3-2019

Making wearable sensing less obtrusive

Huy Vu TRAN
Singapore Management University, hvtran.2014@phdis.smu.edu.sg

Archan MISRA
Singapore Management University, archanm@smu.edu.sg

Citation

TRAN, Huy Vu and MISRA, Archan. Making wearable sensing less obtrusive. (2019). *2019 IEEE International Conference on Pervasive Computing and Communications Workshops: Kyoto, Japan, March 11-15: Proceedings*. 453-454.

Available at: https://ink.library.smu.edu.sg/sis_research/4421

Published in 2019 IEEE International Conference on Pervasive Computing and Communications Workshops: Kyoto, Japan, March 11-15: Proceedings, pp. 453-454. DOI: https://doi.org/10.1109/PERCOMW.2019.8730740

Making Wearable Sensing Less Obtrusive

Vu H. Tran
Supervised by Prof. Archan Misra
Singapore Management University

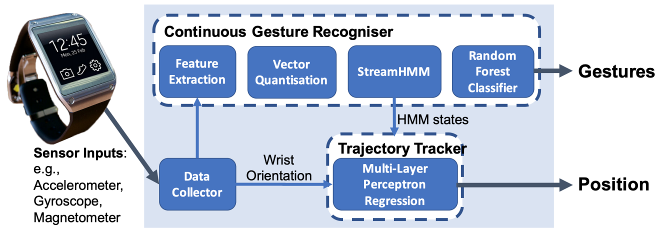

Fig. 1. The framework for early gesture recognition & tracking. The HMM state probability is used as a feature for both gesture classification and hand tracking.

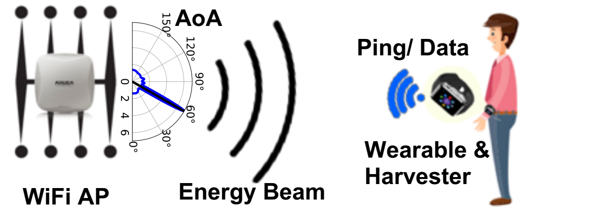

Fig. 2. WiWear system includes: (1) a WiFi AP with AoA and Beamforming capability, and (2) a wearable device (wore by a user) which can harvest energy from WiFi transmission.

***Abstract*—Sensing is a crucial part of any cyber-physical system. Wearable device has its huge potential for sensing applications because it is worn on the user body. However, wearable sensing can cause obtrusiveness to the user. Obtrusiveness can be seen as a perception of a lack of usefulness [1] such as a lag in user interaction channel. In addition, being worn by a user, it is not connected to a power supply, and thus needs to be removed to be charged regularly. This can cause a nuisance to elderly or disabled people. However, there are also opportunities for wearable devices to be used to assist users in daily life activities. In my proposal, I propose three directions to make wearable sensing less obtrusive: (1) Reduce obtrusiveness in user interaction with the device, (2) reduce the obtrusiveness in powering the device, and (3) using wearable to reduce obtrusiveness in user interaction with the surrounding environment.**

I. Current Progress

A. Gesture recognition and hand tracking for interactive applications

The rich set of sensors in wearable devices (e.g. smartwatch, smartglasses) makes it suitable for gesture recognition which can be used as an input modality. However, previous gesture recognition techniques suffer from latency problem. The sensor readings must be segmented to select suspected segments of data before being classified into different gestures. This is extremely undesirable in interactive applications such as a virtual table tennis game. In our work on early gesture recognition and hand tracking [3], we found that about 80% of 12 users in one of our experiments perceive a latency of more than 100 msec. Therefore a system cannot wait until the end of gestures then classify them.

We proposed a classification model which uses HMM state probabilities as a feature to recognize 6 common Table Tennis gestures (See Figure 1). We presented an HMM model that processes input stream continuously and avoid the conventional segmentation, thus classifies gestures as early as possible. HMM states also function as an indicator of the gesture progress. Knowing the gesture being performed can limit the probable position of the wrist, and knowing the progress of the gesture can confine the probable space even more. We proposed a regression-based model for hand tracking which uses HMM state probabilities to improve the estimation of wrist position. In our paper, up to 93% of gestures can be recognized correctly before 50% of gesture duration. We also achieved a medium hand tracking error of 6.2cm.

B. Moving toward battery-less with WiWear

Though wearable devices provide many opportunities for human sensing (e.g. inertial, vital signal). The fact that it has to be removed and charged in everyone or several days. This causes many troubles with elderly or disabled people. A wearable device which can operate on harvested power would enable minimal obtrusive fine grain sensing such as elderly/patient monitoring. Though harvesting energy using solar cell or RFID reader is possible, they are either inefficient (solar cell) or require high deployment cost (RFID) in indoor environments where WiFi is highly available. Recently WiFi based energy harvesting has been studied; however, the efficiency is low and no study addresses the problem of WiFi harvesting for wearable devices (moving objects).

We proposed a framework for battery-less wearable devices which operate on energy harvested from WiFi transmissions (See Figure 2). We implemented and evaluated the system in a meeting room environment. The framework includes a wearable device which is powered from a WiFi energy harvester. We implemented the wearable device including one accelerometer and one GFSK transceiver to transmit ”ping” packets and data packets to the AP. We implemented the WiFi AP on 2 WARPv3 boards based on a reference design of 802.11g. We modified the AP to be able to detect raw GFSK packets from the wearable and estimate the AoA (Angle of

Arrival). We also implemented the beamforming module into the AP so that it updates the beam direction based on the AoA information. By using an 8-antenna (i.e. transmission power is 8 times higher than using 1 antenna) linear array for beamforming, the harvested energy increases almost 100 times compared to one antenna. At 1 meter, the system can harvest more than 200μW. We evaluated the system with 4 different users in a meeting room at 4 distances of 1.3m, 1.4m, 2m, and 2.2m accordingly. The wearable recorded acceleration of user hand at 10Hz. In all 4 cases, we achieved positive net energy after the experiment. These results imply that the system is able to transfer enough energy for the wearable to work in an office environment.

