A Review of Indoor Location Methods

Haolun Jiang(✉)

Qingdao No.2 Middle School, Qingdao 266061, Shandong, China
James.mail_526@qq.com

Abstract. Aiming at the current common mainstream indoor positioning, this paper summarizes the basic positioning principles of WIFI, Bluetooth, UWB, inertial navigation, and visual SLAM methods respectively, and analyzes the possible problems and defects of each positioning method in specific different situations, and lists the corresponding countermeasures. And compares different methods, summarizes the corresponding advantages and disadvantages.

Keywords: Indoor location · advantages and disadvantages · GPS

1 Introduction

With the progress of human society, people are more and more concerned about their precise location information, human activities can be divided into two parts: indoor and outdoor. In cases such as daily travel and unfamiliar places, we are able to find the exact location with the help of GPS (Globel positioning system), Beidou, and other outdoor positioning technologies under the navigation, greatly reducing the time to find unfamiliar places. With the development of the IoT industry, indoor positioning has gradually become an immediate need, with greater market opportunities in industries such as retail, catering, logistics, manufacturing, petrol, electricity, and healthcare.

However, indoor environments are complex, and as satellite signals are easily blocked, they are not suitable for use indoors or in complex situations where there are many tall buildings, thus requiring higher requirements for positioning technology applications. There are currently seven main types of indoor positioning technologies (Table 1).

2 Research on Bluetooth Based Indoor Positioning

It is one of the most commonly used techniques to achieve indoor signal positioning, with the advantage of relatively low hardware costs and easy access to signal strength. RSSI (Received Signal Strength Indication) based positioning techniques can be broadly classified into two categories: one is based on signaling. The other is fingerprint-based positioning techniques. The localization technique based on signal propagation is mainly based on the strength of the terminal signal in propagation for attenuation. As the strength of the received signal varies with the expansion of the distance between the terminal and

© The Author(s) 2023
N. Akhtar et al. (Eds.): PMIS 2023, AHIS 8, pp. 613–621, 2023.
https://doi.org/10.2991/978-94-6463-200-2_63

Table 1. Comparison of common indoor positioning methods

Technology	Accuracy	Advantages	Disadvantages
WI-FI	2-50 m	Easy to install, high total system accuracy	Large feature library build-up, influenced by other signals, needs calibration
UWB	6-10 m	Good penetration, high accuracy	low power consumption High cost
SLAM vision	1 cm-1 m	Low environmental dependence	High cost, low stability
Inertial navigation	5-10 m	Low environmental dependence	High cumulative error, requires calibration
Bluetooth	2-10 m	Low power consumption, easy to integrate	Short range, poor stability, susceptible to noise interference

the AP (Access Point) showing a certain attenuation, the RSSI between the nodes at different terminal locations and different APs are measured to accurately estimate and accurately determine the distance between them and the AP, and then The nodes are then implemented using the principle of trilateral positioning. However, the electromagnetic properties are complicated in indoor environments due to the variation in path attenuation caused by reflections from walls, furniture, and floors. Therefore, although the system is simple to use this RSSI method for fingerprint ranging, the accuracy of the fingerprinting positioning in the user's surroundings is easily affected by the strength of the surroundings, resulting in poor positioning accuracy of 3–7 m. In addition, the other common fingerprint positioning automatic technology based on the strength of the user's fingerprint positioning signal is the Microsoft fingerprint signal positioning automatic technology, the continuous changes in the working environment will certainly still directly affect the fingerprint database in the RSSI, so in this fingerprint database still need to constantly update its technology, at the same time the maintenance of this fingerprint database is also already very need to spend a lot of time and human costs, so The operation of the fingerprint database based on location recognition technology is already subject to serious technical limitations in terms of its practicality [1].

Although Bluetooth technology has the characteristics of low power consumption, low cost, miniaturization, and high universality, the existing system equipment on the market have problems such as complexity, high positioning delay, poor positioning accuracy, and poor versatility. The theoretical positioning accuracy is improved by using the relationship between the two-dimensional angle of the signal and the geometric position to achieve more accurate positioning.

3 Research on WI-FI Based Indoor Positioning

In today's world of smartphones, WiFi is almost a standard feature of smartphones. Users use WiFi for positioning, which not only displays a map of the user's location but also enhances the playability of various social networks, so we have the potential for WiFi to become one of the most common indoor positioning technologies for civilian use in the future [2] (Fig. 1).

