Analysis on Characteristics of Indoor Wireless Positioning inside Large Cruise Ships

Ziheng Zhang, Dening Song* and Jinghua Li

College of Mechanical and Electrical Engineering, Harbin Engineering University, 150001, China

*Corresponding author's e-mail: songdening@hrbeu.edu.cn

Abstract. As a representative of modern tourism equipment, large cruise ships have huge internal spaces and complex structures, providing tourists with rich and diverse entertainment activities and living spaces. Positioning inside the large cruise ships is significant for improving the efficiency of cruise management, ensuring the safety of tourists, and improving the service quality onboard. However, the particularity of the internal environment of cruise ships, comparing with that of the common indoor environment and the outdoor environment, makes it difficult for routine positioning methods to apply. Therefore, this article aims to comprehensively explore the characteristics of the indoor positioning on large cruise ships, and summarized four unique specialties of the cruise-ship onboard positioning, which provides guidance for developing the onboard positioning algorithms.

Keywords: large cruise ships; indoor positioning; wireless location

1 Introduction

In the 21st century, the tourism industry has become an important force to promote economic development, and large cruise tourism is among the bright pearls. As an important part of the high -end tourism market, large cruise ships not only provide tourists with a comfortable living environment and rich entertainment activities. It also allows tourists to appreciate the scenery and culture from all over the world through its unique navigation trajectory and stopping sites. However, with the increasingly complex space inside the cruise ship and the diversification of tourist needs, how to provide tourists with more convenient and efficient services has become an important challenge for the cruise industry.

Indoor positioning technology, as an emerging technical means, can achieve precise positioning of the targets in the indoor space through wireless signals, sensors and other methods. On large cruise ships, the application of indoor positioning technology can not only provide tourists with personalized navigation services, help them quickly find their destinations and enjoy various services, but also provide real -time tourist distribution information for cruise managers, which will help Improve the safety and operating efficiency of cruise ships. However, the indoor positioning technology on large

G. Zhao et al. (eds.), *Proceedings of the 2024 7th International Symposium on Traffic Transportation and Civil Architecture (ISTTCA 2024)*, Advances in Engineering Research 241,
https://doi.org/10.2991/978-94-6463-514-0_21

cruise ships does not happen overnight. The complex spatial structure, changing signal communication environment, and the diversity of tourist needs have brought many challenges to the application of indoor positioning technology. Therefore, in -depth analysis of the characteristics of the indoor positioning technology of large cruise ships, and exploring its advantages and limitations in practical applications, which is of great significance to promote the further development of the technology.

At present, indoor positioning technology has been widely used in many areas, but the application in the special scenario of large cruise ships is still in the exploration stage. Due to the complexity of the internal space structure of the cruise ship, the particularity of the signal communication environment, and the diversity of tourist needs, the application of indoor positioning technology on the cruise ship is facing many challenges. This article will conduct in -depth analysis of the characteristics of large -scale indoor positioning technology, and discuss from various aspects such as technical principles, application scenarios, and practical challenges. By comparing the advantages and disadvantages of different positioning technologies, we will strive to reveal the complexity and particularity of the indoor positioning of large cruise ships, and provide useful reference and revelation for future technical research and application.

2 Literature Review for Indoor Positioning

The indoor positioning technology of the cruise ship is mainly implemented based on a variety of technical principles such as wireless signal transmission, sensor technology, and image processing. Specifically, including Wireless Local Area Network (WLAN), Bluetooth Low Energy (BLE), Ultra-Wide Band (UWB), Inertial Measurement Unit (IMU), Radio Frequency Identification (RFID), Geomagnetic, Ultrasound, etc. [1] These technologies can measure the precise calculation of the target position by measuring the dissemination time, strength, and angle of the wireless signal, combined with the map information of the cruise. This section will analyze the application of these technologies in the cruise scene one by one.

2.1 Wireless Local Area Network (WLAN)

WLAN positioning technology has the advantages of convenient installation, flexible use, economic conservation, and easy expansion. However, WLAN technology uses radio frequency signals as the transmission medium of service data, which makes it easy for attackers to eavesdrop on and tamper with the service data transmitted in the wireless channel [2]. In addition, WLAN technology is greatly affected by Non-Line-of-Sight (NLOS) and relatively low accuracy. Therefore, WLAN technology can be used for indoor positioning in cruise ships, but it needs to be optimized for NLOS and network security.

