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Cuff-Less Non-Invasive Blood Pressure Measurement Using Various Machine Learning Regression Techniques and Analysis

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ABSTRACT

This paper proposes a new approach for non-invasive cuff-less arterial blood pressure (BP) estimation using pulse transit time (PTT). The ECG and PPG signals were acquired at a sampling rate of 500Hz. Standard cuff-based sphygmomanometer is used to take reference BP and heart rate simultaneously. The hardware for the acquiring the ECG and PPG signals were designed and fabricated and were made and study was carried out with 60 subjects during various activities. The objective of this work is to estimate the systolic BP and diastolic BP using PTT techniques and to apply regression analysis using machine learning methods for estimating the BP, compare the results with recording simultaneously carried out using the standard devices. The proposed work concludes that AdaBoost algorithm has highest accuracy in estimating systolic and diastolic BP values. The readings obtained are in accordance with the AHA standards and are in acceptable limits and can be used for measuring BP in wearable devices.

KEYWORDS

Blood Pressure, Diastolic BP, Electrocardiogram, Machine Learning Techniques, Non-Invasive, Pulse Transit Time, Systolic BP

1. INTRODUCTION

Blood Pressure (BP) is the force excreted by the blood on the blood vessels and arteries during circulation. The pressure reduces as the blood flows away from the heart. BP is one of the most vital parameters studied and analyzed in medical and health care systems. The blood pressure varies with every heartbeat and the pressure is highest when the heart contracts and pumps the blood to arteries, known as Systolic Blood Pressure (SBP). During the relaxation interval of the heart, the pressure is least and it is known as Diastolic Blood Pressure (DBP). A wearable physiological monitoring system developed by Pandian P S et al (2008) named 'Smart Vest', measures and transmits biomedical signals like ECG, PPG, GSR, blood pressure and body temperature to a remote monitoring system. The heart rate is derived from the ECG signals. The systolic and diastolic blood pressures are derived non-

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invasively using Pulse Transit Time technique. At the remote base station non-invasive BP computation is carried out using the calibration equation and the trend analysis is done. Heiko Gesche et.al (2011) have proposed that there is a correlation between pulse wave velocity (PWV) and SBP. The aim of the study was to develop a nonlinear algorithm and a one point calibration for the measurement of SBP. It was found that SBP calculated from PTT with the reference BP measured from cuff-based device had a correlation in the range of $r = 0.69\ to\ 0.99$ an empherical formula was developed to calculate the SBP. Yan et.al (2007) proposed a novel calibration method for non-invasive BP measurement using pulse transit time technique. In their work they explained that PTT and BP are linearly related by the equation $PTT = a \cdot BP_{eq} + b$ where a & b are constants. Assuming that the pressure under arm cuff linearly decreases across the artery then:

$$BP_{eq} = P_0 - \frac{0.5\left(L_1 + L_2\right)\Delta P}{L_1 + L_2}$$

where L_1 & L_2 represents cuff width and the artery length from the cuff to the finger, P_0 is the mean BP at the heart and ΔP is the internal pressure drop under cuff. With these calibration equations they calculated the BP non-invasively. Wan Suhaimizan Zaki et.al (2016) have developed a system for continuously monitoring the blood pressure without using the cuff. In this method, two types of PTT were measured. In the first method PTT_1 was measured at the fingertip and the PTT_2 was measured at the brachial artery. The experiment showed that PTT_1 has good correlation with BP whereas PTT_2 has weak correlation.

Qingxue Zhang et.al (2017) developed a highly wearable cuff-less blood pressure and heart rate (HR) monitoring system. In this study different SBP models were used for BP estimation. Some of the models used are 1) $SBP = a * \ln\left(PTT\right) + b$;2) $SBP = a * \ln\left(PTT\right) + b * \ln\left(HR\right) + c$ the above models were used for SBP estimation. The first model is SBP-PTT model and the second model is SBP- PTT & HR. The study revealed that performance of the SBP- PTT & HR models were much better than the SBP-PTT models. A calibration free method with high accuracy to estimate BP was proposed by Mohamad Kachuee et al (2015). It uses HR and features from PTT and PPG as the inputs for machine learning algorithm. The features of PTT are 1) PTT1: the distance between ECG R peak and PPG peak. 2) PTT2: the distance between ECG R peak and minimum point of PPG. 3) The distance between ECG R peak and the maximum slope of PPG. With these points as input, the BP is estimated using ANN and SVM algorithms. Surendhra Goli et al (2014) have shown that Pulse Wave Velocity (PWV) has strong relation with BP. The algorithm used in this method is $BP = a * PWV + b$ where PWV is derived using the pulse transit time. The calibration constants a and b was calculated using the least square method. The linear regression equation was used for finding SBP & DBP. Zunyi Tang et al (2016) presented an unobtrusive continuous BP monitoring system based on Pulse Arrival Time (PAT) for long term home care monitoring of elderly people. PAT is defined as the time interval between R-peak of ECG and the first derivative of PPG in the same cardiac cycle. The study showed that PAT has linear correlation with SBP and non-linear correlation with DBP. Niranjan Kumar et.al (2014) in their work have developed the calibration equations for estimating BP using the heart rate, pulse transit time as the inputs. Oleh Viunytskyi et.al(2020) have proposed non invasive cuffless blood pressure measurement using machine learning. In this work the ECG and PPG signal were acquired and then the pulse transit time is computed. From this the systolic and diastolic BP is computed. The results are compared with the standard BP instruments.

Sen Yang et.al (2021) have proposed a non invasive cuffless blood pressure estimation using deep learning model. in this work the ECG and PPG signals are acquired from the hardware and the pulse arrival time (PAT) is calculated. from the PPG signal the systolic and the diastolic peaks

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