RNN for Non-Invasive Blood Pressure Prediction Based on PPG Signals

Syamsul Rizal[1,2], Dong-Seong Kim[1,*]

[1] ICT-CRC, Kumoh National Institute of Technology , Gumi-si, 39177, South Korea

[2] School of Electrical Engineering, Telkom University, Bandung, 40257, Indonesia

[1]syamsulrizal@kumoh.ac.kr, *dskim@kumoh.ac.kr

PPG 신호를 이용한 비침습적 혈압 예측을 위한 RNN

리잘 삼술, 김동성*

금오공과대학교, *금오공과대학교

Abstract

Accurate blood pressure monitoring is crucial for diagnosing and managing cardiovascular diseases. Traditional methods, although reliable, often require invasive techniques or sophisticated equipment. This paper presents an innovative approach utilizing Recurrent Neural Network (RNN) models to estimate blood pressure non-invasively from photoplethysmogram (PPG) signals and demographic data. We developed a dual-input model architecture that synergistically processes PPG signals alongside personal physiological characteristics. Our experimental results demonstrate the model's high accuracy, with a significant reduction in Mean Absolute Deviation (MAD), surpassing the standard thresholds set by IEEE (< 4mmHg) with grade A. This research not only advances the field of non-invasive blood pressure monitoring but also holds substantial potential for integrating into wearable health technology, offering a promising avenue for continuous, real-time monitoring in telemedicine and remote healthcare scenarios.

Ⅰ. Introduction

Blood pressure (BP) monitoring is a critical aspect of cardiovascular health management [1]. Accurate and timely BP measurements are essential for diagnosing hypertension and other related cardiovascular diseases. Traditional BP measurement techniques, predominantly sphygmomanometers, though reliable, require manual operation and can be uncomfortable due to the invasive cuff-based mechanism. Moreover, these methods provide only sporadic measurements, lacking the capability for continuous monitoring which is essential for capturing the dynamic nature of BP.

Neural network models have undergone significant development over many years, finding applications in diverse fields. Particularly, Convolutional Neural Networks (CNNs) have gained prominence in several areas such as recognition systems [2], [3], classification, clustering, and time-based signal prediction including electroencephalogram (EEG), electrocardiogram (ECG), and photoplethysmogram (PPG). Recent innovations in wearable technology have spurred interest in non-invasive methods for continuous blood pressure (BP) monitoring. In this context, PPG signals, which are obtained through light-based measurements reflecting blood volume changes in microvascular tissues, have shown promise. These signals are crucial indicators of various cardiovascular parameters, including BP [4], [5]. However, the challenge lies in accurately estimating BP from PPG signals due to the propensity of these signals to be affected by motion artifacts and individual physiological variances.

This paper introduces a novel approach to address these challenges by employing a Recurrent Neural Network (RNN) model. RNNs, a type of recurrent neural network, are particularly adept at processing time-series data, making them well-suited for analyzing PPG signals. Our model uniquely fuses PPG signal analysis with personal demographic data, aiming to enhance the accuracy of BP estimation. By leveraging the temporal dynamics of PPG signals and personal physiological characteristics, we aim to provide a more accurate, personalized, and non-invasive method for BP estimation. This study not only contributes to the field of medical signal processing but also has significant implications for the development of wearable health monitoring technologies, potentially transforming the landscape of remote healthcare and telemedicine.

Ⅱ. Method

Our methodology integrates a dual-input model utilizing RNN to estimate blood pressure from PPG signals and demographic data. The dataset used in our study, provided by Liang et al., includes 657 data segments from 219 individuals, collected at Guilin People's Hospital in China [6]. This diverse dataset covers a wide age range and includes conditions like hypertension and diabetes, making it ideal for investigating the relationship between PPG signals and cardiovascular health.