2.2 Bluetooth Low Energy (BLE)

The range-based BLE indoor positioning system is simple and easy to operate, the price

is low, and the power consumption is low. However, it is easily affected by indoor complex environment, and different material obstacles are different from the paths caused by signals [3]. At present, some scholars have proposed the Bluetooth -based indoor positioning technology for the ship scene, but the requirements of the algorithm are very high. In practical applications, try to avoid the appearance of the obscuration.

2.3 Ultra-Wide Band (UWB)

The indoor positioning accuracy of UWB technology is on the order of 10cm, and the anti-interference ability is strong, and it will not conflict with the existing radio frequency system. The positioning principle of the UWB sensor ranging technology is shown in the Figure 1. The distance between the anchor points and the target by measuring the signal dissemination time between the anchor point and the target is measured. In the two -dimensional plane, at least three distance circles are required, and the radius is R1, R2 and R3, so that the three circles are in the only point, which produces the only position estimation result. But it should be noted that the three anchor points cannot be located on the same straight line.

However, the cost of UWB base station is high, and other cheap positioning technologies should be preferred in situations where the positioning accuracy is not high [1]. It can also be used for multi-source data fusion with other technologies to reduce the overall hardware cost when the positioning accuracy is required.

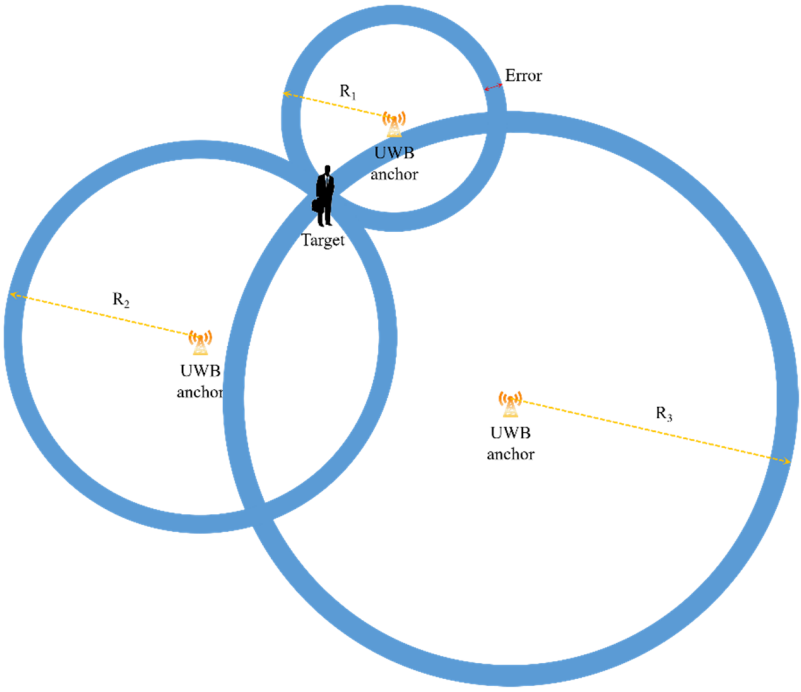


Fig. 1. The positioning principle of the UWB sensor ranging technology.

2.4 Inertial Measurement Unit (IMU)

IMU is a device that measures the attitude Angle (or angular rate) and acceleration of the object in three axes. It has the characteristics of high stability and is not affected by the surrounding environment [4]. However, IMU will produce a large cumulative error over time, coupled with the error of gait judgment and step calculation, so that the inertial positioning system cannot work accurately for a long time. Therefore, it needs to be used together with other sensors for multi-source data fusion to correct the accumulated error of IMU.

2.5 Radio Frequency Identification (RFID)

RFID mainly depends on the signal strength between the label and the reader, but within the large cruise ship, due to the complex structure and the changing signal transmission path, the signal is attenuation and interference, which affects the accuracy of the positioning. Especially in the case of a large number of metal structures and electronic devices in the cruise ship, the spread and receiving of the RFID signal may be severely disturbed, resulting in a decrease in positioning accuracy. Secondly, RFID technology is not specifically used to solve the problem of positioning, and its action distance is limited to about one meter. Although the price of a single label is cheap, there is huge space inside the large cruise ship and requires a large number of readers. Therefore, RFID has lost its low price, but it can be combined with IMU technology to correct its cumulative errors at key nodes.

2.6 Geomagnetic

Geomagnetic navigation offers the advantages of negligible cumulative error and robust anti-interference capability [5]. The geomagnetic positioning technology depends on the strength and distribution characteristics of the geomagnetic field to achieve positioning. Nevertheless, within large cruise ships, due to the existence of hull structure, metal material, and various equipment, indoor magnetic fields may be severely interfered and distorted. This interference will cause the ground magnetic field distribution to become complex and unstable, making it difficult for the geomagnetic positioning technology to accurately measure and identify the characteristics of the magnetic field, which affects the accuracy of the positioning. In addition, as a cruise ship operates on water, which lacks a definite ground coordinate system, the applicability of geomagnetic positioning techniques in such scenarios is limited.

