Poster: FlexibleBP: Blood Pressure Monitoring Using Wrist-worn Flexible Sensor

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ABSTRACT

We propose *FlexibleBP*, a novel cuffless blood pressure monitoring system using a wrist-worn flexible sensor to enhance comfort and accuracy. By capturing pulse wave signals from the radial artery, we develop a personalized estimation framework incorporating a Transformer model with fine-tuning. Experiments with 36 participants confirm *FlexibleBP*'s accuracy, meeting AAMI standards. This work marks a step toward more user-friendly, advanced wearable BP monitoring solutions.

CCS CONCEPTS

• **Human-centered computing → Ubiquitous and mobile computing systems and tools**;

KEYWORDS

Blood Pressure Monitoring, Mobile Health, Deep Learning

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1 INTRODUCTION

Blood pressure (BP) is crucial for heart and arterial health. Hypertension, the leading cause of cardiovascular diseases [2], emphasizes the need for accurate BP monitoring. However, arterial catheterization's invasiveness and cuff discomfort from non-invasive methods like auscultation [3, 5] highlighting the need for developing comfortable, non-invasive BP monitoring.

Non-invasive BP monitoring uses various methods. Optical approaches like PPG (photoplethysmography) suffer from light sensitivity, skin color, and rigid materials. Ultrasound requires bulky, high-precision equipment, while flexible pressure sensors, converting pulse-generated signals into electrical signals, offer simplicity, low cost, and skin compliance.

Thus, We propose *FlexibleBP*, a cuffless BP monitoring system using a manually made wrist-worn flexible sensor to capture radial artery signals based on Reflected Wave Transit Time (RWTT)[7]. Main challenges include limited research on RWTT-based monitoring with flexible sensors and significant individual variability in BP. *FlexibleBP* integrates RWTT extraction and BP estimation within a personalized framework using Transformer [6] and fine-tuning.

In summary, our contributions are:

- Introduction of the first cuffless BP monitoring system using a wrist-worn flexible sensor based on RWTT.
- Development of a personalized adaptation framework with a Transformer model and fine-tuning to address individual variability among different users, enabling accuracy.
- Evaluation on 36 volunteers, achieving systolic/diastolic BP estimation errors of 2.61 ± 5.59 mmHg and 1.37 ± 5.75 mmHg, proving the effectiveness of the *FlexibleBP* design.

2 SYSTEM DESIGN

This section introduces the system design of flexible material BP, as shown in Fig. 1, the system including **Preprocessing**: the methods for noise reduction and signal smoothing; **Feature Extraction**: After selecting the optimal waveform fragment, pulse wave features are extracted through derivation for personalized deep learning training. **Personalized Adaptation BP Estimation Framework**: Predict the blood pressure through two stages of model training.

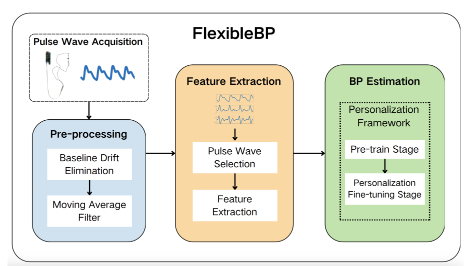

Figure 1: System overview of *FlexibleBP*.

After obtaining raw sensor data from the wrist's radial artery, a 9-layer wavelet transform is applied to remove baseline drift, followed by a 51-window moving average filter to smooth the signal.

