Theory and Practice of Science and Technology
2024, VOL. 5, NO. 6, 69-73
DOI: 10.47297/taposatWSP2633-456910.20240506

Challenges in the Study of Robustness of Intelligent Wireless Positioning Systems in Complex Environments

Shihao Huang[1], Yang Zhang[1], Xianlei Tang[2], Xi Wang[2], Xiru Zhou[3]

[1]College of Information Science and Engineering, Shandong Agricultural University, Taian, Shandong, 271000, China

[2]School of Economics and Management, Shandong Agricultural University, Taian, Shandong, 271000, China

[3]School of Medicine, Wuhan City University, Wuhan, Hubei, 430000, China

ABSTRACT
This paper summarizes the main challenges of existing research. The importance of robustness research on intelligent wireless positioning systems for complex environments is self-evident. It is related to the effectiveness and reliability of positioning technology in changeable and challenging practical application scenarios. In summary, the robustness research on intelligent wireless positioning systems for complex environments is of great significance for improving the performance of positioning technology, enhancing system adaptability, improving user experience, promoting technological innovation and development, ensuring the security and reliability of key applications, and promoting industry standards and standardization.

KEYWORDS
Wireless positioning; Robustness; Complex environment; Research challenges

1 Introduction

Wireless positioning systems play a vital role in modern society, and their applications are extensive and penetrate into all aspects of daily life. Especially in complex environments, such as indoors, urban canyons, and mountainous areas, traditional positioning methods fail or their accuracy is greatly reduced due to factors such as building occlusion and terrain undulations. Therefore, it is particularly important to study and improve the robustness of wireless positioning systems in these complex environments. This can not only improve the efficiency and success rate of emergency rescue and disaster response, but also bring huge economic value to the business field, while meeting the needs of emerging technologies such as smart homes and unmanned driving.

In short, the application demand of wireless positioning systems in complex environments is urgent, and continuous research and innovation are needed to improve their performance and adaptability.

In modern society, the importance of wireless positioning systems is becoming increasingly prominent, and improving their robustness is even more important. Imagine that accurate location information can save lives during emergency rescue or disaster response; in daily life, it can make it easier for us to find our destination or enjoy the convenience of smart homes.

However, in complex environments such as indoors, in urban canyons or in mountainous areas,

problems such as multipath effects, non-line-of-sight propagation and electromagnetic interference often lead to reduced positioning accuracy or even system failure. Therefore, improving the robustness of wireless positioning systems means that they can remain stable and accurate in these challenges, which can not only improve our quality of life, but also save lives at critical moments. Such progress will also promote the application of wireless positioning technology in more fields and bring greater value to society.

2 The main impact of complex environment on wireless positioning system

2.1 Multipath effect

In indoor environment, multipath effect manifests as reflection, refraction and scattering of signals, affecting positioning accuracy and stability.

2.2 Non-line-of-sight propagation

In complex terrains such as urban canyons and mountainous areas, non-line-of-sight propagation leads to weakened signal strength and increased transmission delay, affecting the accuracy and reliability of positioning algorithms.

2.3 Electromagnetic interference

In urban environments, industrial areas and natural environments, electromagnetic interference will cause the stability of wireless positioning systems to decrease, increase bit error rate and positioning errors.

2.4 Dynamic changes in the environment

The position, number and state of objects in the wireless signal propagation environment change over time, such as personnel movement, object occlusion and weather changes. These changes will affect the propagation path and characteristics of the signal, resulting in a decrease in the stability and accuracy of the positioning system.

3 Research challenges of the robustness of wireless positioning systems in complex environments

3.1 Modeling and compensation of multipath effects

In complex environments, wireless signals may encounter multiple obstacles, causing the signal to reach the receiver through multiple paths. This phenomenon is called multipath effect. Multipath effect causes phase change and time delay of the signal, thus affecting the positioning accuracy. How to accurately model and compensate for the impact of multipath effect on signal propagation is the key to improving positioning accuracy. Researchers need to develop more sophisticated models to describe multipath effects and design effective compensation algorithms to reduce their negative impact on positioning results.