2.7 Ultrasound

Ultrasonic has good physical characteristics. It is not sensitive to external light and electromagnetic fields, low cost, and easy to achieve [6]. It is a very widely used positioning method. However, it is easily affected by the NLOS and multi -diameter effects, which can only be applied to LOS. Secondly, compared with radio waves or light waves, the transmission speed of ultrasonic waves is slow, which may lead to a long

position response time. In large cruise ships, a fast and accurate positioning response is essential for safety management and operational efficiency. Therefore, the response speed of ultrasonic positioning technology may not meet the actual needs of the cruise ship.

The common indoor positioning technologies and their characteristics are shown in the Table 1.

Table 1. Common indoor positioning technologies and their characteristics.

Indoor Positioning Technologies	Advantages	Applicability
WLAN	Mature technology Easy to operate Low cost No additional hardware is required	Middle
BLE	Easy to operate Low cost Low-power consumption	High
UWB	Strong anti-interference ability High accuracy High stability	High
IMU	Wide application Easy to operate Low cost High stability	Middle
RFID	Low cost Easy to deploy High positioning accuracy	Low
Geomagnetic	Low cost Energy saving No cumulative error	No
Ultrasound	Mature technology High accuracy Anti-interference	Middle

3 Special Characteristics Analysis for Indoor Positioning on Cruise Ships

3.1 Material and Multipath Effect

First of all, unlike the ordinary indoor environment with most structures in concrete, the shot of the ship, the deck and other parts are made of metal [7]. This hull material

has higher reflection capacity than the signal. The energy of losses is relatively small. Therefore, the signal energy transmitted along the reflection path is increased compared to the ordinary indoor environment. As the signal energy changes, the signal power will change accordingly. Therefore, the signal transmission of reflex path transmission in the ship environment remains a high sex ratio, making the positioning system cannot accurately identify the LOS path.

Furthermore, in the ordinary indoor environment, the signal will only be reflected by the surface of the wall, the NLOS path is relatively single, and during the continuous transmission of the signal, the NLOS path is basically consistent. In the internal environment of the cruise ship, because its special metal environmental signal will pass through a single reflection of the wall, multiple reflexes between the walls, and multiple reflexes inside the metal cabin to produce three special NLOS paths inside the walls. The multipath error becomes more serious (As shown in Figure 2). Moreover, the height of the deck of the ship is generally lower than the general environment. This also causes the probability of receiving the reflex path to receive the receiver.

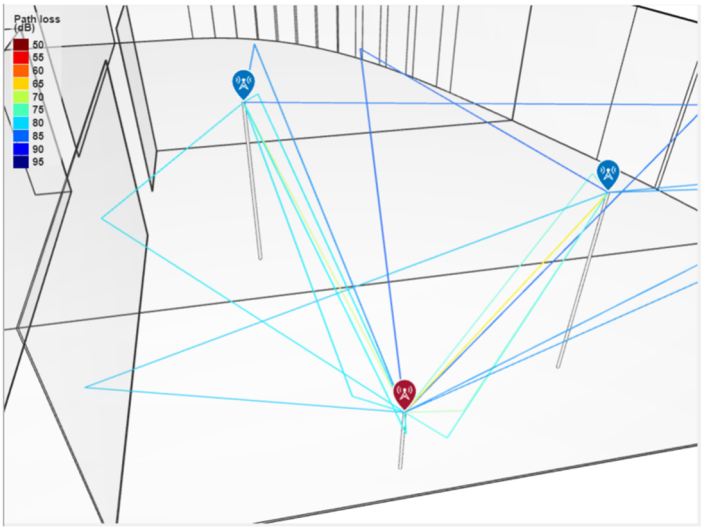


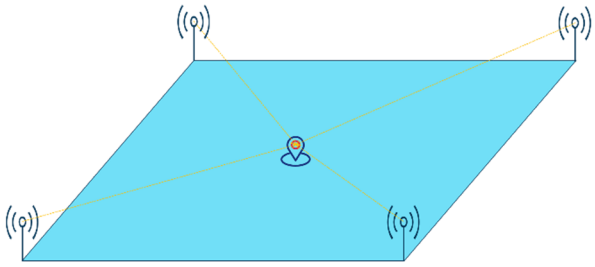
Fig. 2. The multipath effect inside the cruise ship.

