BEHAVIOR RECOGNITION BASED ON WI-FI CSI: PART 1


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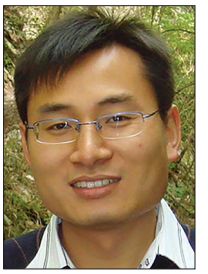
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Human behavior recognition is the core technology that enables a wide variety of human-machine systems and applications (e.g., healthcare, smart homes, and fitness tracking). Traditional approaches mainly use cameras, radars, or wearable sensors. However, all these approaches have certain disadvantages. For example, camera-based approaches have the limitations of requiring line of sight with enough lighting, potentially breaching human privacy. Low-cost radar-based solutions have limited operation range of just tens of centimeters.

Recently, Wi-Fi channel state information (CSI)-based human behavior recognition approaches are attracting increasing attention. The rationale is that different human behaviors introduce different multi-path distortions in Wi-Fi CSI. Compared to traditional approaches, the key advantages of Wi-Fi CSI-based approaches are that they do not require lighting, provide better coverage as they can operate through walls, preserve user privacy, and do not require users to carry any devices as they rely on the Wi-Fi signals reflected by humans. As a result, the recognition of quite a number of behaviors that are difficult based on traditional approaches have now become possible, including fine-grained movements (e.g., gesture and lip language), keystrokes, drawings, gait patterns, vital signals (e.g., breathing rate), and so on. However, Wi-Fi CSI-based behavior recognition still faces a number of challenges: What are the fundamental theories and models that can steer the development of accurate, robust, and fine-grained CSI sensing systems? How do we overcome the impact of noise and ensure the performance of CSI-enabled systems? How do we recognize the behavior of multiple users?

This Feature Topic provides an opportunity for researchers and product developers to review and discuss the state of the art and trends of CSI-based behavior recognition techniques. A total of 16 articles were submitted from around the globe via the open call. In order to ensure high reviewing standards, three to four reviewers evaluated each article. The finally accepted articles are organized into Part 1 and Part 2. In Part 1 (this issue), you can find four of them as follows; the other ones will be published as Part 2 in a later issue. The selected articles cover different topics, such as literature review, pattern/model-based recognition approaches, and novel applications.

The first article, "Device-Free WiFi Human Sensing: From Pattern-Based to Model-Based Approaches," by Wu *et al.*, reviews the research in Wi-Fi CSI-based device-free human behavior sensing in recent years. The authors point out the research trend that would evolve from pattern-based to model-based approaches, and suggest that researchers leverage the Fresnel zone model as the basis of wireless human sensing and extend it to a general sensing model.

In the second article, "A Survey on Behavior Recognition Using WiFi Channel State Information," Yousefi *et al.* present a survey of recent techniques for human behavior recognition using channel information of Wi-Fi devices. They then show the performance of deep learning techniques such as LSTM for supervised classification of user activities. Finally, the authors discuss the challenges in activity recognition using Wi-Fi CSI and suggest research directions for future study.

The third article, "Wi-Fi Radar: Recognizing Human Behavior with Commodity Wi-Fi" by Zou *et al.*, first defines Wi-Fi radar, which is a novel kind of system based on commodity Wi-Fi. By surveying the latest works, the authors summarize the general framework of existing Wi-Fi radar systems, and figure out that the design of these systems mainly follows a data-driven approach or a model-based approach. For each kind of Wi-Fi radar, the article gives a detailed introduction to the fundamental principles and state-of-the-art applications.

The fourth article, "Human Behavior Recognition Using Wi-Fi CSI: Challenges and Opportunities" by Chen *et al.*, provides a tutorial on human behavior recognition (HBR) using Wi-Fi CSI. The article first reviews the state of the art of HBR, based on the techniques that have driven recent progress. It then provides insights on the future directions of HBR research.

In concluding this overview, we would like to address our special thanks to Dr. Osman Gebizlioglu, the Editor-in-Chief of *IEEE Communications Magazine*, and Jennifer Porcello and Peggy Kang for their great support and effort throughout the whole publication process of this Feature Topic. We are also grateful to all the authors for submitting their papers and the reviewers for their professional and timely work in making it possible to publish this Feature Topic.

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