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Motion-tolerant heart rate detection independent on attached location for wrist-worn PPG device

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Abstract— **Photoplethysmography (PPG) -based heart rate measurement at anterior region of forearm (palm side) was explored for wrist-worn PPG device. Our motion artifact reduction framework showed high robustness at near the wrist where the motion artifact had large impact on PPG signal. Furthermore, our implemented framework on edge device was verified running in real-time processing. These results suggested realizing various applications such as healthcare by PPG-based heart rate measurement at anterior region of forearm.**

I. Introduction

Many PPG device that measured heart rate at posterior region of forearm are becoming popular. However, PPG measurement at other location around the wrist have not been validated. Since users do not wear PPG device at the same location every time, it is beneficial for robust heart rate monitoring to verify the accuracy on the location around the wrist where it can be worn. In this paper, we examined the accuracy and the calculation cost of heart rate monitoring around the anterior region of forearm using our previously developed motion artifact reduction framework with both red and green PPG signals [1].

II. Methods

Healthy participants (N=14) conducted 13 representative motion tasks which covered major daily activities [2]. 13 motions tasks were classified into three categories: rest (3 sleeping postures), daily activities (stand, meal, keyboard typing, writing, wiping desk, reading books, playing smart phone game), and exercise (walking, running and cool-down). FUKUDA FCP-7541 is attached on the participant's chest as reference heart rate. With instructions of commercial wearable devices, PPG measurement at anterior region of forearm were recorded at two places such as one finger-width and three-finger widths above wrist on the participant's non-dominant hand. The participant was instructed to perform the motion tasks with their non-dominant hand.

To evaluate amplitude of motion artifact on green-PPG signal as main signal, after applying a band-pass filter in 0.5-5.0 Hz to green-PPG signal, the motion artifact was estimated by subtracting the mean envelope of noiseless signal from the envelope of noise contaminated signal. The pulse rate was calculated from green-PPG signal by our framework which reduced noise by adaptive filtering using both accelerometer and red-PPG, then estimated pulse rate using a feature of high autocorrelation of pulse wave (Fig.1). Decimation processing to reduce calculation cost was introduced while keeping calculation algorithm. Both heart rate and pulse rate were resampled to 1 Hz. To evaluate error with heart rate, we used mean absolute percent error (MAPE).

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III. Results and Conclusion

As shown in Fig. 2, the motion artifact superimposed on the green-PPG signal increased as the device position approaches the wrist (Fig. 2A). Our framework achieved robust motion artifact reduction even near the wrist (Fig. 2B). Mean MAPE of the participants for all tasks at two positions were from 5.2 to 6.3 %, which meant health care application could work [3]. Furthermore, calculation cost was about 1.8 MCPS on the ARM Cortex-M4F, and it was verified real-time processing. The balance between small calculation cost and high robustness can contribute to enhance use case of PPG-based heart rate measurement around the wrist.

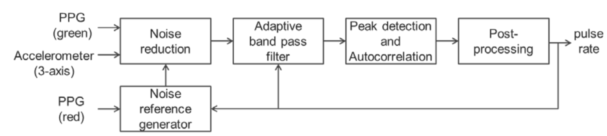

Figure 1. Proposed motion artifact reduction framework.

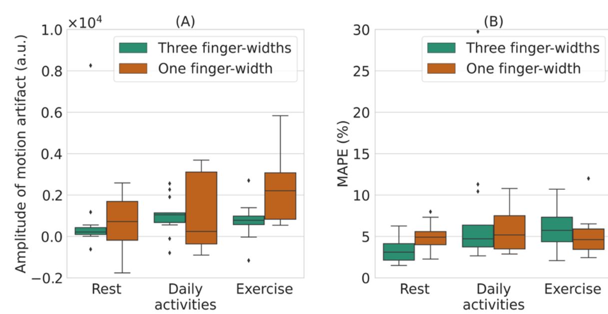

Figure 2. (A) Amplitude of motion artifact. (B) Mean MAPE of the participants across categories of activities.

References

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