MAML-based 24-hour Personalized Blood Pressure Estimation From Wrist Photoplethysmography Signals in Free-living Context

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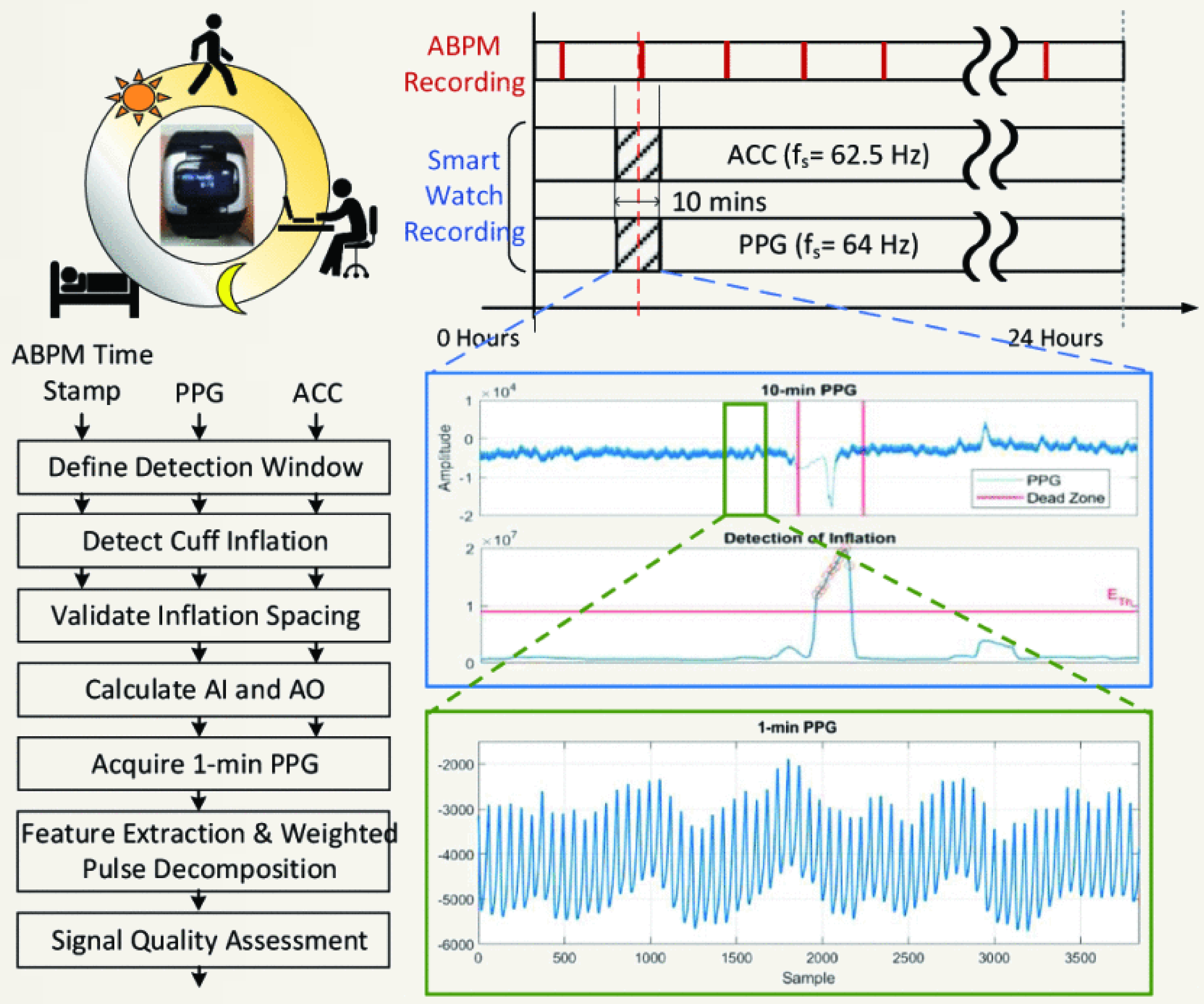
INTRODUCTION

Blood pressure variability at daytime and nighttime, also known as BP dip, has shown its clinical value in diagnosis of cardiovascular diseases. Although the ambulatory BP monitoring (ABPM) device can help to acquire the BP trend in a day, the inflation of the cuff disrupts sleep. Therefore, we aim to develop a solution for 24-hour BP estimation using wearable devices, without interfering nighttime sleep.

