# Blood Pressure Estimation from Photoplethysmography with Motion Artifacts using Long Short Term Memory Network

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**Abstract.** Continuous measurement of Blood Pressure (BP) is important in hypertensive patients and elderly population. Traditional cuff based methods are not comfortable to use since one requires to wear a cuff throughout the day. A more suitable method is to estimate the BP using the PhotoPlethysmoGraphy (PPG) signal. However, it is difficult to estimate a BP when the PPG is corrupted with Motion Artifacts (MAs). In this paper, a Long Short Term Memory (LSTM), which is an extension of Recurrent Neural Networks (RNN), is used to improve the accuracy of the estimation of the BP from the corrupted PPG. It shows that our technique excellently performs achieving the accuracy of 97.86.

## Introduction

Continuous monitoring of Blood Pressure (BP) has become a very common health measure due to an increase in the elderly population as well as the overall increase in people having heart attacks. Hypertensive patients need to have continuous BP measurement and monitoring. One of the methods for measuring the BP is using a sphygmomanometer. In this method a stethoscope is required along with the experience and measurement skill of nurses or physicians. Sphygmomanometers need the use of a cuff which can be a hindrance to patients if its continuous use is required.

Another method is applanation tonometry which needs to compress the radial artery. This method can measure peripheral BP continuously. An advantage of this method is that the method is cuffless. The central BP is derived from the radial BP but the problem is the compression of the radial artery and the difficulty of wearing the device. Volume clamping is another method using a small cuff around a finger. This technique is noninvasive and is considered for a continuous measurement. However, this method has the difficulty in wearing the device [1]. An easier method to measure BP is based on PhotoPlethysmoGraphy (PPG), which uses light to measure the blood volume in an organ. Light absorbance rate changes with the amount of blood flowing through the veins, which varies with the heart rate. Light absorbance rate can be measured using a photodiode. There are two methods, namely transmitted mode and reflected mode. In the transmitted mode, the light emitted from the photodiode travels through the tissue and is received by the receiver at the other side of the body. This method can be used at earlobes or fingertips. In the reflected mode, the light transmitted by the transmitter gets reflected by the tissue and is received by the receiver at the same side of the body. This method can be used at fingertips or wrists.

Since a photodiode can be easily added to a device, which is comfortably worn at the wrist, the reflected mode is used in wearable devices to measure heart rate at the wrist. However, one problem on such deployment is that this signal is affected by Motion Artifacts (MAs). When a person is engaged in physical activities the PPG signal is corrupted by MAs. If the level of corruption is high, then a nontrivial signal processing is required before analyzing the PPG signal. Sparse spectrum based methods [2], independent component analysis, singular value decomposition [3], and adaptive filtering [4] are some of the techniques often used to remove MAs. Most of these methods are highly complex.

To estimate BP from the PPG signal, linear regression methods, Support Vector Machines (SVMs) [5], and Artificial Neural Networks (ANNs) [1] have been used. However, these studies only con-