Blood Pressure Classification Based on PPG and ECG Signals using Convolutional Neural Network

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Abstract

Blood pressure (BP) monitoring is critical in treating hypertension diseases. Accurate BP measurement is essential to classify the BP levels based on the systolic and diastolic values from Arterial Blood Pressure (ABP). Recent studies have focused on employing Photoplethysmogram (PPG) signals to assess blood pressure. However, Electrocardiogram (ECG) signals strongly correlate with the ABP. Therefore, we used PPG and ECG signals to input the parallel Convolutional Neural Network. This study used 221 patients from the MIMIC III dataset, which provided PPG, ECG, and ABP signals. After preprocessing, we obtained 14,298 signals that consisted of 9,150 signals of train data, 2,288 signals of validation data, and 2,860 signals of test data. In the training process, we applied 5-fold cross-validation to select the best model. The highest test accuracy of 94% is obtained in classifying BP levels into hypotension, normal, prehypertension, hypertension stage 1, and hypertension stage 2. The result shows that the proposed method is a promising solution to monitor BP levels automatically.

Ⅰ. Introduction

Blood pressure monitoring (BP) is crucial for patients with hypertension and other cardiovascular illnesses [1]. Hypertension raises the risk of hemorrhagic stroke, heart failure, heart attack, and chronic renal disease [2]. Early detection to prevent dangerous complications because of hypertension is very critical. Sun et al. proposed CNN and Hilbert Huang Transform (HTT) method to classify BP levels [3]. The proposed method obtained 98,90% in classifying normotension and hypertension.

Furthermore, several studies have proven that PPG and ECG are correlated with ABP. Liou et al. extract the information from ECG and PPG signals to estimate the systolic and diastolic blood pressure [4]. Meanwhile, Yen et al. combined PPG and ECG signals as an input to the CNN model and obtained 76% in classifying normal, prehypertension, hypertension stage 1, and hypertension stage 2 [5].

In this study, we developed a system to classify BP levels using PPG and ECG signals as input to the parallel CNN architecture to improve the classification accuracy in classifying BP levels into hypotension, normal, prehypertension, hypertension stage 1, and hypertension stage 2.

Ⅱ. Methodology

A. The proposed CNN architecture

This study used ECG and PPG signals as input to the parallel CNN architecture, as shown in Figure 2. The convolutional layer automatically extracts the essential characteristics of ECG and PPG signals, and the max-pooling layer down-sampled the features.

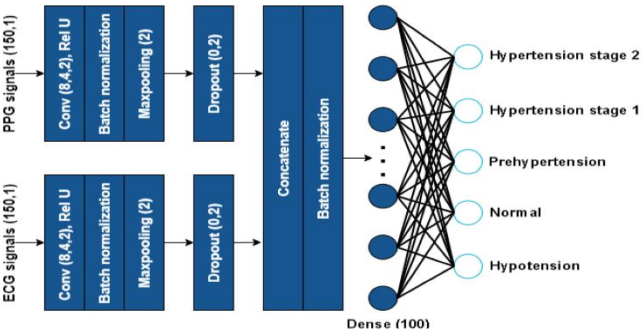

Figure 2. The proposed CNN architecture.

Furthermore, we applied batch normalization and dropout in the feature extraction layer to prevent overfitting. The ECG and PPG signal properties will be concatenated as input to the classification layer. In the classification layer, we applied batch normalization, a hidden layer, and the output layer with a softmax activation function.

B. Results

A total of 2860 test data signals comprised 407 data of hypotension, 1200 data of normal, 182 data of prehypertension, 540 data of hypertension stage 1, and 531 data of hypertension stage 2 used to evaluate the models obtained from the training process using 5-fold cross-validation. The performance result of the selected model on test data using ECG and PPG signals as input to the parallel CNN architecture is represented in Table 1.

Table 1. The performance of the proposed CNN architecture.

BP Levels	Precision	Recall	F1-score	Accuracy
Hypotension	0.93	0.94	0.93	94%
Normal	0.95	0.96	0.96	
Prehypertension	0.90	0.88	0.89	
Hypertension Stage 1	0.93	0.91	0.92	
Hypertension Stage 2	0.94	0.94	0.94	

As shown in Table 1, the proposed model successfully classified the test data with an accuracy of 94%. Furthermore, based on the value of precision, recall, and F1 score, the proposed model classified these BP levels correctly according to their class. The proposed parallel CNN architecture extracted the essential information from PPG and ECG in more detail compared with the conventional CNN architecture. Therefore, the proposed parallel CNN architecture outperformed the previous studies proposed by Yen et al. [5] that provided 76% accuracy in classifying 4 classes. Moreover, this study successfully expanded the classification system ability to classify 5 classes. However, due to the imbalanced dataset for prehypertension conditions, the performance for classifying prehypertension is the lowest compared to others BP levels conditions. As a solution, for further research, we have to expand the number of dataset especially for prehypertension to provide the balanced dataset and improve the classification accuracy.

Ⅲ. Conclusion

This study designed a blood pressure classification system using PPG and ECG signals as input to the parallel CNN architecture. The proposed method provided a promising solution in classifying the blood pressure levels into five categories: hypotension, normal, prehypertension, hypertension stage 1, and hypertension stage 2. However, the performance needs to be improved to solve false detection due to the imbalanced dataset. Therefore, we have to conduct further research using a larger number of datasets and several machine learning or deep learning models.

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