Towards Radio-based Activity Sensing on Wearables

Biyi Fang‡, Nicholas D. Lane†, Mi Zhang‡, Fahim Kawsar†
‡Michigan State University, †Bell Labs

1. INTRODUCTION

The popularity of wearables continues to rise. However, their functions and applications are constrained by the types of sensors that are currently available. Accelerometers and gyroscope can only track motions of body parts to which they are attached. Microphones and cameras are powerful but also capture privacy sensitive information. Physiological sensors are intrusive since they often require skin contact and must be placed at certain body locations to function.

Recently, radio-based sensing has drawn significant attention as it provides a contactless and privacy-preserving approach to detect and monitor human activities. In this work, we contribute to the search for a new sensing modality for the next generation of wearable devices by exploring the feasibility of radio-based human activity sensing and recognition in the context of wearable setting. We envision radio-based sensing has the potential to fundamentally transform wearables as we currently know them. As the first step to achieve our vision, we have developed *HeadScan*, a first-of-its-kind wearable for radio-based sensing of a number of human activities that involve head and mouth movements include eating, drinking, coughing, and speaking [2]. We have conducted wide-ranging experiments to examine the feasibility and performance of HeadScan. Our experimental results highlight the enormous potential of our radio-based sensing approach and provide guidance to future explorations.

2. SYSTEM OVERVIEW

Figure 1 (a) provides a conceptual illustration of how HeadScan is worn while it tracks the movements of head and mouth of the user. HeadScan consists of two small unobtrusive commercial off-the-shelf 5GHz antennas placed on the shoulder and collar of the user respectively as well as one wearable unit that can be worn on the arm of the user. One antenna acts as the radio transmitter (Tx) that continuously sends the radio signals while the other antenna acts as the radio receiver (Rx) that continuously receives the radio signals. The wearable unit contains two HummingBoard Pro (HMB) devices [1], each connected with an Intel WiFi Link 5300 card with the modified firmware [3]. HeadScan extracts the Channel State Information (CSI) measurements from the received radio signals. It then incorporates a radio signal processing pipeline to convert the raw CSI measurements into the targeted human activities. Figure 1 (b) shows the example waveforms of the targeted four activities. As illustrated, HeadScan is able to capture the characteristic head and mouth-related movements of the four activities. As an example, the waveform of eating reflects the periodical mouth movements when people are chewing food.

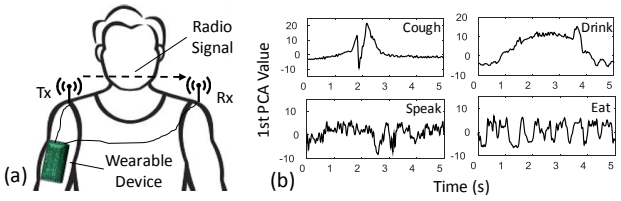

Figure 1: (a) Illustration of HeadScan. (b) Example waveforms of the targeted four activities: coughing, drinking, speaking, and eating.

3. EVALUATION

To examine the feasibility and performance of HeadScan, we recruited seven participants and conducted extensive experiments including a quantitative comparison between our radio-based sensing approach with conventional skin-contact audio-based sensing approach. We replicated one state-of-the-art audio-based wearable system called BodyScope from [4]. Our results show that HeadScan achieves an average classification accuracy of 86.3% compared to 81.6% from the audio-based sensing approach on the same set of activities. We have also conducted experiments to examine the impact of a number of key factors on the activity recognition performance of radio-based sensing. Specifically, we have identified the best on-body locations to place Tx and Rx are collar and shoulder. We have found HeadScan could achieve competitive activity recognition performance with a sampling rate as low as 10Hz without sacrificing the regular wireless data transmission. Finally, we have found HeadScan is robust to non-user interferences caused by the movements of nearby people, indicating significant potential for real world applications.

4. CONCLUSION AND FUTURE WORK

In this work, we presented the development and evaluation of HeadScan, a wearable system that uses radio as a sensing modality to capture and recognize head and mouth-related activities including eating, drinking, coughing and speaking. For future work, we plan to develop the next generation of our wearable prototype with smaller form factor and reduced power consumption. We also plan to broadly investigate other potential use cases.

5. REFERENCES

[1] HummingBoard Pro. `http://goo.gl/Y85x4y`.
[2] B. Fang et al. HeadScan: A wearable system for radio-based sensing of head and mouth-related activities. In *International Conference on Information Processing in Sensor Networks (IPSN)*, 2016.
[3] D. Halperin et al. Tool release: Gathering 802.11n traces with channel state information. *ACM SIGCOMM CCR*, 41(1):53, Jan. 2011.
[4] K. Yatani et al. BodyScope: A wearable acoustic sensor for activity recognition. In *ACM Conference on Ubiquitous Computing*, 2012.