Understanding the Quality of Body Movement by Leveraging WiFi Sensing

Xijia Wei, Fangzhan Shi, Shuang Wu, Kevin Ketty, Youngjun Cho, and Nadia Berthouze

University College London

Human activity recognition (HAR) has become a research hotspot for many years. Various HAR systems have been developed for detecting different types of activities from body-motion samplings. Indeed, body-movement behaviours reveal rich information related to emotional states, which can be utilized in the interaction process to address cognitive functions, emotional regulation, and the mediation of affective and social communication [1]. It is crucial to understand the quality of body movements (e.g., hesitation, stiffness, rigidity, and fear of movement) rather than simply recognising activity types.

Various sensors are used for capturing body movement and physiological states, such as wearable sensors including IMU, ECG (electrocardiogram), and PPG (Photoplethysmography) sensors, or optical sensors including RGB or depth cameras. However, such sensors require users to continuously wear them or work in LOS (Line-of-Sight) environments with limited sensing range. These sensors are considered intrusive and may raise privacy concerns. The variability of such intrusive sensors due to acceptability and privacy concerns significantly affects system performances, hindering the widespread adoption of HAR technologies beyond laboratory settings to real-world applications in areas such as healthcare, physical rehabilitation, and home monitoring.

The widely existing WiFi routers benefit users with many functionalities besides providing wireless internet services. Commodity WiFi routers use channel state information (CSI) to scan the signal propagation environment for improving wireless communication quality. CSI describes the scattering, fading, and power decay of the wireless signals altered by obstacles. Pioneering works indicate that body motions can impact signal multipath reflection. To date, many WiFi sensing studies have focused on detecting different types of activities (e.g., walking, standing, falling) [2]. However, we haven't found studies that look at the feasibility to detect qualities of body movement that relate to affective states using WiFi signals in an ambient and non-intrusive manner.

Commodity WiFi routers have time-varying phase error issues due to clock asynchronisation between signal transmitter and receiver, which overwhelms the signal propagation signature altered by body movements. To address this issue towards capturing accurate body-motion samplings, we customized the WiFi protocol by adding a time synchronisation mechanism to acquire a valid round-trip phase for sensing purposes [3]. With the available phase information, we could better understand the detailed information carried by the motions revealing body-movement qualities.

We have collected data from over 16 participants simulating those people with chronic pain when performing standing up, sitting down, stretching forward, and picking up in three stages of simulating healthy persons, with hesitation, or rigidly. We employ various feature extraction strategies (amplitude, phase, statistic features, dynamic time warping, and micro-Doppler spectrograms) and use different pattern-matching, machine learning and deep learning techniques. To evaluate the system's performance, we deploy leave-one-subject-out and leave-one-participant-out cross-validations. Our results show that WiFi sensing is feasible for capturing the quality of body movements, showing promising potential for delivering passive and non-intrusive sensing solutions. We are expanding the system to capture more user mobility patterns with higher robustness across different environments.

References

[1] N. Bianchi-Berthouze, "Understanding the role of body movement in player engagement," *Human–Computer Interaction*, vol. 28, no. 1, pp. 40–75, 2013.

[2] J. Liu, H. Liu, Y. Chen, Y. Wang, and C. Wang, "Wireless sensing for human activity: A survey," *IEEE Communications Surveys & Tutorials*, vol. 22, no. 3, pp. 1629–1645, 2019.

[3] F. Shi, W. Li, A. Amiri, S. Vishwakarma, C. Tang, P. Brennan, and K. Chetty, "Pi-nic: Indoor sensing using synchronized off-the-shelf wireless network interface cards and raspberry pis," in *2022 2nd IEEE International Symposium on Joint Communications & Sensing (JC&S)*, pp. 1–6, IEEE, 2022.