg. The assessment of the systolic and the diastolic arterial blood pressure has both physiological and clinical Significance. There are several non-invasive methods to measure BP such as cuff sphygmomanometer, placatory, oscillometric method. Sphygmomanometer, which is based on an external cuff and audible detection of Korotkoff sounds, is considered to be the most accurate non-invasive method, and has been accepted as the reference standard to which other methods are compared. Non–constrained and continuous BP measurement is preferred for ubiquitous healthcare application.

1.1 ECG Electrocardiogram is a graphic recording or display of the time variant Voltages produced by the myocardium during the cardiac cycle. The P, QRS, and T reflect the rhythmic electrical depolarization and re polarization of the myocardium associated with the contraction of the atria and ventricles.

1.2 PPG Photoplethysmography is based on the determination of the optical properties of a selected skin area. For this purpose non visible infrared light is emitted into the skin. More or less light is absorbed, depending on the blood volume. Blood volume changes can then be determined by measuring the reflected light.

1.3 PTT Pulse Transit Time is the time taken for the arterial pulse pressure wave to travel from the aortic valve to a peripheral site (usually the finger). The stiffness and tension in the arterial walls are the principle factors determining the speed of transmission of the pulse wave, and this in turn depends to a large extent on blood pressure. An increase in BP increases arterial wall tension and stiffness, thus shortening PTT; and conversely, a drop in BP lessens the stiffness and tension in the arterial walls, thus lengthening PTT. Pulse transit time is inversely proportional to blood pressure and the falls in blood pressure corresponds to rises in pulse transit time. PTT is typically about 250 ms.

II. Method

2.1. Korotkoff Method

The auscultatory method or method of Korotkoff was introduced by the Russian army physician N.Korotkoff, 1905. In his experiments, Korotkoff discovered that sound emitted distally from a partially occluded limb. He realized that this sound was indicative of arterial flow and that together with the occlusive cuff could be used to determine blood pressure.

2.2. Oscillometric Method:

This method is similar to ordinary Sphygmomanometer Method, except that small fluctuations in the cuff are measured rather than Korotkoff sounds.

2.3 Automated Indirect Method:

The pressure cuff is automatically inflated to about 220 mm of Hg and allowed to deflate slowly. The sensor picks up the oscillations from the artery near the surface, just below the compression cuff. The pressure reading at the inset of oscillations represents the systolic pressure.

2.4 Pulse Wave Velocity Method:

Pulse wave velocity in the brachial artery can be calculated by recording the ECG and the PPG signals. The velocity of the pulse wave progressing through the arteries depends on blood pressure. Based on the pulse wave velocity blood pressure variation can be estimated even without using a cuff. It is based on the calculation of the PTT, PWV by which the estimation of BP of the patient can be done. To calculate the PTT and PWV, it is required to record the Electrocardiogram (ECG) of the patient with the PPG signal by which the PTT and PWV will be calculated. This is further required and ECG and PPG sensor/machine for the recording of the data.

2.5 PTT-BP Model

PTT is defined as the time between the ECGR peak and the peak and the peak of the PPG pulse within the same cardiac cycle, as illustrated in Figure 2.5

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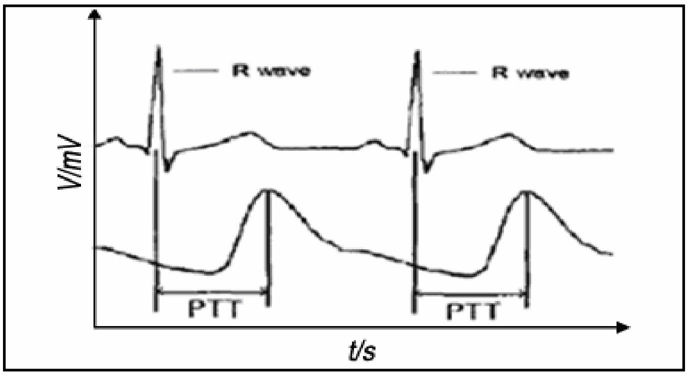


Fig. 2.5: The definition of PTT

III. Experimental Implementation

The methodology of the proposed work is based on the detection of the site of the pulse wave PTT used to determine BP. The period between the R wave of the electrocardiogram and the peripheral pulse wave will be calculated to determine PTT. The study of pulse wave velocity (PWV), the speed at which a pressure pulse is transmitted from the heart through the arterial tree will be measured using pulse transit distance (Δx) with the following relationship.

$$PWV = \Delta x / PTT$$

The relation of Pulse Transit Time (PTT) for indicating Blood Pressure (BP) changes as:

$$BP = A \text{ in } (PTT) + B$$

Where A and B are patients-dependent coefficients. Based on the above relationship, the BP of the patient will be calculated.