The first is for static signal processing techniques. The advantage of this method is that the number of signals collected can be increased to improve the accuracy of the processing, but the disadvantage is that the collection time is long and real-time positioning cannot be achieved. How to improve the accuracy of processing without a long acquisition time has become a key issue for static signal processing methods. There are currently two main types of processing techniques for dynamic signals: the mean-value model method and the low-slope model method. The mean interference model is designed to reduce errors in small probability signal values by extracting an average value for each signal parameter obtained from the analysis of the acquisition data as a basis for estimating the interference strength of each signal. The Gaussian model approach uses a Gaussian model to filter the signals with high probability and then applies an average value to the most likely large and small probability emission signals. By comparing the mean Bell model with the Gaussian model we can directly conclude that the Gaussian model is superior. However, using a Gaussian model to describe the distribution of a signal in an indoor environment is inaccurate [3]. When the system needs to move in real-time, if the RSSI signal takes a long time to process, it will not be able to keep up with the movement speed, resulting in position misalignment, which can produce a large positioning error. Therefore, a second Wi-Fi-based RSSI positioning method was born. The dynamic RSSI signal processing method is a positioning method proposed for mobile positioning. It has the advantage of good real-time performance, but its positioning accuracy is not enough, how to improve the accuracy is its current main challenge, existing processing methods such as mean filtering method, Kalman filtering, etc. [4, 5].

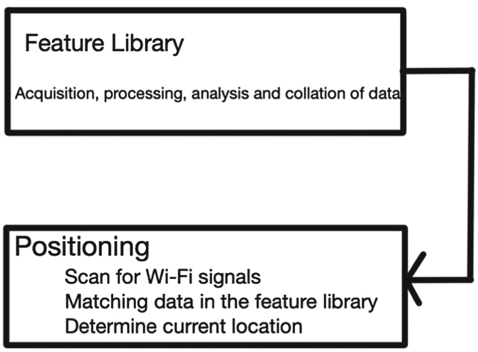

Fig. 1. Wi-Fi location framework

4 UWB-Based Indoor Positioning Research

UWB automatic positioning system technology is not only a kind of indoor automatic positioning system technology, but it is also an innovative technology with a broad development prospect in today's indoor automatic positioning system technology, and it has several characteristics such as strong system penetration, low power consumption, good resistance to multipath interference, high security, low system operation complexity, and the ability to provide accurate and fast positioning system accuracy for the highest number of customers. [6] Therefore, UWB object location tracking technology has been widely used indoors for stationary or free directional movement of any object and anywhere else to achieve object location data tracing and object navigation for everyone, and this can provide our people with very accurate object location data [7].

The detection method used in UWB positioning technology is TOF (Time of Flight) ranging, which is a one-way ranging technique that uses a pair of data signals to measure the space between two points by calculating the round-trip time of flight between a pair of transceivers. The time gap between the data signal received from the transmitter and the data signal received from the transmitter and the data signal received from the transmitter is recorded and the time gap between the data signal received from the receiver and the data signal received from the transmitter and the data signal sent from the receiver is recorded and the distance between the two is calculated. Finally, the position of the target to be measured is measured from the distance information of at least three base stations. [8] In the TOA (Time of Arrival) algorithm, each base station is used as the center of a circle, and the distance from the target to the base station is used as the circle. In the 3D case, more than four base stations are usually required, and these four base stations cannot be in the same plane, so each base station is used as the center of a sphere, and the intersection of the spheres is the position of the target to be measured in space [9] (Fig. 2).

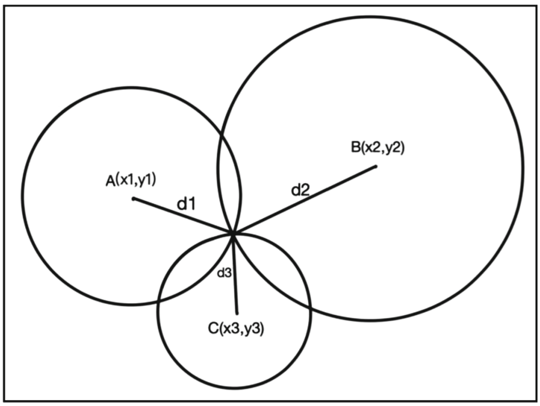

Fig. 2. Principle of TOA algorithm for localization technique in 2D case

5 Research on Indoor Localisation Based on SLAM Vision

Visual SLAM (simultaneous localization and mapping) is a continuous video stream that is analyzed by photographing the surrounding environment at a certain rate. In visual SLAM, different cameras can be used to implement SLAM, and there are three main types of cameras commonly used: monocular cameras, binocular cameras, and depth cameras [10].

