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Blood pressure estimation using Photoplethysmography signals' spatial features utilizing Residual Networks

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Introduction. Continuous and non-invasive blood pressure (BP) monitoring is essential for early detection and management of hypertension.[1]. Traditional cuff-based methods, although reliable, are unsuitable for continuous monitoring and can cause discomfort [2]. Photoplethysmography (PPG) signals have been widely explored for this purpose due to their ability to capture blood volume changes in peripheral circulation. However, extracting meaningful features from PPG signals for accurate BP estimation remains a challenge [3]. We propose a deep learning approach utilizing Residual Networks (ResNet), a convolutional neural network (CNN) architecture originally designed for image recognition.

The main part. The proposed solution leverages the spatial features of PPG signals utilizing Residual Networks. The raw PPG data from 2506 subjects (from the MIMIC III and the VITALDB databases) was preprocessed through filtering and segmentation into 10-second windows at a 125 Hz sampling rate. Additionally, we computed the first and second derivatives of the PPG signal, which were then combined with the original PPG waveform to form a three-channel input for the ResNet model. The proposed deep residual network is trained on a dataset of PPG signals with corresponding systolic (SBP) and diastolic (DBP) blood pressure labels. The ResNet architecture effectively learns spatial dependencies in the PPG waveform and its derivatives, enabling robust feature extraction for BP estimation. The model demonstrated strong predictive performance, however, the model's errors deviated from a normal distribution (KS test $P_{DBP} = 0.0474$ and $P_{SBP} = 0.0488$), therefore, the interquartile range for SBP [Q1,Q3] = [-6.85, 7.22] with a median of 0.10 mmHg and for DBP [Q1,Q3] = [-4.29, 4.65] with a median of 0.13 mmHg. These results meet the accuracy standards set by the Association for the Advancement of Medical Instrumentation (AAMI) and the British Hypertension Society (BHS) for the DBP estimation, validating the effectiveness of the approach.

Conclusions. Our study highlights the potential of ResNet for BP estimation using processed PPG signals and their derivatives, emphasizing the importance of spatial feature extraction in deep learning models. Future work will focus on optimizing the network architecture, incorporating additional physiological parameters, and evaluating the model on diverse datasets to enhance its generalizability and real-world applicability.

List of sources used:

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