Introduction to the Special Issue on Wireless Sensing for Health Monitoring and Elderly Care

Wireless sensing for health is an emerging paradigm that has drawn significant attention recently. It leverages signals from widely available wireless communication technologies, such as WiFi, mmWave, and RFID, to provide powerful sensing capabilities for healthcare monitoring tasks. This innovative approach enables continuous and contactless health monitoring, utilizing RF signals to support applications like heart rate monitoring, breathing rate tracking, sleep analysis, daily behavior monitoring, and fitness assessments. The evolution of wireless sensing for health has progressed from single-point, coarse-grained measurements (e.g., single data streams and received signal strength) to more sophisticated, multi-dimensional data (e.g., multiple data streams and **Channel State Information (CSI)**). Unlike traditional sensor-based systems, wireless health sensing does not require users to wear or carry devices, allowing for unobtrusive, seamless monitoring of health metrics in various environments, from homes to clinical settings, without the need for direct user interaction.

Wireless health sensing enables a broad range of contactless monitoring applications, each with significant impacts on healthcare and personal well-being. For example, physiological signal monitoring technologies like WiFi, mmWave, and RFID facilitate continuous, real-time tracking of vital signs such as heart and breathing rates. Such technologies allow for early health issue detection, personalized treatment plans, and proactive health management. It is particularly impactful in clinical and eldercare settings where uninterrupted monitoring enhances patient safety and quality of care. Another wireless health sensing application is daily behavior monitoring, which captures patterns in everyday activities. This technology offers comprehensive insights into behavioral changes that might indicate health concerns, such as falling, reduced mobility, or irregular routines. Such information is beneficial for chronic disease management, as it enables caregivers and healthcare providers to monitor and respond to changes in a patient's routine non-intrusively. Furthermore, wireless sensing-based sleep monitoring systems can unobtrusively track sleep patterns and behaviors, analyzing movement and physiological indicators throughout the night. Patients and doctors can obtain insights into sleep quality and identify sleep disorders without wearing dedicated sensors that could disrupt natural sleep. Finally, fitness tracking leverages wireless sensing to accurately track physical activity levels and exercise patterns. With advanced AI technologies, such systems can support users in managing their fitness goals and maintaining active lifestyles without hiring expensive professional trainers.

This special issue is dedicated to original research that highlights the potential of wireless sensing to improve the quality of care and enhance the well-being of elderly and vulnerable individuals. This compilation of research articles reflects the latest advancements and ongoing discussions in the field, aiming to provide a comprehensive overview of the potential of wireless sensing to improve the quality of care and enhance the well-being of elderly and vulnerable individuals. This special issue features three articles from leading researchers in the field. Each article contributes uniquely to our understanding of wireless sensing in healthcare:

(1) *WiLife: Long-term Daily Status Monitoring and Habit Mining of the Elderly Leveraging Ubiquitous Wi-Fi Signals* by Li et al.—This article explores Wi-Fi-based long-term and continuous monitoring of the daily

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routines of the elderly. Unlike systems that focus on acute safety issues, such as fall detection and vital sign monitoring, this work emphasizes the importance of observing the daily activities of the elderly over extended periods. By tracking these routines, we can gain valuable insights into their living habits and overall health. This ongoing observation enables early detection of potential health issues and facilitates timely interventions if their conditions begin to deteriorate. To achieve this, the work introduces "WiLife," an innovative Wi-Fi-based framework for continuous monitoring of the elderly's spatio-temporal daily status information. WiLife employs a strategy of partitioning living spaces into functional areas and categorizing daily activities into atomic states. By encapsulating daily life status into a unique series of triple unit formats: ⟨Time, Area, State⟩, WiLife provides valuable insights into when, where, and how activities occur. Field implementations spanning 1,080 hours (45 days × 24 hours) in real-world home environments demonstrate WiLife's exceptional capability to understand individual living habits and detect irregularities in a timely manner.

(2) *Heart Rate Variability Estimation Based on RFID Tag-Pair in Dynamic Environments* by Wu et al.—In this article, the authors introduce a novel RFID-based sensing system that utilizes only two RFID tags—one on the chest and one on the shoulder—to monitor **Heart Rate Variability (HRV)** in daily life. They develop an efficient cancellation algorithm to mitigate interference from respiratory activity and body movements across temporal and spatial domains, enabling accurate HRV monitoring even during dynamic movement. This approach provides a non-invasive solution for continuous, 24/7 cardiac monitoring, particularly suited to long-term heart health surveillance in elderly patients.

(3) *Wi-PT-Hand: Wireless Sensing Based Low-cost Physical Rehabilitation Tracking for Hand Movements* by Touhiduzzaman et al.—This article presents a low-cost, device-free system for tracking physical rehabilitation exercises using wireless sensing. By leveraging CSI from ambient WiFi signals, the system overcomes the limitations of wearable and camera-based solutions, such as cost, setup complexity, and privacy concerns. It employs a lightweight, edge-compatible design with Bayesian optimization and hierarchical deep learning to segment activity, classify wrist and finger movements, and count exercise repetitions. Extensive evaluations demonstrate its robustness across diverse user conditions and environments, making it a scalable and accessible solution for at-home rehabilitation that enhances therapy effectiveness while minimizing costs and preserving privacy.

Together, these articles highlight the transformative potential of wireless sensing in healthcare by addressing diverse aspects such as daily activity monitoring, vital sign tracking, and rehabilitation support. A common theme across the contributions is the innovative use of wireless signals to enable contactless and real-time health monitoring. These studies collectively demonstrate the practicality of wireless sensing systems in enhancing care delivery, improving patient outcomes, and supporting independent living. They also showcase advancements in algorithmic optimization, system robustness, and scalability, paving the way for more integrated and user-friendly healthcare solutions.

We would like to express our gratitude to all authors, reviewers, and contributors for their hard work and dedication in bringing this special issue to fruition. We hope to inspire further research on wireless sensing for healthcare and shape the future of healthcare by enhancing the quality of life for individuals worldwide.

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