The use of only one camera for SLAM is called monocular SLAM, which is of great interest to researchers because of the particular simplicity and low cost of this sensor architecture. However, it requires panning before depth can be calculated, as well as the inability to determine the true scale. Vision SLAM based on binoculars and depth cameras can measure the distance of an object from us and overcome the disadvantage that monoculars cannot know the distance. A binocular camera consists of two monocular cameras and the baseline of the distance between the two cameras is known. We can use this baseline to estimate the spatial position of each pixel. However, a binocular camera on a computer requires extensive calculations to estimate the depth of each pixel point. The disadvantages of a binocular or multi-vision camera are that it is complex to configure and calibrate, its depth range and accuracy are limited by the baseline and resolution of the binocular, and the computation of parallax is very computationally intensive, requiring acceleration using GPU and FPGA devices to output the distance information for the entire image in real-time. Therefore, the computational effort is one of the main constraints for vision SLAM based on binocular or multinocular cameras. The most important feature of depth cameras is that they can measure the distance of an object from the camera by actively emitting light towards the object and receiving the returned light through the infrared structured light or Time-of-Flight principle. By physically measuring the entire segment of the hand, a large amount of computation can therefore be saved compared to binoculars.

5.1 Introduction to the Classic SLAM Solution

With the boom in visual SLAM technology, the solutions are being optimized as the technology advances.

ORB-SLAM is by far the most sensor-complete visual SLAM system available, and it can be used with good results with monocular, binocular, and RGB-D cameras alike.ORB-SLAM is also the best-performing, most complete, and best-used of today's visual SLAM systems, and it can be used in both large and small scenes. The ORB algorithm can be described as The ORB algorithm can be considered an improvement on PTAM, using its architecture and optimizing on top of it. The whole ORB system is divided into three parts: tracking, map building, and loopback detection. In the tracking part, ORB features are extracted from the image and, after extraction, features are matched to the previous frame to give a rough estimate of the camera pose. It locates the camera by each frame of the image and chooses whether to add a keyframe or not. In the build section, new keyframes are processed and the reconstruction of the map is completed using the BA model. For the newly added keyframes, loopback detection is performed. ORB's loopback detection is excellent, effectively preventing cumulative errors and enabling rapid retrieval after loss, something that many existing SLAM systems are not perfect at. ORB-SLAM has some drawbacks, as the three parts of ORB-SLAM effectively solve the SLAM problem, but also impose a heavy burden on the CPU, which makes it difficult to port it to other devices, as it can only be used on PCs. It is difficult to port it to other devices. Despite this drawback, ORB has the obvious advantage of being able to perform visual SLAM on the PC.

6 Research on Indoor Positioning Based on Inertial Navigation

An inertial navigation system is an aided navigation system that uses motion sensors (accelerometers) and rotation sensors (gyroscopes) to measure the acceleration and angular velocity of an object and a computer to apply Newtonian mechanics to continuously estimate the position, altitude, and velocity of the moving object. It does not require an external reference system and is a stand-alone navigation technology. Inertial Navigation System (INS) uses measurements provided by accelerometers and gyroscopes to track the position and orientation of an object relative to a known starting point, bearing, and velocity. The Inertial Measurement Unit (IMU) typically contains three orthogonal rate gyroscopes and three orthogonal accelerometers that measure angular velocity and linear acceleration respectively. By processing the signals from these devices, the position and orientation of the device can be tracked (Fig. 3).

Specifically, the gyroscope measures the angular velocity of the sensor frame with respect to the inertial reference system. By using the original orientation of the system in the inertial reference system as the initial condition and integrating the angular velocity, the current angle of deflection relative to the initial condition can be obtained, so the current orientation of the system is always known [11]. By tracking the current angular velocity of the system and the current linear acceleration of the system measured relative to the moving system, the linear acceleration vector of the system in the inertial reference system can be determined. Combined with the deflection direction and deflection distance, the current heading, velocity, and position of the object frame can be readily and accurately known. Specifically, the accelerometer measures the linear acceleration of the sensor frame, but in a direction that can only be measured relative to the moving system. In turn, the inertial acceleration (using the original velocity as the initial condition) can be integrated using the correct kinematic equation to produce the inertial velocity of the system and integrated again (using the original position as the initial condition) to produce the inertial distance.

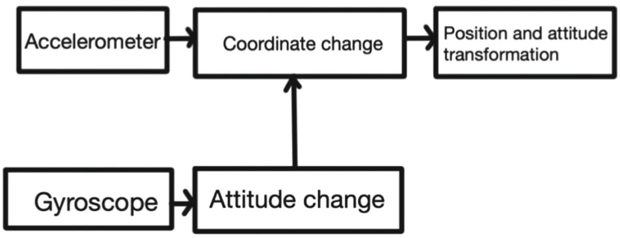

Fig. 3. Illustration of the inertial navigation positioning process

6.1 Walking Heading Projection

Voyage position projection is an effective method for position projection of pedestrians or moving objects. The method is based on the superposition of the previous moment's position phase and the change of position, which enables the current position of the target to be projected. The pedestrian heading projection uses the movement characteristics of pedestrians walking in stride, using inertial sensors to detect the walking pace and estimate the step length, and then calculates the displacement of the current position relative to the previous position based on the heading. This model does not require high sensor accuracy and has low computational complexity. The system first identifies whether a step is present by collecting the appropriate data; then estimates the step length based on the detected step data and estimates the direction of travel for that step, and so on and so forth, to achieve a heading projection for each step. The implementation of each known component is described next [12].