PROTOCCAL AND PROCESSING FLOW



A. Detect Cuff Inflation

We had to isolate 1-minute PPG and ACC signals corresponding to each ABPM measurement from the 24-hour recording. The cuff inflation of ABPM measurement often causes significant deviations in the PPG waveform due to blood circulation interruption. It can be identified using energy detection with a defined threshold, marking the identified region as a dead zone.

B. Calculate Activity Index (AI) and Activity Occurrence (AO)

Given that $\sigma_c^2(t)$ denotes the variance of 1-minute ACC signal of channel c starting at time t, where $c \in \{x, y, z\}$, the **AI** and argument of minimal $AI(t)$ associated with the sth ABPM time stamp are then described by

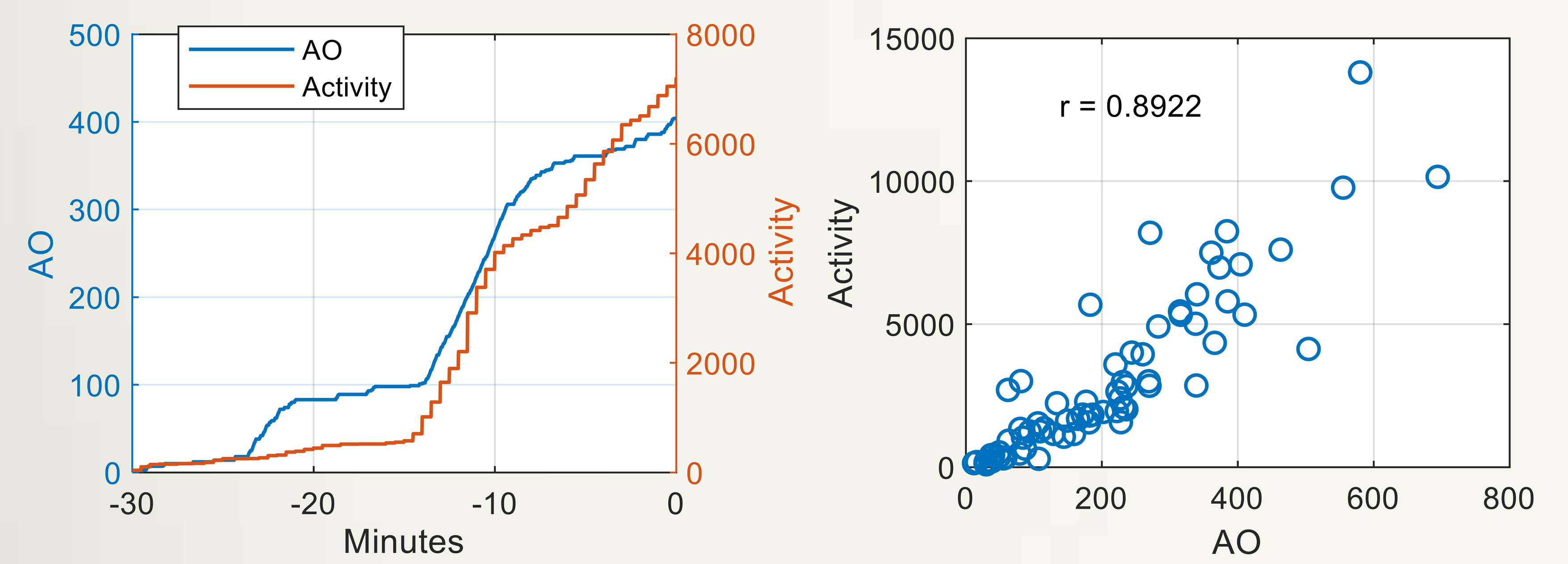
$$AI(t) = \sqrt{\sigma_x^2(t) + \sigma_y^2(t) + \sigma_z^2(t)}.$$

$$t_s = \arg\min AI(t).$$

The 1-minute PPG segment with the lowest activity is then picked out as $\mathbf{P}(t_s)$ corresponding to the sth ABPM record.

