Research on Human Body Recognition in the Field of Disability Assistance Based on Wireless Sensing Technology

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Abstract. With the global rise in both the aging population and the number of individuals with disabilities, leveraging advanced technology to enhance their quality of life has emerged as a crucial societal focus. This paper examines the current research and future potential of human behavior sensing through increasingly popular wireless networks like WiFi, particularly in aiding disabled populations. It begins by outlining the foundational principles of wireless sensing—specifically, how human movement affects signal modulation to recognize behaviors. The discussion then extends to notable recent studies that have employed this technology to assist visually impaired individuals, facilitate communication for the deaf and mute, and provide monitoring for the elderly and disabled. Key technical challenges in practical implementations are analyzed, including issues related to sensing accuracy and privacy protection in real-world settings, which predominantly remain experimental and confined to laboratory environments. The paper concludes by projecting the significant potential and expansive future applications of integrating this technology in disability assistance, aiming to systematically compile the progress and outline the operational modes, key technological considerations, challenges, and future directions of wireless sensing technologies to aid disabled individuals. This synthesis serves as a reference for further research in the field.

Keywords: Wireless Sensing Technology, Human Body Recognition, Disability Field.

1 Introduction

As the global trend of population aging intensifies, the number of people with disabilities continues to grow. According to the World Health Organization (WHO) [7], there are about 1 billion people with disabilities worldwide, of whom about 200 million are classified as moderately or severely disabled. This phenomenon reveals the multiple challenges posed by an aging society, especially the various disabilities that arise from it, which not only have a significant impact on the lives of individuals

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but also pose a heavy economic and psychological burden on families and society. Traditional ways of assisting people with disabilities, such as manual care and wearable devices, although capable of providing help to a certain extent, face many limitations, such as high labor costs, inconvenience in use, and limited coverage. Therefore, how to effectively improve the quality of life of people with disabilities has become an urgent social problem.

In recent years, with the rapid development of wireless communication technology and the Internet of Things (IoT), wireless sensing technology has been widely used in many industries. The progress of this technology is mainly reflected in its affordability, ease of deployment, and good privacy protection. Thus it has been widely used in smart home and human-computer interaction. The introduction of wireless sensing technology in assisting the disabled shows great potential and prospects, which not only can realize automatic identification and assistance of disabled people's behavior but also can significantly improve their self-care ability and quality of life.

The application of wireless sensor assistive technologies enables people with disabilities to enjoy more convenient and efficient assistance. These technologies can monitor the activity status of the disabled in real time and provide necessary support and assistance promptly. For example, smart sensors can monitor the movement trajectory of the elderly and automatically send alerts to family members or caregivers when emergencies such as falls occur, ensuring timely assistance. In addition, these sensors can also help people with disabilities manage their daily lives, such as reminding them to take medication and recording health data, thus greatly reducing the pressure of home care. Wireless sensing technology can also be integrated into a variety of smart devices to provide personalized help and support, enabling people with disabilities to better integrate into society and enjoy a more independent and dignified life.

As technology continues to advance, the prospects for the application of wireless sensing technology to help people with disabilities are also expanding. Combined with artificial intelligence and big data analysis technology, it can provide more accurate and intelligent services for people with disabilities. By analyzing the data collected by sensors, potential risks can be predicted and prevented, personalized health advice can be provided, and the quality of life of people with disabilities can be further improved.

In summary, along with the aging trend and the increase in the number of people with disabilities, the limitations of the traditional ways of assisting people with disabilities are becoming more and more obvious, and it is particularly important to innovate and develop new assistive technologies. As an emerging and widely applied technology, wireless sensor assistive technology is expected to provide more intelligent and humanized help for the disabled, thus significantly improving their living standard and self-care ability, and reducing the burden of family and society. With the continuous progress of science and technology and the expansion of applications, it is believed that wireless sensor assistive technology will play a more important role in the future, helping more disabled people to realize a better quality of life.

2 Working Principles of Wireless Sensing Technology

Wireless sensing technology mainly utilizes the propagation, reflection and attenuation of wireless signals in the environment to recognize human activities and environmental changes. Specifically, it mainly includes the following steps

2.1 Signal Acquisition

The wireless sensing system first collects wireless signals in the environment through wireless devices. These signals contain a variety of information such as reflection, scattering and attenuation, which can reflect the dynamic changes in the environment.

2.2 Signal Processing

The acquired signals often contain a lot of noise and need to go through pre-processing steps such as filtering and denoising. For example, the CSI signal is filtered using a Kalman filter to remove low-frequency noise [2]. In practical applications, it is also necessary to consider the real-time processing capability of the signal to ensure the response speed of the system.

