Calibration-Free Blood Pressure Trend Estimation from Wearable PPG: A Feasibility Study

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I. Introduction

Continuous monitoring of cardiovascular health remains a major challenge in real-world settings, particularly when relying on wearable sensors with limited contextual information. Hypertension is a major contributor to cardiovascular disease [1], yet conventional cuff-based measurement is episodic and poorly suited to frequent monitoring or large-scale screening. Wearable photoplethysmography (PPG) sensors offer a promising route toward more accessible blood pressure tracking by capturing vascular pulse dynamics non-invasively.

However, cuffless estimation is strongly affected by individual physiology, including vascular stiffness, skin characteristics, medication status, and cardiovascular history. In many practical settings, models may not have access to such information or to individual calibration. This motivates a more cautious question: to what extent is calibration-free, user-blind blood pressure trend estimation feasible from PPG signals in a small-data setting?

II. Study Overview

We use the publicly available PPG-BP dataset [2], which includes 651 PPG recordings from 219 subjects. To reduce information leakage, we apply a subject-aware split so that recordings from the same individual do not appear in both training and testing sets. This setup evaluates generalisation to unseen users rather than memorisation of subject-specific patterns.

Two modelling strategies are compared. The first uses physiologically grounded waveform features extracted from PPG and trains conventional machine learning models, including Random Forest, Decision Tree, Support Vector Machine, k-Nearest Neighbours, and Multilayer Perceptron. The second uses transformer-based models, including a transformer trained on engineered features and a compact raw-signal time-series transformer with convolutional preprocessing.

Figure 1 illustrates the overall pipeline of the proposed approach.

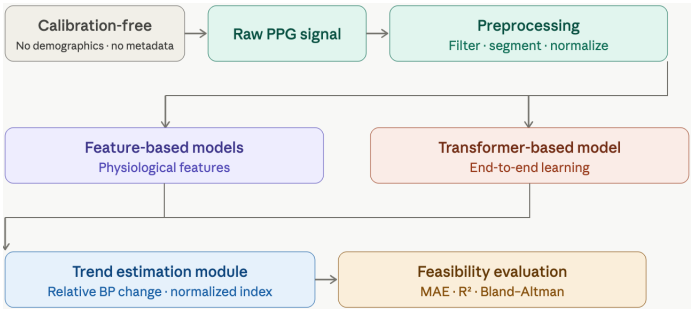

Fig. 1. Overview of the proposed pipeline for calibration-free blood pressure trend estimation using PPG signals. The framework compares feature-based and transformer-based models under a user-blind setting, focusing on relative trend estimation rather than absolute blood pressure values.

Models are evaluated using MAE, R^2, hypertension classification, Bland–Altman agreement, and AAMI/ISO 81060-2:2018 accuracy criteria [3].

III. Results & Discussion

In this small-data, calibration-free setting, feature-based models consistently outperform transformer-based approaches. The Random Forest model achieves the strongest performance, while the compact raw-signal transformer shows substantially higher error and weaker robustness. Figure 2 compares the performance across models.

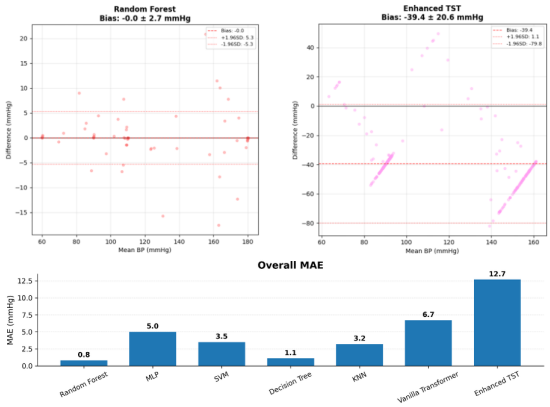

Fig. 2. Comparison of model performance in capturing relative blood pressure trends under a calibration-free setting. Feature-based models achieve lower error compared to transformer-based approaches, highlighting their robustness in limited-data scenarios.

These results should be interpreted as evidence of trend consistency rather than absolute blood pressure accuracy. While MAE is reported to enable comparison with prior work, the primary objective of this feasibility study is to examine whether calibration-free, signal-only PPG models can capture relative blood pressure variation in a small-data regime. From this perspective, the lower errors observed for feature-based models suggest that hand-crafted physiological descriptors provide a useful inductive bias when training data are limited.

The results also show a clear gap between simpler physiologically grounded models and more data-hungry end-to-end approaches. In particular, transformer-based models perform poorly under the current experimental constraints, indicating that model complexity alone is insufficient when calibration, demographic context, skin tone, medical history, medication status, and other subject-specific metadata are unavailable. Overall, the findings support the use of calibration-free PPG modelling as an exploratory tool for trend analysis or early risk stratification, while highlighting that clinically reliable absolute blood pressure estimation will require larger datasets, stronger validation, individual calibration, and richer participant-level context.

References

[1] World Health Organization, "Global report on hypertension: The race against a silent killer," WHO, Geneva, Tech. Rep., 2023.

[2] 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, p. 180020, 2018.

[3] *Non-invasive Sphygmomanometers — Part 2: Clinical Investigation of Intermittent Automated Measurement Type*, International Organization for Standardization Std. ISO 81 060-2:2018, 2018.