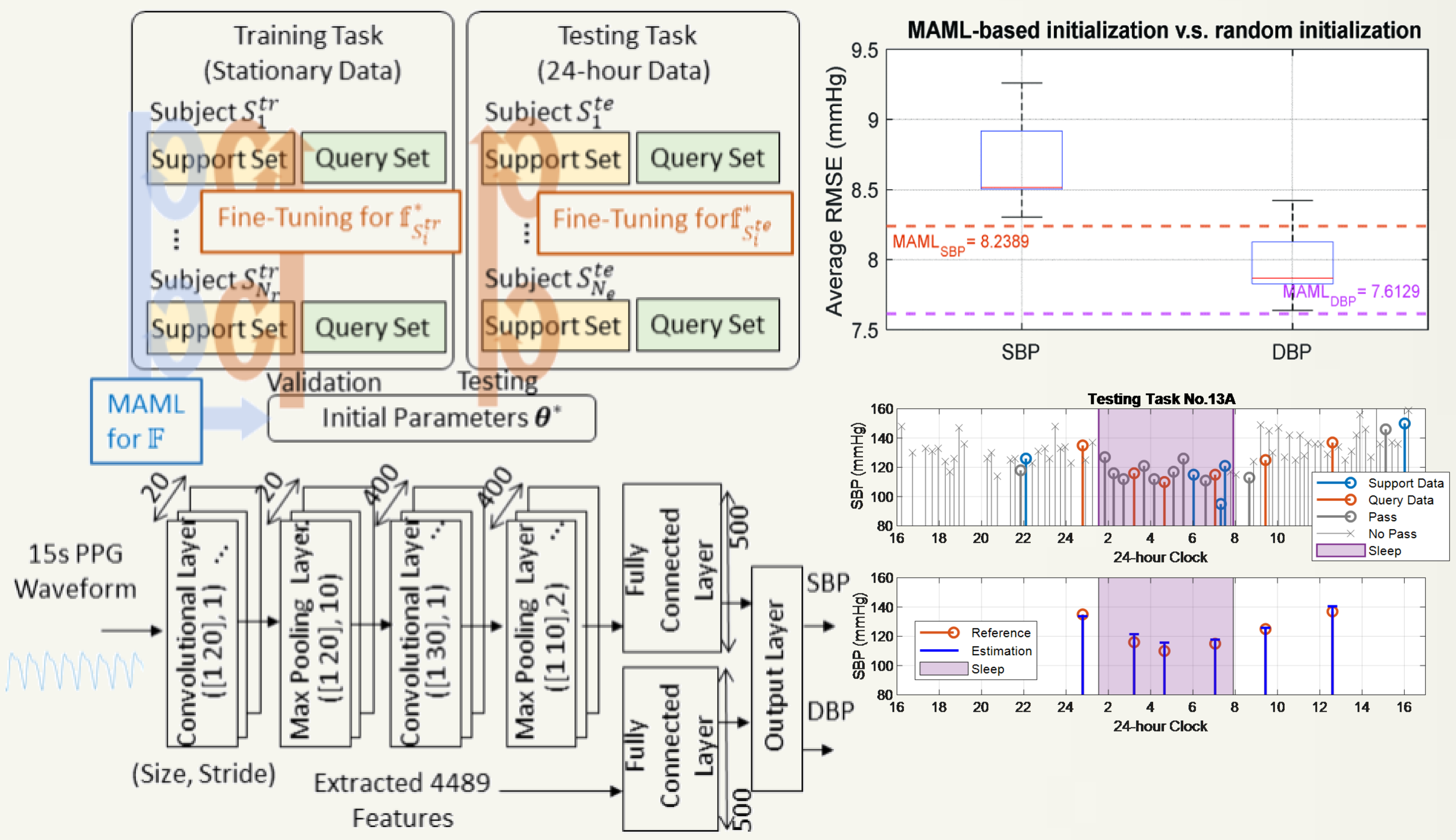
Activity 30 minutes before each ABPM measurement is assessed by comparing average signals between adjacent 1-second epochs in each direction. If the difference exceeds a set threshold, the activity occurrence (**AO**) is increased by 1 for examining the preceding activity state.

The correlation coefficient between AO and the activity value of Philips Actiwatch Spectrum Pro within 30 minutes is 0.89.