2.3 Feature Extraction

By analyzing the signal in the time and frequency domains, the eigenvalues that can reflect human activities and environmental changes are extracted. These eigenvalues can include information such as amplitude, phase, and frequency. For example, Primary Component Analysis (PCA) and Short Time Fourier Transform (STFT) can be used to extract the main features of the signal [3].

2.4 Model Training and Recognition

The extracted feature values are input into a machine learning model for training, and commonly used models include Convolutional neural network (CNN), support vector machine (SVM), and long short-term memory network (LSTM). Through the training and optimization of the model, accurate recognition of human activities and environmental changes can be achieved [4-5].

In practical applications, different scenarios have different requirements for models. For example, in the blind assistance system, the model needs to be able to recognize obstacles in the environment in real time and accurately, while in the elderly monitoring system, the model needs to be able to monitor the daily activities of the elderly for a long time and stably. Therefore, when the model is trained and optimized, it needs to be tailored to the specific application scenario. As shown in Fig 1.

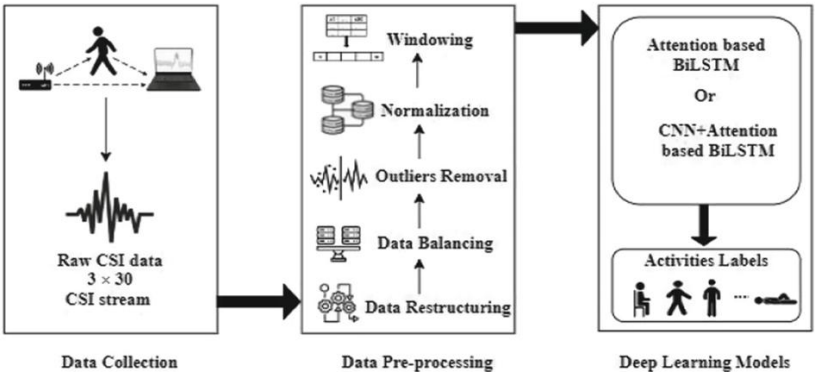

Fig. 1. Working principle of wireless sensing technology [6].

3 Exploration of Wireless Sensing Technology in Disability Assistance

3.1 Assistance Systems for the Blind

Wireless sensing technology can provide real-time environment sensing and navigation services for blind people. For example, Ziyu Bai proposed a WiFi human recognition system called Wi-Fi-RSMID, which realizes the recognition of walking people by analyzing the channel state information (CSI) of WiFi signals using PCA principal component analysis and random forest method. Experiments show that the system achieves an average recognition rate of 75.3%-85.6% for 15 people in different scenarios [7]. Alternatively, a bidirectional LSTM network enhanced with WiFi signals and attention mechanism was used to achieve recognition of 12 daily activities in 3 different environments with an accuracy of 98.54% [8]. These systems can be used for indoor navigation for the blind, providing real-time environmental information to help them avoid obstacles.

Real-time and accuracy are crucial in assistive systems for the blind. To achieve efficient real-time navigation, the system needs to continuously collect and process WiFi signals in the environment, quickly recognize obstacles and generate path planning. Meanwhile, in order to improve the user experience, it can be combined with a voice prompting system to inform the blind of the current environmental information and navigation guidelines in real time. This multimodal fusion can significantly improve the utility of the system and user satisfaction.

In addition, future research can further explore how to optimize path planning through machine learning algorithms, such as using reinforcement learning algorithms to provide the blind with optimal paths based on real-time environmental information. Meanwhile, the system can also combine other sensors (e.g., ultrasonic sensors, infrared sensors) to further improve the accuracy and reliability of navigation.

3.2 Communication Aids for the Deaf and Mute

For deaf people, wireless sensing technology can be used to communicate with others through gesture recognition and sign language interpretation. The WiHGR system proposed by Wei Meng's team utilizes WiFi signals, which are commonly found in the environment, and achieves robust gesture recognition through techniques such as sparse recovery, phase difference extraction, and recurrent neural network enhanced by attention mechanism. As shown in Table 1, the WiHGR system achieves recognition accuracies of 97%, 95%, 96%, and 98% for the four gestures (OK, fist, nod, and open palm) in the conference room scenario with an average of 96.5%, which outperforms all other methods. In the office scenario, the accuracy also reaches 96.3%. Especially for the OK and open palm gestures, which have a large amplitude of movement, the recognition rate is close to 100%. These results show that WiHGR is able to capture the WiFi signal changes caused by gestures with high accuracy and provide reliable sign language recognition for deaf people. As shown in Table 1.

Table 1. There cognition accuracies of all the gestures under the two testing environments [9].