3.2 Deformation and Vibration

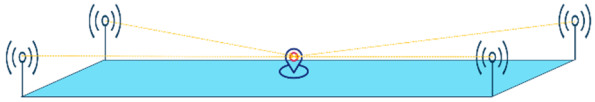
Then, compared with the static indoor environment, the ship will drive at different speeds [8]. During the navigation process, the hull is vulnerable to the inevitable deformation caused by external forces such as cargo accumulation, waves, or ambient temperature changes, resulting in deformation of the hull. The vibration caused by factors such as ship movement, waves of waves, engines and propeller operation will cause dynamic angle changes of up to 1° ~ 1.5°. These deformations will cause the transmission path of the signal to change, resulting in a decrease in the accuracy of the indoor positioning system.

3.3 The Layout of Positioning Base Station

Last but not least, due to the limitation of the volume and shape of the cruise ship, there is a large amount of narrow space inside the cruise, which seriously limits the layout of the positioning base station. This leads to a large difference in positioning effects between different base station layout methods (As shown in Figure 3(a) and Figure 3(b). If the base station layout method in conventional indoor positioning is still used, the accuracy of the positioning system will be seriously affected.



(a)



(b)

Fig. 3. The layout of the positioning base station in the common space (a) and narrow space (b).

4 Solution Strategies Towards Onboard Indoor Positioning

This chapter will propose the corresponding solution strategies for the characteristics of the indoor positioning of the large cruise internal in the third chapter, and provide feasibility recommendations for privacy protection issues and personalized services related to the internal positioning technology of the cruise ship.

4.1 Noise Reduction Algorithm and Filter

Multi-signal classification algorithm (MUSIC) is usually used in the indoor positioning system to reduce the noise in the receiving signal. This algorithm has a good application effect in an environment with a high signal noise or noise. The hull material, the cabin structure, the noise variance is high and unstable, and the MUSIC algorithm is difficult to accurately separate the noise. In order to make the positioning system achieve better results in the ship environment, the receiving signal should be used to filter the receiving signal to reduce the interference of noise, or it should be used in an environment with a low signal -to -noise ratio. The improvement algorithm is separated from the

noise in the receiving signal and improves the accuracy of the positioning system. Lin et al used Self-Learning Mean Optimization Filter (SLMOF) to find the best elevation and azimuth angles [9], which improved the accuracy of the Bluetooth 5.1 Angle of Arrival (AOA) indoor positioning. This method is 72% more accurate than the Kalman Filter (KF).

4.2 Machine Learning Algorithm and Multi-Source Data Fusion

During the navigation process, the ship will cause variation, vibration and swing due to the impact of water flow, temperature and humidity, and uneven heating. This complex and real -time indoor structure dynamic changes usually do not occur in the indoor structure of the land environment. At present, the impact of dynamic changes in the indoor environment on the positioning system has less studies, and the use of existing methods in the ship environment will produce large errors. In order to reduce the impact of hull deformation and vibration, so that the positioning system can maintain a better effect in the ship environment, it is recommended to arrange monitoring equipment on the ship to monitor the motion status, elevation angle, deformation, and tilt of the ship in real time. The influence parameters of the movement are performed online and estimated to obtain the relationship between the state of the ship's motion and the positioning system, so that the positioning system can make adaptive positioning in a dynamic environment generated by the ship's movement. In addition, the advantages and disadvantages of various sensors can be complemented by combining the data of various positioning sensors (such as IMU, Wi-Fi, BLE, UWB, etc.) through multi-source data fusion technology, so as to achieve the effect of "1+1 > 2" and improve the stability and accuracy of the positioning algorithm. Ju-Hyeon Seong et al. proposed a positioning technology that combines Wi-Fi fingerprint and ultra-broadband (UWB) technology to the ship environment [10]. Compared with traditional methods, this method has increased the update of wireless maps by 11.87% on the basis of achieving high-precision positioning.

4.3 Positioning Base Station Layout Optimization

Due to the large number of narrow space inside the large cruise ship, the use of intelligent algorithms to optimize the base station layout scheme in the narrow space, which can significantly improve the positioning effect of the positioning system inside the cruise. Pan et al. proposed a UWB base station layout optimization method based on indoor scenes [11], using a heuristic differential evolution algorithm to search for the optimal base station location.