3.2 Processing of non-line-of-sight propagation

In complex terrain (such as mountainous areas) or densely populated areas of urban high-rise

buildings, the signal may not be able to propagate in a straight line to the receiver, but arrives through reflection, refraction or diffraction. This non-line-of-sight propagation will cause signal strength attenuation and increased transmission delay, further affecting the accuracy of positioning. Developing effective algorithms to deal with the signal attenuation and delay problems caused by non-line-of-sight propagation is an important research direction to improve the robustness of positioning systems.

3.3 Electromagnetic interference suppression

Electromagnetic waves generated by other electronic devices may interfere with wireless signals, increase the noise level in the received signal, reduce the signal-to-noise ratio, and thus affect the accuracy of signal detection and decoding.

Studying how to maintain the accuracy of signal detection and decoding in a strong electromagnetic interference environment is the key to improving the performance of wireless positioning systems. This may require the development of new signal processing techniques and anti-interference algorithms.

3.4 Hardware performance improvement

Design and optimize hardware equipment so that it can provide stable and reliable performance in complex environments. This includes selecting suitable antenna types, improving the sensitivity of receivers, and enhancing the anti-interference ability of equipment. In addition, the power consumption and cost-effectiveness of the hardware need to be considered to ensure the practicality and economy of the system.

3.5 Algorithm optimization and real-time performance

Improving robustness often requires more complex algorithms, which may increase the computational burden and real-time requirements, affecting the real-time response capability of the system. Therefore, researchers need to optimize the algorithm to improve computational efficiency and reduce latency while ensuring positioning accuracy. This may require the use of technical means such as parallel computing and distributed processing.

3.6 Dynamic environmental adaptability

Factors such as personnel movement, object occlusion, and weather changes can cause changes in the propagation characteristics of wireless signals, making it difficult for positioning systems to adapt to these rapidly changing environmental conditions.

Improving the system's adaptability to dynamic environments is the key to ensuring positioning stability and accuracy. This may require the development of adaptive algorithms and dynamic adjustment mechanisms.

3.7 Data collection and processing efficiency

In fingerprint positioning technology, it takes a lot of time and resources to establish and maintain a location fingerprint database. Improving data collection and processing methods and reducing maintenance costs are important research directions for improving the practicality of fingerprint positioning technology. This may require the use of efficient data acquisition technology and intelligent data processing algorithms.

3.8 Security enhancement

With the development of technology, the security of wireless positioning systems has also become an important consideration. Strengthening the security design of the system and preventing potential security threats and attacks is the key to ensuring system reliability and user privacy. This may require the use of security measures such as encryption technology and access control mechanisms.

3.9 Interdisciplinary integration

Combining knowledge from multiple fields such as signal processing, machine learning, and computer vision to improve the overall performance of the system. For example, using machine learning algorithms for pattern recognition and prediction can improve the accuracy and robustness of positioning; using computer vision technology for scene understanding and analysis can help the system better adapt to complex environments.

3.10 Standardization and compatibility

Promote the formulation of industry standards and improve the compatibility and interoperability between different systems. This will help promote the widespread application and development of technology, reduce user costs and technical barriers, and at the same time, help form unified technical specifications and evaluation standards to promote the healthy development of the industry.

4 Strategies to improve the robustness of wireless positioning systems

4.1 Multipath effect suppression

Use advanced signal processing technologies, such as Kalman filtering and particle filtering, to suppress the errors caused by multipath effects.

4.2 Non-line-of-sight propagation compensation

Use multi-source information fusion technology, such as deep learning models, to compensate for signal attenuation and transmission delay caused by non-line-of-sight propagation.