METHOD OF MAML-BASED PERSONAL MODEL

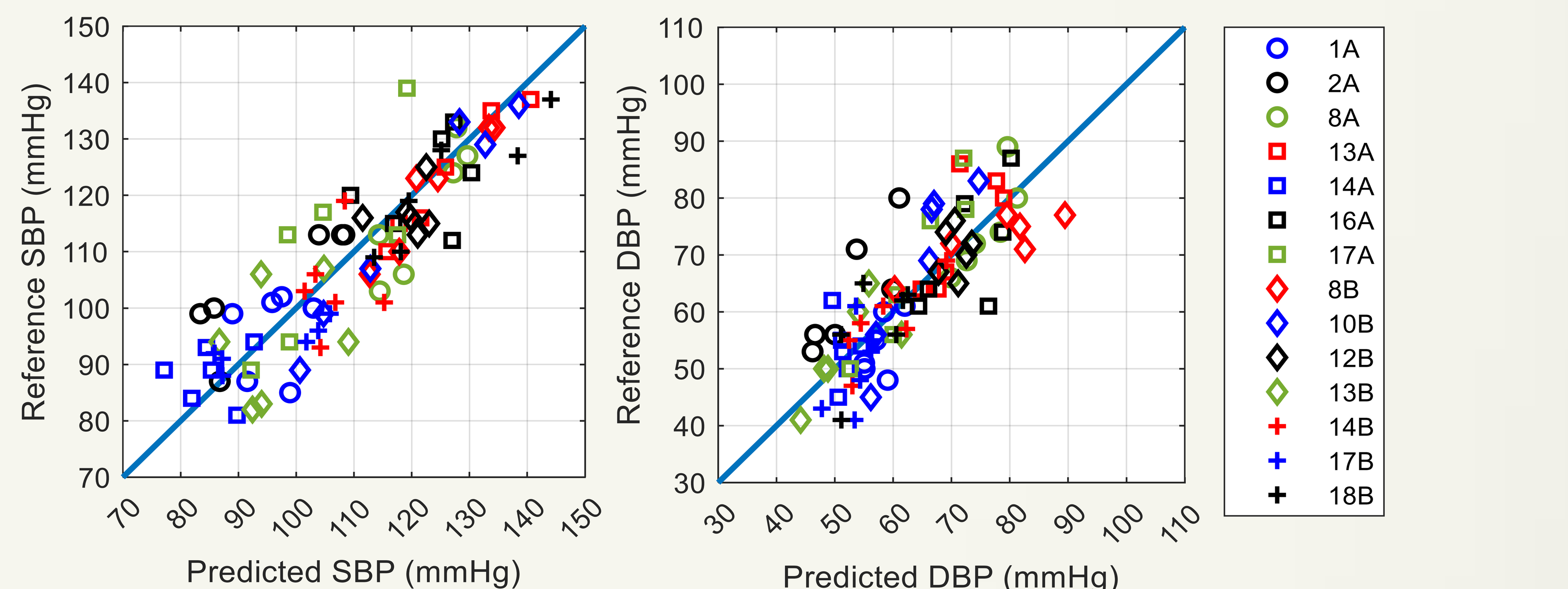
To construct a personal model for 24-hour BP estimation, we propose to use the model agnostic meta learning (MAML) technique [1], which can enhance the capability of the model to adapt quickly to a new task, namely the personal BP trend, with minimal K training data.



EXPERIMENTAL RESULTS

The scatter plots of SBP and DBP estimation results versus reference values for K = 5. Different symbols are used for respective subjects indicated in the legend. We also lists the comparison results of the related paper presenting diurnal and nocturnal BP estimations for tracking BP variability [2].

Our proposed approach provides better estimation and shows the feasibility for 24-hour BP tracking in free-living condition with wrist PPG signals from smart watch.



K	Average RMSE of SBP			MAE of BP Dip
	Daytime	Nighttime	All day	
5	6.55	7.87	7.84	4.45
3	6.73	8.91	8.24	5.99
2	6.95	9.01	8.46	6.61

	Proposed	[2]
Signals	PPG	PPG, ECG
Measurement Site	Wrist only	Arm, thorax and leg
Free-Living Setting	Y	Y
Algorithms	CNN+MAML	PAT Regression
Total Subjects	14	10
Ages (Mean±STD)	55.28±23.24	27±3
Performance (Mean Error±STD)	SBP: 0.89±7.78	SBP: 2.8±8.2
Performance (RMSE)	SBP: 7.78	SBP: 8.7

Reference

[1] C. Finn, P. Abbeel. and S. Levine, “Model-agnostic meta-learning for fast adaptation of deep networks”, arXiv, 2017, doi: 0.48550/ARXIV.1703.03400.

[2] Y. -L. Zheng, B. P. Yan, Y. -T. Zhang and C. C. Y. Poon, "An armband wearable device for overnight and cuff-less blood pressure measurement," in IEEE Transactions on Biomedical Engineering, vol. 61, no. 7, pp. 2179-2186, July 2014, doi: 10.1109/TBME.2014.2318779.