Environment	Method	G-OK	G-Fist	G-Praise	G-Palm	Overall
Meeting room	WiGest	69%	64%	59%	71%	65.8%
	HMM	79%	62%	67%	72%	70.0%
	LSTM	89%	77%	76%	87%	82.3%
	GRU	85%	79%	74%	83%	80.3%
	ABLSTM	94%	88%	90%	97%	92.3%
	Proposed WiHGR	97%	95%	96%	98%	96.5%
Office room	WiGest	71%	62%	64%	73%	67.5%
	HMM	80%	68%	71%	74%	73.3%
	LSTM	90%	74%	78%	83%	81.3%
	GRU	88%	80%	73%	81%	80.5%
	ABLSTM	95%	89%	89%	94%	91.8%
	Proposed WiHGR	98%	96%	95%	96%	96.3%

Gesture recognition systems need to maintain high accuracy in a variety of environments, so data diversity is important. To achieve this goal, researchers can generate more diverse gesture data through data augmentation techniques to enhance the generalization ability of the model. In addition, migration learning techniques in deep learning can be combined to apply models trained in one environment to other environments, reducing retraining time and data requirements

3.3 Monitoring for Elderly and Mobility-Impaired Individuals

In the area of elderly disabled monitoring, it is used to monitor the daily activities and vital signs of the elderly, such as fall detection, respiration monitoring and heart rate monitoring. For example, WiFall system uses CSI amplitude changes to detect indoor falls, and has achieved good results. WiFall Due to the dramatic changes in the

instantaneous speed of the human torso, the WiFi signal propagation environment changes, and there will be an obvious Doppler effect on the CSI, according to which it can be determined whether a fall has occurred. Tensor Beat analyzes the time-frequency characteristics of the CSI, and the respiration rate in a single-person scenario Tensor Beat analyzed the time-frequency characteristics of CSI and estimated the respiration rate in a single-person scenario with an accuracy of 93% and an error of less than 0.5 breaths/min; the accuracy decreased in a multi-person scenario, but it was still 62% in a five-person scenario. In addition, using WiFi sensed human motion speed and posture asymmetry to recognize pain-induced protective behaviors, which is expected to be used for rehabilitation monitoring of disabled people [10].

4 Discussion and Optimization of Key Technologies

The key to wireless sensing technology lies in the effective data processing and feature extraction of the collected signals. Primary Component Analysis (PCA) and Short-Time Fourier Transform (STFT) are commonly used methods to extract the main features from complex signals and to improve the accuracy and efficiency of recognition.

In the process of data processing, it is also necessary to consider the effects of different environments on the signal. For example, in indoor environments, the signal is easily reflected and interfered by obstacles such as walls and furniture, so more complex denoising and filtering techniques are required. In addition, for feature extraction, nonlinear feature extraction methods can be further explored.

5 Challenges and Strategies in the Implementation of Technology

5.1 Environmental interference and noise

Wireless signals are susceptible to interference and noise from environmental factors during propagation, leading to a decrease in recognition accuracy. To solve this problem, multiple antenna configurations and filtering techniques can be used to reduce the impact of noise. For example, Forbes team used Kalman filtering in the system to eliminate low-frequency noise.

5.2 Recognition in multi-subject situations

In multi-subject environments, the activities of multiple individuals can interfere with each other, increasing the difficulty of recognition. To solve this problem, data enhancement and multi-target tracking techniques can be used. For example, more diverse CSI samples can be generated using data enhancement techniques to improve the robustness and adaptability of the model.

Multi-target tracking techniques can be used to achieve simultaneous recognition and tracking of multiple individuals by combining target detection and tracking

algorithms. For example, tracking algorithms such as Kalman filtering and particle filtering can be used in combination with deep learning target detection models to achieve accurate tracking and identification of multiple active individuals.

6 Conclusion

This paper provides an overview of the advancements and future prospects of wireless sensing technology in aiding individuals with disabilities. This innovative technology leverages the disruption of wireless signals, such as WiFi, by human motion to facilitate non-contact behavioral sensing. In the realm of disability assistance, it has promising applications,including aiding visually impaired individuals, facilitating communication for those who are deaf or mute, and monitoring elderly people with disabilities. These applications suggest potential for significantly enhancing the quality of life for disabled individuals by providing new modalities of assistance. Despite its potential, the practical deployment of wireless sensing technology encounters challenges such as environmental adaptability and the recognition of multiple persons simultaneously. Looking ahead, by fusing multiple sensing technologies and combining other sensing technologies such as vision, infrared, ultrasonic and WiFi sensing, by making the best use of strengths and avoiding weaknesses, a more comprehensive and accurate analysis of human behavior can be achieved.. For example, in the gesture recognition system, combining vision and WiFi signals can maintain high accuracy under different lighting and environmental conditions. In addition, the fusion of multimodal data can theoretical and practical advancements in this field evolve, it is expected that wireless sensory technologies will transition from laboratory settings into widespread public use, bringing the benefits of scientific innovation to improve the lives of those with disabilities. Here are the references formatted as requested:

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