4.4 Privacy Protection and Personalized Services

Although the indoor positioning technology of the cruise ship has broad application prospects, it still faces some challenges. First of all, the particularity of the internal environment of the cruise makes the design and implementation of positioning technology more difficult. The internal space of the cruise ship is complex and varied, and

there are a large amount of obscuration and reflex surface, which causes interference to the spread of wireless signals. Secondly, how to ensure the privacy and security of positioning data is also an urgent problem. In the process of collecting and processing the positioning data, corresponding encryption and anonymous measures need to be taken to protect the privacy rights of tourists and employees. In addition, with the development of the cruise industry and the continuous changes in tourist needs, the performance and requirements of indoor positioning technology are also increasing, which has put forward higher requirements for technology research and development and innovation.

In the future, the indoor positioning technology of the cruise ship will pay more attention to the integration and innovation of multiple technologies. By comprehensive use of wireless signals, sensor data, image processing and other technical means, the positioning accuracy and stability are improved. At the same time, with the continuous development of the Internet of Things, big data, artificial intelligence and other technologies, indoor positioning technology will be combined with these technologies to achieve more intelligent and automated management and services.

With the continuous increase of tourists' demand for personalized services, the indoor positioning technology of large cruise ships will pay more attention to providing personalized and customized service experiences. Through in-depth analysis of the behaviour and preferences of tourists, provide tourists with precise service recommendations and customized travel suggestions.

In the process of collecting and processing positioning data, the indoor positioning technology of cruise ships will pay more attention to privacy protection and security issues. By strengthening measures such as data encryption and anonymity, the privacy rights of tourists and employees are effectively protected. At the same time, establish a comprehensive security management mechanism and emergency plan to improve the anti -attack capability and fault tolerance of the indoor positioning system.

5 Conclusion

Large cruise indoor positioning technology has unique characteristics and application value. Through in-depth research on its technical principles, application scenarios, and challenges facing, we can provide strong technical support for the development of the cruise industry. In the future, with the continuous advancement of technology and the continuous expansion of application scenarios, the indoor positioning technology of the cruise will play a more important role in improving management efficiency, ensuring the safety of tourists, and improving tourist experience. At the same time, we also need to pay attention to the double -edged sword effect of technological development. While enjoying the convenience and benefits brought by technology, we will strengthen the supervision and management of privacy protection and security, and ensure the healthy development of technology and the maximum social value.

Acknowledgement

This research is funded by the Natural Science Foundation of Hainan Province (Grant number 624MS082), and the Ministerial Civil Ship Research Project of China (Grant number 2019331).

References

1. Kegen Y, Ian Sharp, Y Jay Guo Ground-Based Wireless Positioning. 2012. John Wiley & Sons Ltd. Publishing, The Hoboken.
2. Xia Zhou (Huawei Technologies Co., Ltd). (2022) What is WLAN? https://info.support.huawei.com/info-finder/encyclopedia/zh/WLAN.html.
3. Wang Minmin, Yang Lan, Wang Jian (2024) BLE Favorite Factors Evaluation and Analysis. Navigation Positioning Journal, 1-10.
4. Yuan Guoliang, Xie Kui. Research on WiFi-assisted IMU indoor positioning Method. Information Technology and Network Security, 2018, 37 (05): 62-65+70.
5. Kong Weixiao, Huang Kang, LI Weiqiang, et al. Review of the research status of indoor geomagnetic positioning. Metallurgical Management,2023(07):69-71.
6. Hu Senkang, Xu Zheng, Liu Wei, Shi Qingfan. An Accurate Ultrasonic Positioning System. Physics and Engineering, 2021, 31 (01): 120-123
7. Wang Guoyu, Liu Kezhong, Chen Mozi, et al., Analysis of the influencing factors of the ship carrier in the corner of the signal -based arrival angle. Journal of Dalian Maritime University,2020,46(04): 24-31. DOI: 10.16411/j.cnki.issn1006-7736.2020.04.004.
8. Jiang Guangwen, Fu Sihua, Chao Zhichao, et al. Pose-relayvideometrics based ship deformation measurement sys-tem and sea trials. Chinese Science Bulletin, 2011, 56(1):113-118.
9. Lin Q, Son J, Shin H. A self-learning mean optimization filter to improve bluetooth 5.1 AoA indoor positioning accuracy for ship environments. Journal of King Saud University - Computer and Information Sciences, 2023, 35(3): 59-73.
10. Seong J-H, Choi E-C, Lee J-S, et al. High-Speed Positioning and Automatic Updating Technique Using Wi-Fi and UWB in a Ship. Wireless Personal Communications, 2016, 94(3): 1105-21.
11. Pan H, Qi X, Liu M, et al. Indoor scenario-based UWB anchor placement optimization method for indoor localization. Expert Systems with Applications, 2022, 205.