

Achieving Robust and Cost-effective Head Nodding and Body Gesture Recognition in Real-world Scenarios with WiFi-CSI Analysis

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論 文 名 : Achieving Robust and Cost-effective Head Nodding and Body Gesture Recognition in Real-world Scenarios with Wi-Fi CSI Analysis

(WiFi-CSI分析に基づく実環境シナリオでの環境変化に頑健で低コストな頭部およびジェスチャ認識の実現)

区 分 : 甲

論 文 内 容 の 要 旨

Wireless gesture recognition (GR) sensing systems utilizing Wi-Fi Channel State Information (CSI) signals have emerged as foundational technologies with broad implications for cutting-edge applications. These systems offer distinct advantages over traditional methods like vision-based and wearable sensors, as they are widely accessible, user-friendly, and incorporate robust privacy protection mechanisms. However, existing GR approaches face challenges in real-world scenarios as they are tailored to specific user environments. Additionally, current Wi-Fi CSI tools present drawbacks, such as limited device support, hardware compatibility issues, complex setup procedures, constrained data processing capabilities, and a lack of official support and updates.

Our research addresses the challenges mentioned earlier through two applications: enabling communication between quadriplegic individuals and others, and monitoring workers' moods using gesture recognition. We utilize the ESP32 microcontroller, known for its compact size, energy efficiency, and cost-effectiveness, making it suitable for limited power and memory resources. Our work introduces three innovative and cost-efficient systems that are feasible for real-world deployment and exhibit robustness in various environmental conditions.

We begin by introducing the Wi-Nod system as a key component of a novel communication system tailored for individuals with quadriplegia. Wi-Fi CSI is utilized to encode Morse symbols, with head down and right motions representing dot and dash, respectively, and head left motion representing the new symbol, space. To establish distinct signatures for each head motion, the system employs Short Time Fourier Transform (STFT). Furthermore, a learning model based on the inception module is implemented to improve classification accuracy and diversity user robustness.

Next, we propose HeMoFi4Q which is the extension of the Wi-Nod system. HeMoFi4Q

introduces a new communication method based on the combination between different Wi-Nod classified blocks to make the 26-alphabet characters. It utilizes Wi-Fi CSI waveforms to passively track head motions and derive distinctive gesture signatures for each character. Employing a real wheelchair and an ESP32 microcontroller, our approach diverges from previous HAR CSI systems by addressing domain-independent challenges in multi-human environments. Drawing inspiration from few-shot learning algorithms, we enhance location robustness by integrating samples from unseen environments during the learning phase. Our focus on domain independence involves studying the impact of amplitude and phase features, leading to improved recognition accuracy with minimal samples.

In addition to the quadriplegia communication systems, we introduce a passive desk body gesture recognition system aiming to autonomously identify the mood of a worker. Here, this system incorporates a multiple input multiple output (MIMO) configuration, employing three ESP32 microcontrollers sharing a common channel to enhance the reliability and robustness of data transmission. Additionally, the calibrated phase variations in the wavelet domain are inputted into a straightforward machine learning model. This system aims to develop an on-desk body gesture recognition system on a single chip.

We conducted comprehensive experiments to evaluate the performance of the aforementioned three systems individually. The results demonstrated significant advancements in environmental robustness, particularly in multi-human context environments that closely resemble real-world scenarios.