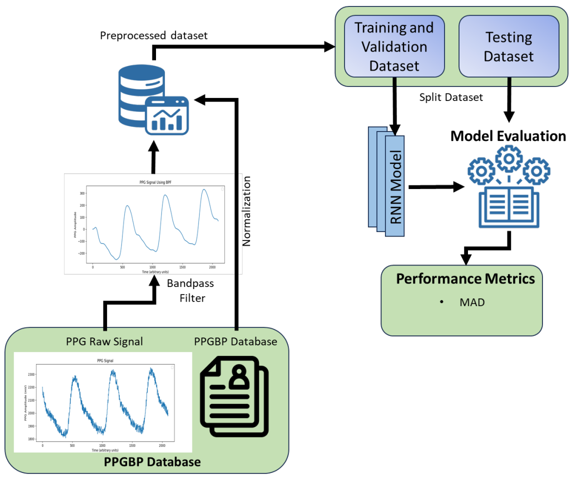

Figure.1 Schematic of Data Preprocessing and System Model

Table 1 Hyperparameter Proposed Model

Parameter	Value
Optimizer	Adamax
Learning Rate	0.005
Loss Function	MSE
Batch Size	128
Activation Function (Output)	Linear

Table 2 Performance evaluation of the proposed method for SBP and DBP prediction based on IEEE Standard

Assessment Evaluation	IEEE Standard		
	MAD (<4mmHg)	MAPD (%)	Grade
SBP	1.4	1.1	A
DBP	1.1	1.7	A

The proposed method's efficacy for systolic blood pressure (SBP) and diastolic blood pressure (DBP) prediction was evaluated against the IEEE Standard. The Mean Absolute Deviation (MAD) for SBP was 1.4 mmHg and for DBP was 1.1 mmHg, demonstrating exceptional precision in BP estimation. The Mean Absolute Percentage Deviation (MAPD) was 1.1% for SBP and 1.7% for DBP, further underlining the accuracy of our model. Both SBP and DBP predictions were awarded an 'A' grade, indicating a high level of conformity with the IEEE Standard benchmarks. These results highlight the potential of our GRU-based fusion model to provide accurate and reliable non-invasive blood pressure monitoring.

Ⅲ. Conclusion

Our research demonstrates the effectiveness of a dual-input Recurrent Neural Networks (RNNs) model for non-invasive blood pressure estimation using photoplethysmogram (PPG) signals and demographic data. The precision of our model is reflected in the Mean Absolute Deviation (MAD) and Mean Absolute Percentage Deviation (MAPD) for both systolic and diastolic blood pressure predictions, which adhere to the stringent IEEE Standard benchmarks with an exemplary 'A' grade. These results not only validate the model's capability in accurate BP estimation but also underscore its potential integration into wearable health technology for continuous monitoring. Looking ahead, we envision further refinement of the model to enhance its application in telemedicine and remote patient monitoring, with the ultimate goal of providing a user-friendly, efficient, and cost-effective solution for cardiovascular health management.

ACKNOWLEDGMENT

"This research was supported by the MSIT(Ministry of Science and ICT), Korea, under the Innovative Human Resource Development for Local Intellectualization support program (IITP-2023-2020-0-01612) supervised by the IITP(Institute for Information & communications Technology Planning & Evaluation)"

"This work was supported by Priority Research Centers Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education, Science and Technology"(2018R1A6A1A03024003)"

REFERENCES

[1] T. Hansen, J. Jeppesen, S. Rasmussen, H. Ibsen, and C. Torppedersen, "Ambulatory blood pressure monitoring and risk of cardiovascular disease: A population based study," American Journal of Hypertension, vol. 19, no. 3, pp. 243- 250, Mar. 2006.

[2] Dini, Mohamed & Shanto, Md Javed Ahmed & Kwon, Gi-Hyeob & Kim, Dong-Seong & Jun, Taesoo. (2023). "Emotion Type Recognition Scheme Using EEG Based Signals," KICS Winter Conference 2023.

[3] Ann Janeth Garcia, Ali Aouto, Jae-Min Lee, Dong-Seong Kim, "CNN-32DC: An improved radar-based drone recognition system based on Convolutional Neural Network," ICT Express, vol. 8, no. 4, 2022, pp. 606-610.

[4] X. Xing, Z. Ma, M. Zhang, Y. Zhou, W. Dong, and M. Song, "An unobtrusive and calibration-free blood pressure estimation method using photoplethysmography and biometrics," Scientific Reports, vol. 9, no. 1, Jun. 2019.

[5] M. Ghamari, "A review on wearable photoplethysmography sensors and their potential future applications in health care," International Journal of Biosensors amp; Bioelectronics, vol. 4, no. 4, 2018.

[6] Y. Liang, Z. Chen, G. Liu, and M. Elgendi, "A new, short-recorded photoplethysmogram dataset for blood pressure monitoring in china," Scientific Data, vol. 5, no. 1, Feb. 2018