B

# Blood Pressure Estimation with Considering of Stroke Volume Effect

**Moha'med O. Al-Jaafreh**
*University of Technology, Australia*

**Adel A. Al-Jumaily**
*University of Technology, Australia*

## INTRODUCTION

The mean arterial pressure (MAP) is a very important cardiovascular parameter for physicians to diagnose various cardiovascular diseases. Many algorithms were used to estimate MAP with different accuracy. These algorithms used different factors, such as blood level, pulses, and external applied pressure, photo-plethysmography (PPG) signal features, heart rate (HR), and other factors. In addition, some natural-based techniques were employed to minimize the difference between estimated and measured blood pressure, as well as to measure blood pressure continuously.

This article presents an algorithm to estimate MAP, utilizing the HR, Stroke Volume (SV), and Total Peripheral Resistance (TPR), with considering SV changing influence; this consideration is investigated mathematically, and by the Particle Swarm Optimization (PSO) technique.

This new algorithm was implemented on 20 cases of mimic database (Mimic Database, http://www.physionet.org/physiobank/database/mimicdb); 10 cases for training to investigate the suitable values of these factors, and all cases for verification and examining the performance of these techniques. The achieved results of estimated MAP by these techniques are compared with real MAP, and illustrated in tables and figures.

## BACKGROUND

The cardiovascular system consists of heart, vessels, and blood. In a healthy person, the heart pumps the blood in vessels with synchronous pulses (HR) and pulse wave velocity (PWV). The force of blood flux, which is caused by heart beating, forms a pressure against blood vessels' walls.

Blood pressure (BP) is a vital measurement used by the physicians for diagnosing the health situation of subjects, and saving them from critical diseases or some dangerous circumstances, such as hypertension, hypotension, artery stiffness, coma or heart attack.

Many models have used to estimate BP; these models rely on factors such as blood level, pulses, external applied pressure, PPG signal features, HR, artery volume changes, and many other factors.

The first model has been used to estimate BP, and depends on the blood level factor (O'Brien & O'Malley, 1981); blood level is related to BP, according to Equation 1:

$$P = \rho \times g \times h \quad (1)$$

Where P is blood pressure,
$\rho$ is blood density,
g is acceleration of gravity,
h is blood level.

The blood level is measured by inserting a catheter on the subject's artery; the blood level is elevated in the inserted catheter by BP affect, and this blood pressure is computed by Equation 1 and displayed on a monitor or drawn on paper. This method is known as the arterial cannulation method—it was first used by Ludwig on 1847. It is an accurate and reliable method, but it is very invasive, and causes limb ischemia, thrombosis, hemorrhages, and other bad affects (Kasirajan, Simmons, King, Shumaker, DeAnda, & Higgins, 2002).

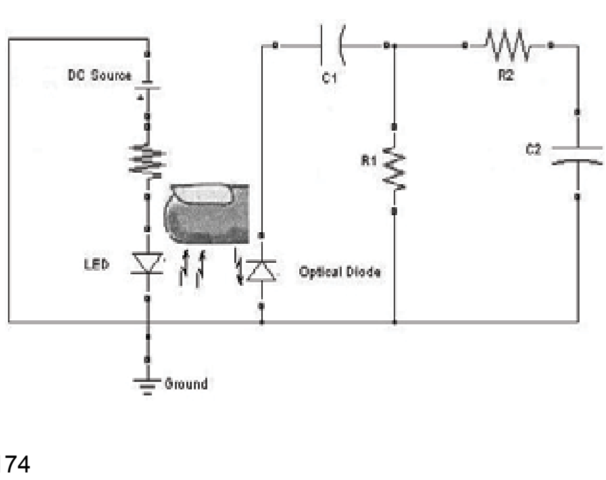
The second method to estimate BP is the Auscultatory method. It is first used by Korotkoff in 1905 (Beecher, 2003). This method depends on heart pulses and external applied pressure factors. First, the blood flow is obscured by applied external pressure on an artery by inflation of an air cuff; second, the pressure is reduced slowly. Finally, the blood pressure equals applied pressure when the blood starts flowing on the squeezed artery, and the heart pulse is heard by an expert physician or nurse, while reducing that applied pressure (Geddes, Hoff, & Badger, 1966).

This method has to be implemented by a physician or nurse by using sphygmomanometer, which consists of a cuff to apply pressure, and a mercury (Hg) meter to measure that pressure. The Auscultatory method is more widely used than the arterial cannulation method, because it is not invasive. But it is a discontinuous method, because of the inflation and defilation of the cuff, which is wrapped around the subject's arm. Also, it is uncomfortable, because of the affect of applied pressure.

On other hand, BP has been estimated depending on pulse arrival time and PWV (Bazett & Dreyer, 1922; Lansdown, 1957). Afterwards, Mackay (1964) estimated BP by piezoelectric pressure transducers, and developed the tonometry method. Soon after, depending on PPG and artery volume changes, some methods were developed to estimate BP, such as volume-compensation and local pressurization. In addition, pulse wave velocity and pulse arrival time have been used to estimate BP changes (Chen, Kobayashi, Ichikawa, Takeuchi, & Togawa, 2000; Geddes, Voelz, Babbs, Bourland, & Tacker, 1981; Piston & Stradling, 1998).

Finally, the cuffless and real-time measurement methods have been developed to estimate BP. Actually, these methods are noninvasive, continuous, and comfortable methods, because they relied on a PPG signal. The PPG sensor continuously emits light by a light-emitting diode, as a transmitter, through the subject's finger, and then the PPG signal is extracted by an optical diode as a receiver. A PPG sensor circuit is shown in Figure 1.

*Figure 1. Circuit model*




The cuffless and real-time measurement methods are used to estimate BP, by using the PPG signal's features through mathematical models, which depend on the relationship between BP and the PPG signal's features. The BP and PPG signal's features' relationship is complex and dynamic (Shaltis, Reisner, & Asada, 2005). This relation has been studied—Yan and Zhang (2005) stated that the normalized harmonic area of a discrete period transform of the PPG signal has a high correlation with BP. Moreover, the time interval between the peak of electrocardiograph (ECG) and the front foot of the PPG signal, also known as the $PTT_f$; has a high correlation with BP variability (Ma & Zhang, 2005).

Furthermore, a model has been found to estimate BP by using a weighted PTT ($PTT_w$); this feature is dependent on that specified subject. $PTT_w$ depends on calibrating measurements of systolic and diastolic BP (Poon & Zhang, 2005).

Moreover, some work of PPG-based methods has established correlation between the frequency of the PPG signal, HR, and BP (Ganong, 2003). MAP is related to HR, as shown in Equation 2:

$$MAP = HR \times SV \times TPR \quad (2)$$

Where MAP is mean arterial pressure,
SV is stroke volume,
HR is heart rate,
TPR is total peripheral resistance.

This correlation depends on constant factors SV and TPR. In reality, these factors are not constant, and the relationship between MAP and HR is nonlinear.

In our work, a new algorithm is developed to estimate MAP, utilizing the HR, stroke volume, and total peripheral resistance, and considering SV changing influence; this consideration is investigated mathematically, and by the Particle Swarm Optimization technique.

This new algorithm was implemented on 20 cases of mimic database (refer to Mimic Database Web site); 10 cases for training to investigate the suitable values of these factors, and all cases for verification, and examining the performance of these techniques.

## Related Content