7 Conclusion

Location-based services are the basis for the construction of the Internet of Things and smart cities, and the existing Global Positioning System (GPS) cannot be effectively used in indoor environments, so indoor positioning technology has attracted a lot of attention from researchers.

Indoor positioning technology aims to solve the problem that existing satellite positioning systems (GPS, Beidou, etc.) cannot achieve positioning inside buildings, and helps to achieve continuous and seamless positioning and navigation services indoors and outdoors. China's Xixia Project has already conducted research on wide-area indoor and outdoor precise positioning and navigation technologies and has established a preliminary urban indoor and outdoor fusion positioning application system based on Beidou navigation system, mobile communication, Internet and satellite communication system, integrating wide-area real-time precise positioning and indoor positioning technologies. In the future, integrated indoor and outdoor navigation and positioning applications combined with the new generation of 5G communication technology will definitely become the mainstream direction of application development.

Indoor positioning technology has been widely used in many industry sectors. In terms of its functions, it can be generally divided into five main areas: indoor positioning tracking, indoor path navigation, indoor guided tour interpretation, indoor business promotion, and indoor behavioral pattern analysis. In terms of application areas, it mainly involves commercial, transportation, tourism, medical, education, and fire safety fields related to large buildings (such as airports, museums, hospitals, shopping malls, and car parks).

Indoor positioning applications in China are not yet widespread, and many are still in the laboratory research stage, making it difficult to balance cost and positioning quality. However, with the improvement of indoor positioning technology in terms of positioning accuracy and efficiency as well as the continuous reduction of cost, indoor positioning applications will be further popularised and developed in the direction of multi-field applications and multi-technology integration.

With the in-depth development and application of the Internet of Things, cloud computing, artificial intelligence, robotics, and wearable devices, indoor positioning technology, and its application are bound to be an essential part of the new generation of the information technology revolution. However, compared with outdoor positioning technology, indoor positioning technology has problems such as complex and diverse technologies, varying stability and accuracy, and conflicting costs and quality, on the one hand, and requires the support of indoor spatial models and maps with diversified contents and frequent updates on the other. The research on key technologies requires the establishment of rapid collection and updating of large-scale indoor maps, and the integrated representation of indoor and outdoor 2D and 3D maps.

References

1. Chen Young-guang, LI Xiu-he.Signal Strength Based Indoor Geolocation[J].ACTA ELECTRONIC SINICA,2004(09):1456–1458.Another reference
2. Ezhumalai Balaji, Song Moonbae, Park Kwangjin. An Efficient Indoor Positioning Method Based on Wi-Fi RSS Fingerprint and Classification Algorithm[J]. Sensors, 2021, 21(10):
3. Zhang Ming-hua. Research on WLAN-based Indoor Positioning Technology[D]. Shanghai Jiaotong University, 2009.
4. Luo Li. Research on WIFI indoor positioning technology based on Android [D]. Southwest Jiaotong University, 2014.
5. Sang N, Yuan X.C, Zhou R. An SVM classification and regression based approach for WiFi indoor localization[J]. Computer Application Research,2014,31(06):1820-1823.
6. Zhanjun Hao, Beibei Li, Xiaochao Dang, Filippo Cacace. A Method for Improving UWB Indoor Positioning[J]. Mathematical Problems in Engineering,2018,2018:
7. Tang L, Li Q. Research on UWB-based indoor positioning algorithm[J]. Industrial Control Computer,2017,30(06):103-104.
8. Zhang Zhongjuan. Research on indoor positioning technology based on UWB [D]. Tianjin University,2012.
9. Xianyue Zou, Anhang Wang, Shiyu Li, Shuai Wang. Research and Analysis on UWB Indoor Positioning System[J]. International Journal of Social Science and Education Research,2020,3(11):
10. Jiang Han. Research on visual indoor localization algorithm based on SLAM [D]. Harbin Institute of Technology,2020.
11. Wang Zihui, Cheng Xianghong. Adaptive optimization online IMU self-calibration method for visual-inertial navigation systems[J]. Measurement,2021,180:
12. Yue Zhang, Guoliang Yuan. Overview of Application Research on Inertial Navigation Unit [J]. International Core Journal of Engineering,2021,7(5):

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (http://creativecommons.org/licenses/by-nc/4.0/), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.