4.3 Electromagnetic interference suppression

Use spectrum sensing and interference elimination technology to reduce the impact of electromagnetic interference on signal detection and decoding.

4.4 Adaptation to dynamic changes in the environment

Use adaptive filtering and data fusion technology to enable the system to adapt to dynamic changes in the environment.

5 Conclusion and Outlook

This paper summarizes the main challenges of existing research. The importance of robustness

research on intelligent wireless positioning systems for complex environments is self-evident. It is related to the effectiveness and reliability of positioning technology in changeable and challenging practical application scenarios. In summary, the robustness research on intelligent wireless positioning systems for complex environments is of great significance for improving the performance of positioning technology, enhancing system adaptability, improving user experience, promoting technological innovation and development, ensuring the security and reliability of key applications, and promoting industry standards and standardization.

The research on the robustness of intelligent wireless positioning systems for complex environments is an evolving field with broad research directions and room for improvement. Future research should focus on developing more efficient algorithms, enhancing the adaptability of the system to complex and changing environments, integrating multi-source information to improve positioning accuracy and reliability, strengthening anti-interference and safety mechanisms, promoting industry standardization, optimizing energy efficiency, and innovating application scenarios to meet the growing technical needs.

Funding

National College Student Entrepreneurship Training Project, Project No.: 20241043029X

About the Author

Shihao Huang, Shandong Agricultural University, Electronic Information Science and Technology; Yang Zhang, Shandong Agricultural University, Artificial Intelligence; Xianlei Tang, Shandong Agricultural University, Agricultural and Forestry Economics and Management; Xi Wang, Shandong Agricultural University, Agricultural and Forestry Economics and Management; Xiru Zhou, Wuhan City College, Nursing.

References

[1] Nebojsa B , Marko S , Nebojsa B , et al. SMART WIRELESS HEALTH CARE SYSTEM USING GRAPH LSTM POLLUTION PREDICTION AND DRAGONFLY NODE LOCALIZATION[J]. Sustainable Computing: Informatics and Systems, 2022, (prepublish):100711-.

[2] Patil S ,Banerjee S ,Tallur S .Smart structural health monitoring (SHM) system for on-board localization of defects in pipes using torsional ultrasonic guided waves[J].Scientific Reports,2024,14(1):24455-24455.

[3] Tiantian Y , Ruping W . Design and implementation of a smart elderly positioning management system based on wireless communication network[J].EURASIP Journal on Wireless Communications and Networking,2021,2021(1):

[4] Robotics; Studies from NTUST Reveal New Findings on Robotics (Detection, Localization and Analysis of Oil Spills in Water Through Wireless Thermal Imaging and Spectrometer Based Intelligent System) [J]. Journal of Robotics & Machine Learning,2019,

[5] Machine Learning - Intelligent Transportation Systems; Findings from Beihang University in the Area of Intelligent Transportation Systems Reported (A Wireless Localization Algorithm With Bpnn-mea-qpso for Connected Vehicle)[J]. Telecommunications Weekly,2019,

[6] Technology; Data on Ambient Intelligence and Humanized Computing Described by Researchers at University of Naples (Calibration-less indoor location systems based on wireless sensors)[J].Telecommunications Weekly,2015,

[7] Broadcom Corporation; Brcm Wireless and Connectivity; Broadcom Announces Industry's First GNSS Location Hub for Smartphones to Support Galileo Satellite System[J].Telecommunications Weekly,2014,

[8] Kamalakannan K , Subashini S . Global Positioning System Assisted Intelligent Wireless Video Processing and Monitoring Systems Using Mobile[J].Research Journal of Information Technology,2013,5(4):118-120.

[9] Renganthan.B ,Vinothini.K ,Chinnadurai.S .A Smart Wireless Home Maneuver for Indoor Blind Pedestrians via Indoor Positioning System[J]. International Journal of Innovative Technology and Exploring Engineering (IJITEE), 2013, 2(4): 245-248.