II. Future work

A. Enhancing the harvesting devices

In our study, WiWear [4], we use a common whip antenna for harvesting which has very low gain toward the pole. We plan to design a new antenna that is more suitable for energy harvesting on wearable devices or adopt opportunistic harvesting from multiple energy sources. The idea of integrating multiple harvesters (the size of the harvesting circuit is only about $0.5cm^2$) to cover different directions is also considered. Based on our observation, in office environments, there are usually several APs to cover different locations. This brings an opportunity to harvest energy from multiple APs, or scheduling which AP to serve which device based on the location information.

B. Multimodal access point: Communication, Energy, and Sensing

The usual purpose of a WiFi AP is communication. Recently it can be used for sensing purpose (using WiFi signal). We have also shown that a WiFi AP can be used for energy transfer. Though an AP can be good enough for each of these tasks, the question is that how it serves these 3 tasks concurrently, what is the scheduling scheme to support sufficient bandwidth for communication, sufficient energy for battery-less devices and still support device-free sensing. However, to achieve an optimal (or nearly optimal) scheduling for multiple devices, the system needs a fast and low-power communication channel from the AP to the devices to exchange and update parameters of the scheduling algorithm. For example, the AP should have the information of device's energy level, distance to the AP, and the current communication demand to create a schedule that maximizes survival time while ensuring that the normal communication is not affected.

C. Device-free sensing: a case of visible light

Similar to the case of device-free sensing using radio wave, one can achieve device free sensing with visible light. Recently we have seen studies where an off-the-shelf camera is used to measure vibration frequencies of machines using a strobe light source. A common method to measure this type of vibration is to mount accelerometer on the machine or use an expensive laser device. Roy et. al. [5] proposed to a new technique using a strobe light source and a common camera to estimate vibration frequencies. It would be more practical to use a portable/wearable camera to measure the vibration. For example, a worker can use his smartglasses to probe machines for anomalies in a factory. However, it is challenging because of the motion artifact caused by the user or the constraint on the power budget for the camera. We believe that this new probing technique, if combined with visible light communication (VLC), can have many interesting applications. For example, in a factory, there are many machines or parts with different vibration characteristics. A worker must have a list of normal/abnormal characteristics of these objects at hand so that he may know what is going wrong. VLC can shine the hidden information onto each of these objects (as introduced by Panasonic [8]). A smartglasses set then decodes this information and show it to the worker.

III. Conclusion

We showed our effort toward reducing obtrusiveness for wearable sensing. We first addressed the problem of latency or lag in gesture recognition for interactive applications. We then proposed and evaluated a framework for battery-less wearable devices. We believe this type of wearable reduces the obtrusiveness of device removal for charging which is difficult for elderly or disabled people. We also discuss the possibility of using wearable devices to make vibration sensing less obtrusive.

IV. Acknowledgment

I would like to thank my supervisor Prof. Archan Misra for his guidance and support in my work.

References

[1] Hensel, B. K., Demiris, G., & Courtney, K. L. (2006). Defining obtrusiveness in home telehealth technologies: A conceptual framework. Journal of the American Medical Informatics Association, 13(4), 428-431.

[2] Park, T., Lee, J., Hwang, I., Yoo, C., Nachman, L., & Song, J. (2011, November). E-gesture: a collaborative architecture for energy-efficient gesture recognition with hand-worn sensor and mobile devices. In Proceedings of the 9th ACM Conference on Embedded Networked Sensor Systems (pp. 260-273). ACM.

[3] Vu, T. H., Misra, A., Roy, Q., Wei, K. C. T., & Lee, Y. (2018). Smartwatch-based Early Gesture Detection & Trajectory Tracking for Interactive Gesture-Driven Applications. Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies, 2(1), 39.

[4] Vu, T. H., Misra, A., Xiong, J., Balan, R. (2019, March). WiWear: Wearable Sensing via Directional WiFi Energy Harvesting. In Procedings of the 17th IEEE International Conference on Pervasive Computing and Communications (accepted to appear at PerCom 2019).

[5] Roy, D., Ghose, A., Chakravarty, T., Mukherjee, S., Pal, A., & Misra, A. (2018, June). Analysing Multi-Point Multi-Frequency Machine Vibrations using Optical Sampling. In Proceedings of the 1st International Workshop on Internet of People, Assistive Robots and ThingS (pp. 55-59). ACM.

[6] Talla, V., Kellogg, B., Ransford, B., Naderiparizi, S., Gollakota, S., & Smith, J. R. (2015, December). Powering the next billion devices with Wi-Fi. In Proceedings of the 11th ACM Conference on Emerging Networking Experiments and Technologies (p. 4). ACM.

[7] WARP v3 Kit., https://mangocomm.com/products/kits/warp-v3-kit, 17 12 2018.

[8] Light ID technology, https://www.panasonic.com/global/corporate/technology-design/technology/lightid.html, 17 12 2018