Estimation of Continuous Blood Pressure Prediction using Convolutional Neural Network

Nurul Qashri Mahardika T, Da Un Jeong, Ki Moo Lim*
IT Convergence Engineering Kumoh National Institute of Technology, *Medical IT Convergence Engineering Kumoh National Institute of Technology.

nurulqikaa@kumoh.ac.kr, dawny6960@kumoh.ac.kr, *kmlim@kumoh.ac.kr

Abstract

Cardiovascular disease (CVD) is one of the causes of death worldwide, such as hypertension. Hypertension is a hazardous disease and does not show visible symptoms. However, one way to determine hypertension is to measure blood pressure. Recently, many have researched to estimate blood pressure using deep learning. Here, we use data taken from Physionet. SBP and DBP values were obtained from extracting ABP based on peak-to-peak of PPG segmentation. The PPG signal is input data into the proposed convolutional neural network model. The mean absolute error and R2 score were used to evaluate the performances. The results obtained are 0.6425 and 0.6032 for SBP and DBP, respectively. However, this result can be improved by increasing the number of subjects to obtain a consistent distribution of SBP and DBP.

Keywords: Blood pressure (BP), photoplethysmogram (PPG), convolutional neural network (CNN), hypertension

Ⅰ. Introduction

Hypertension is one of the most dangerous things because it can appear suddenly and cause a stroke and death. According to the World Health Federation, the number of deaths from hypertension increase yearly. They estimated that around 1,28 billion adults worldwide with an age range of 30 – 79 years suffer from hypertension, 46% of adults are unaware that they have an indication of hypertension, and 42% with hypertension were diagnosed. Another 21% of adults could control hypertension [1]. BP monitoring is a standard clinical measurement of fundamental health that assist and diagnose several cardiovascular diseases such as hypertension [2]. However, many people neglect to do early detection of hypertension symptoms through blood pressure measurements due to a lack of awareness of hypertension. There are several methods for measuring hypertension, which are invasive and noninvasive methods. Recently, there have been many methods for BP prediction and evaluation with a noninvasive method. Previously, Athaya et al. 2021 predicted arterial blood pressure (ABP) using a photoplethysmogram (PPG) with a U-Net Architecture [3]. Jeong et al. 2021 used the MIMIC II database and PPG and electrocardiogram (ECG) as the input to detect blood pressure via combining the CNN-LSTM and BiLSTM model [4]. This study verifies a method to estimate the BP by extracting features using convolutional neural networks. In this study, we assumed that using the new types of data MIMIC III and two cycles of peak-to-peak PPG as input data into CNN can estimate BP and increase performance.

II. Material and Methods

A. Dataset

We collected the PPG signal from Multiparameter Intelligent Monitoring in Intensive Care (MIMIC III) database. We used randomly chose 50 subjects with normal and abnormal cases each subject to obtain 150,000 samples (1,800 s). The database contains biological signals such as ABP, PPG, and ECG with a 125 Hz sampling rate. We extracted the SBP and DBP

values from the ABP signal and used them as the ground truth in the training and testing process.

B. Preprocessing

Before the signal was trained into a machine learning model, preprocessing was applied. We extracted the PPG and ABP based on the detected two cycles of peak-to-peak PPG. Interpolation was applied based on the maximum peak to peak of PPG. We used the Z-score treatment to remove the outliers of SBP and DBP. Finally, we normalized the PPG amplitude with a Min-Max Scaller. The first set is the training set which is 80% of the total selected data, and the testing set is 20% of the total selected data.

C. Proposed Model and Architecture

The model was trained in Jupyter Notebook (version 6.4.8) in this experiment and implemented using Keras with the Tensorflow backend. The input shape was (None, 180,1), and the output shapes for SBP and DBP were (None, 1). Our proposed CNN model consists of 12 layers. The kernel size of each layer is 2,4,6, and 8 with strides = 2, followed by a rectified linear unit (ReLU) as the activation function. To avoid overfitting, we added batch normalization and dropout with a dropout rate of 0.1 in the first convolution layer, and also L2 regularization was applied to improve the performance model. The convolutional layer is connected to the specific layer with the max-pooling layer. The number of fully-connected neurons is 96, both SBP and DBP. To make the model deeper, we add deep MLP followed by a rectified linear unit (ReLU) as the activation function. Finally, we used the linear function as the activation function of the output of SBP and DBP.

III. Performance Evaluation

The proposed method in this paper feasible method to estimate the SBP and DBP estimation based on the single channel of PPG with 2 cycles of peak-to-peak PPG. We evaluate the performance of estimation of SBP and DBP by the proposed model using the determination coefficient (R^2) and the mean absolute error (MAE). As the result, the R^2 score were 0.6425 and 0.6032 for SBP and DBP, respectively. And for the MAE shows 10,5 and 1,0 for SBP and DBP, respectively. The results show that the proposed model can be used to monitor BP conditions in daily life. However, based on the results obtained, performance can be improved again by adding the length data and increasing the number of patients.

ACKNOWLEDGMENT

This research was partially supported by the Ministry of Food and Drug Safety (22213MFDS3922), the NRF (National Research Foundation of Korea) under the Basic Science Research Program (2022R1A2C2006326), and the MSIT (Ministry of Science and ICT), Korea, under the Grand Information Technology Research Center support program (IITP-2022-2020-0-01612) supervised by the IITP (Institute for Information & communications Technology Planning & Evaluation).

References

[1] WHO. Cardiovascular Diseases (CVDs). Available online: https://www.who.int/news-room/fact sheets/detail/cardiovascular-diseases (cvds)#:~:text=CVDs%20are%20the%20number%201,to%20heart%20attack%20and%20stroke

[2] Ahmad Dagamseh et al., *"Towards a portable-noninvasive blood pressure monitoring system utilizing the photoplethysmogram signal"*, Biomedical Optics Express, Vol. 12, pp. 7732 - 7751, 2021

[3] Athaya, T.; Choi, S. *"An Estimation Method of Continuous Non-Invasive Arterial Blood Pressure using Photoplethysmography; A U-Net Architecture-Based Approach"*. Sensors, 2021, 21, 1867.

[4] Jeong et al et al., "*Combined deep CNN-LSTM Network-Based Multitasking Learning Architecture for Non-Invasive Continuous Blood Pressure Estimation using Difference in ECG-PPG Features.* 2021. https://doi.org/10.1038/s41598-021-92997-0