In the data collected in our experiment, each segment is 40 seconds long. After noise removal, we use an algorithm to automatically select the most stable, standard-compliant 5-second segment that best represents the pulse waveform. Subsequently, *FlexibleBP* performs feature extraction based on the fiducial points [4] of each signal segment and its first and second derivatives, as shown in Fig. 2

We propose the pre-training stage and personal fine-tuning stage of the *FlexibleBP* as shown in Fig. 3. The pre-training stage uses

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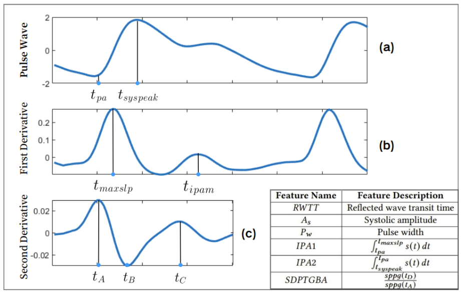

Figure 2: Overview of the fiducial points and features.

a Transformer architecture with Position Encoding, Multi-Head Attention, Encoder, and Decoder, utilizing all users' data except the current user's. During fine-tuning stage, we add the manually extracted features to the decoder layer, with half of the current user's data for personalized fine-tuning and half for model testing.

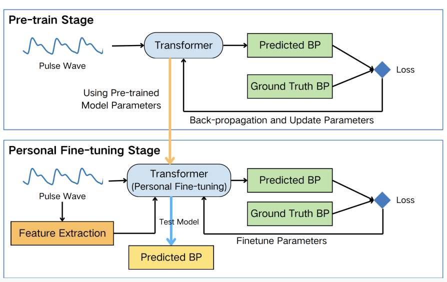

Figure 3: Overview of the proposed personalization fine-tuning steps.

3 RESULT

3.1 Implementation and Evaluation

As shown in Fig. 4, we developed a wristband prototype with a capacitive, flexible sensor that connects to a computer via USB, capturing data at a 500 Hz sampling rate. In an ethics-approved experiment, 36 volunteers provided 40-second pulse wave signals, blood pressure, and heart rate readings across three protocols—resting, cold water, and deep breathing—resulting in over 5,000 minutes of sensor data.

We evaluated accuracy using three metrics: mean error (ME), standard deviation (STD), and Pearson's correlation coefficient (P).

3.2 System Performance

The proposed ABP monitoring system shows strong accuracy in a user-independent setting. As shown in Fig. 5, over 95% of data points fall within the limits of agreement in the Bland-Altman diagram, confirming robustness. Pearson coefficients of 0.91 for SBP and 0.76 for DBP demonstrate a strong correlation between estimated and reference values. The system meets the Advancement of Medical Instruments (AAMI) standard [1] with a mean error of 2.61 mmHg (SBP) and 1.37 mmHg (DBP) and standard deviations of 5.59 mmHg (SBP) and 5.75 mmHg (DBP), all within the required limits.

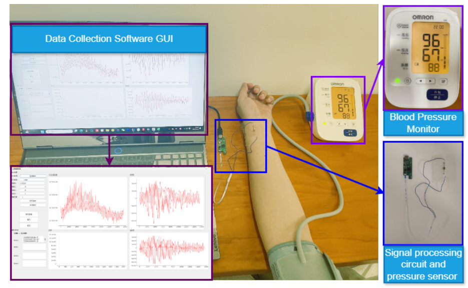

Figure 4: BP measurement experiment demonstration

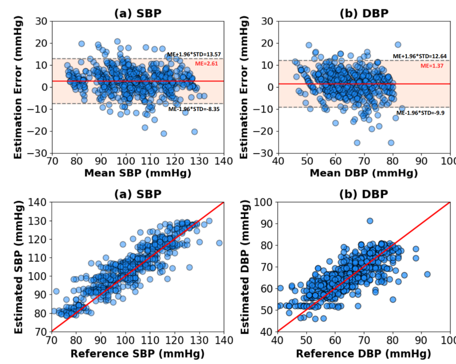

Figure 5: Bland-Altman and correlation diagram of SBP and DBP

4 CONCLUSION

In this study, we introduce a wrist-worn blood pressure monitoring system using a flexible sensor to collect pulse wave signals and predict blood pressure. We utilize this sensor to collect wrist pulse wave signals, preprocess them for noise reduction, extract morphological features, and employ a personalized adaptation framework for blood pressure prediction. The system meets AAMI standards for accuracy, marking a significant advancement in portable, user-friendly blood pressure monitoring.

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