Towards Wearable based Wireless Sensing

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1. INTRODUCTION

The popularity of wearables continues to rise. However, their functionality and applications are constrained by the limitations of the types of sensors that are currently available. Accelerometers, gyroscope and barometers struggle to capture complex user behaviors. Microphones and cameras are more powerful, but capture privacy sensitive data. Physiological sensors are obtrusive to users, often require skin contact, and must be placed at certain body positions.

In this work, we explore the feasibility of radio-based sensing for wearables through the design and prototyping of WiWear [2]. This first-of-its-kind wearable sensing modality tracks a number of human activities while only requiring a pair of antenna patches placed on the shoulder and collar of the user, that focus on area surrounding the head. WiWear continuously collects Channel State Information (CSI) fluctuations that are caused by the movements of mouth and head of a user. It then uses a sparse coding-based signal processing pipeline to recognize four common activities: Cough, Drink, Eat, and Speak. The most notable design goals that WiWear achieves are: 1) WiWear automatically tracks human activities that are critical to our health and wellbeing; 2) the design of WiWear enables a contact-free sensor operation yet still maintaining a high recognition accuracy of targeted activities; and 3) its radio-based sensing satisfies privacy-preserving need of wearables.

2. SYSTEM OVERVIEW

As illustrated in Fig. 1 (a), WiWear consists of two components: 1) two small antennas (21 x 21 mm; 5 g) contacts to user's collar or shoulder that operate as sensors; and 2) one WiWear unit (85 x 60 x 36 mm; 390 g) attached to the arm or belt of the user. WiWear unit contains two HummingBoard Pro (HMB) [1] devices each containing an Intel 5300 Wireless Adapter with an onboard modified firmware [3]. During operation, HMB sends packets periodically to its surrounding area via the transmitter antenna (Tx) and another HMB captures the CSI via the receiver antenna (Rx). Examples of CSI waveforms of different activities are shown in Fig. 1 (b). As illustrated, CSIs are able to capture the movements of mouth and head. For example, the waveform of eat activity reflects the periodical mouth movements when people are chewing foods.

3. EVALUATION

To evaluate the feasibility of WiWear under different testing conditions, we recruited seven subjects and collected 7.2 hours of four targeted activities as well as the idle activity. We also duplicated a state-of-the-art audio sensing device, BodyScope, as our counterpart modality comparison

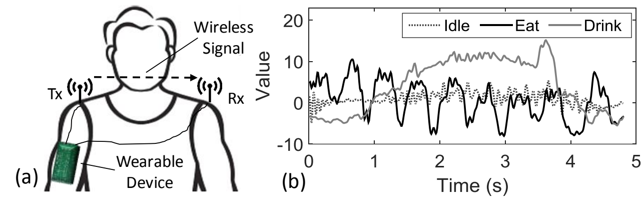

Figure 1: (a) WiWear Operation. (b) Examples of CSI waveforms of three activities.

[4]. Our results show that WiWear achieves an average of 86.3% classification accuracy using leave-one-subject-out cross validation. This result indicates the feasibility of WiWear as an activity sensing system (as compared to 81.6% using BodyScope). Meanwhile, WiWear achieves 72.3% and 62.0% classification accuracy with radio frequency interference (RFI) caused by adjacent and the same channel, respectively, which indicates that WiWear is robust to RFI noise. Additionally, we explored performance of WiWear on different antenna location combinations and discovered that the best location to place Tx and Rx is neck and shoulder. Lastly, we explored the performance of WiWear under different CSI sampling rates. The result shows that WiWear can be configured at a sampling rate as low as 10 Hz, which can be achieved without sacrificing large wireless bandwidth, while still maintaining a high classification accuracy (i.e., 80.6%).

4. CONCLUSION AND FUTURE WORK

In this work, we presented the design, implementation and evaluation of WiWear, a wearable sensing system that captures and recognizes CSIs that reflect head and mouth movements. Immediate future work include shrinking the size of the WiWear prototype. This will enable much lager scale real world experiments. Finally, we plan to broadly investigate other potential use cases.

5. REFERENCES

[1] HummingBoard Pro. `http://goo.gl/Y85x4y`.

[2] B. Fang et al. Wiwear: A wearable device for contact-less radio-based sensing of body-related activities. In *to appear the 15th ACM International Conference on Information Processing in Sensor Networks*, 2016.

[3] D. Halperin et al. Tool release: Gathering 802.11 n traces with channel state information. *ACM SIGCOMM Computer Communication Review*, 2011.

[4] K. Yatani et al. Bodyscope: A wearable acoustic sensor for activity recognition. In *Proceedings of the 2012 ACM Conference on Ubiquitous Computing*, New York, NY, USA, 2012.