The principle of the algorithm is shown in Fig. It mainly includes the preprocessing the data in inflation stage, the noise elimination in all stages, the extraction of oscillation amplitudes, and calculation of blood pressure. The particular description for measurement is introduced as follows:

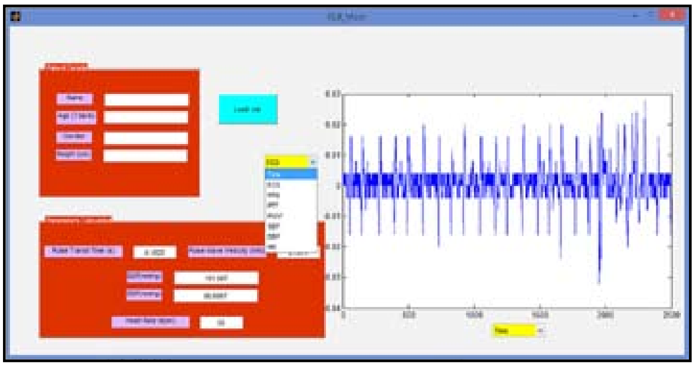
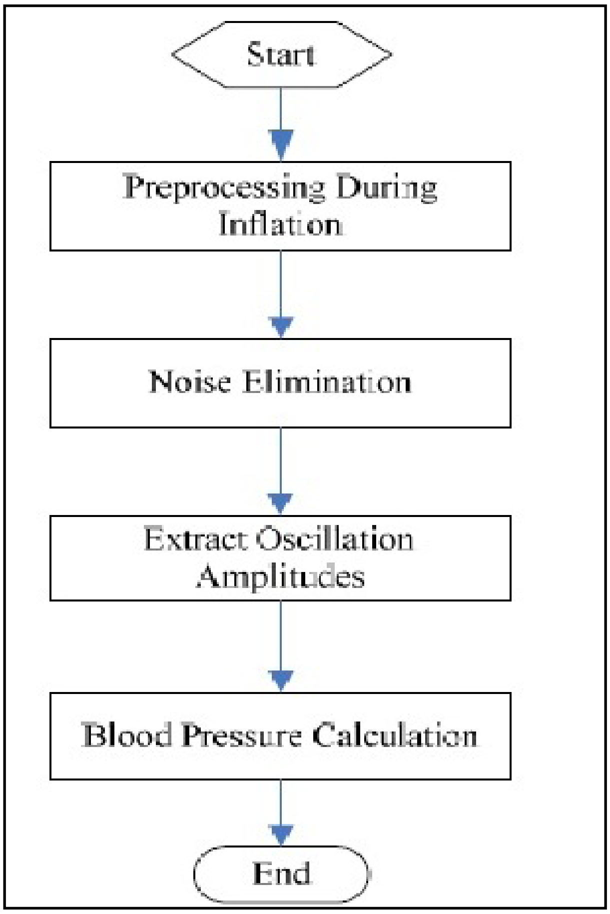


Fig. 4.1: Main GUI



IV. Result

The system is developed for systolic blood pressure (SBP) measurement using pulse transit time. The computation of PTT involves the measurement of two cardiovascular parameters, the ECG and PPG signal. PTT is calculated as the time interval between the ECG R wave and the pulse waveform detected by photoplethysmographic finger probe. Blood pressure is calculated by using the following formula.

$$BP = \frac{1}{\propto}\left[\ln\left(\frac{L^2\, d\, P}{E_0\, h}\right) - 2\ln(PTT)\right]$$

Where, E0 is Young's Modulus of arterial wall at zero pressure, h is the brachial artery wall thickness, d is inner radius of brachial artery, ρ is the blood density, L is distance of heart from fingertip and PTT is the pulse transit time. The pulse signals acquired by four healthy volunteers are analysed and the pulse transit time and pulse wave velocity is calculated as shown in the table 4.2. The Systolic and Diastolic Blood Pressure is measured by automatic blood pressure machine also with the Heart Rate measurement using the Photoplethysmography unit present in the automatic BP measuring system. The PTT-BR, PTT-RD and PTT-BD signifies the Pulse Transit Time between the Brachial and Radial arterial pulse, Pulse Transit Time between the Radial and Digital arterial pulse and Pulse Transit Time between the Brachial and Digital arterial pulse respectively. Fig 4.1shows the main graphical unit interface of subject result.

S.NO Subject	PTT (s)	P V W (m/s)	S B P (mmHg)	DBP (mmHg)	HR (bpm)
1	0.285591	3.50585	114.75	74.75	81
2	0.1625	2.7077	101.67	66.667	56
3	0.14515	3.01865	99.1429	60.7143	68
4	0.1598	0.1598	103.4	60.2	80

Table 4.2: Table shows the recorded and analysed parameters of four different subjects from different sensor placement sites. Here, HR* is the heart rate measured by the automatic BP machine and HR is the heart rate measured by pulse sensor circuit

V. Conclusion

This system represents a non-invasive, easy and reliable technique for detection of the pulse wave that allows assessment of blood pressure. The aim of the study was to confirm the reproducibility of a pulse wave measurement using the photoplethysmographic sensor. The measurement was carried out for different subjects of different age and gender. The results lie within acceptable limit. PTT offers a number of advantages over more conventional tests in that it is easy to measure, well tolerated by patients, relatively cheap and, perhaps most importantly is fully portable thus lending itself to domiciliary studies. However the sensor needs accurate and fixed positioning for consistent result. The sensor is also depending on surrounding lighting therefore it requires shielding. The systolic pressure can be easily obtained by measuring the pulse that reaches the sensor after the cuff is deflated. Getting the diastolic pressure is more complicated. Hence the designed PTT device in this paper shows potential to be used in the areas of continuous long term BP monitoring.

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