ISSN: 2664-9640

Overview of indoor positioning technology and algorithm

Ziqiang Qin[1], Ziwei Xiao[2]

[1] School of transportation, Chongqing Jiaotong University, Chongqing 400074, China;

[2] School of transportation, Chongqing Jiaotong University, Chongqing, China.

Abstract

In this paper, the commonly used algorithms and technologies in indoor positioning are introduced in detail, and the advantages and disadvantages of each technology are compared horizontally. Through research, the application progress of indoor positioning is analyzed, and the challenges faced by indoor positioning are discussed. Finally, the future development of indoor positioning technology is prospected.

Keywords

Indoor positioning; Positional information; Location technique.

1. Introduction

With the rapid development of the Internet, people's way of life has changed a lot, the demand for Location Based Service (LBS) is growing. Over the years, Global Navigation Satellite System (GNSS) has developed rapidly and its technology has gradually matured, which can meet the needs of users for LBS in outdoor open environment. However, in large shopping malls, underground garages, tunnels and other sheltered environments, GNSS signals are blocked by obstacles and difficult to achieve positioning. Therefore, indoor positioning has become the research and development focus of academia and industry. In the field of indoor positioning, the early research directions mainly focus on infrared positioning technology, ultrasonic positioning technology, radio frequency identification (RFID) positioning technology. Due to the continuous development of communication technology and electronic manufacturing technology, researchers have studied new technologies such as Bluetooth Low Energy (BLE) positioning technology, Ultra Wide Band (UWB) positioning technology and computer vision positioning technology. Indoor positioning can be used for building and safety management, medical monitoring systems, indoor navigation, disaster management, and personalized positioning services for events and retail[1].

This paper first briefly introduces the mathematical principle of the main indoor positioning technology, and then introduces the current mainstream indoor positioning technology in detail. Finally, the challenges faced by the development of indoor space positioning technology are discussed, and the main research directions in the future are prospected.

2. Indoor positioning Algorithm

2.1. TOA ranging method

TOA is the arrival time. The principle is to measure the signal arrival time difference ti, i = 1,2...n between the node U (x, y, z) to be located and the transmitter (x_i, y_i, z_i), where n is the number of transmitters involved in positioning. Assuming the measured transmission time is ti, the distance between the node to be located and the transmitter R_i = ti × c, c is the propagation velocity of electromagnetic wave in free space.After TOA ranging, the available location estimation algorithms are Taylor series algorithm[2], and improved Chan algorithm[3].

ISSN: 2664-9640

2.2. TDOA positioning algorithm

The TDOA method also transmits the same signal from the unknown node to multiple different reference nodes, and uses the arrival time difference to locate and calculate. The hyperbolic intersection point can be used to determine the location of the mobile station. This method only requires strict clock synchronization between the reference nodes, without accurate synchronization between the base station and the mobile station. The principle is shown in Figure 1.

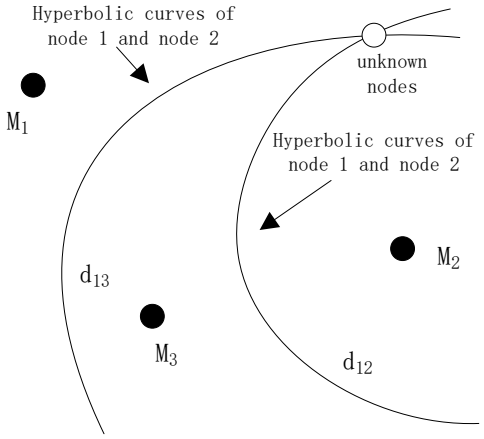

Figure 1: TDOA Principle

2.3. Multilateration

Multilateral positioning method determines the position of the target by measuring the distance between the target to be measured and the known reference point. In two-dimensional space, three edges can determine the position.

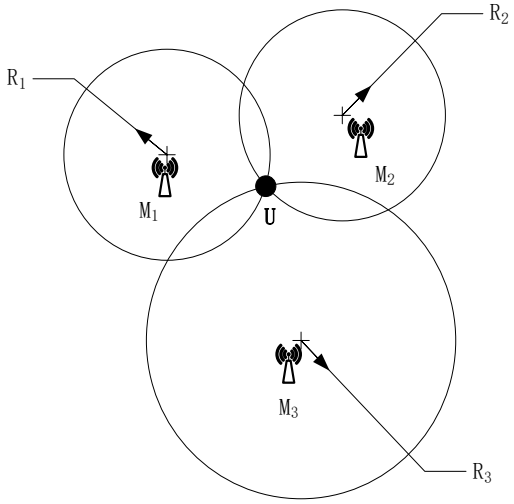

Figure 2: Trilateral Positioning Principle

2.4. Triangular positioning algorithm

Triangular positioning method is also called AOA positioning method, which mainly measures the arrival angle between the signal mobile station and the base station. The ray formed by the base station must pass through the mobile station, and the intersection of the two rays is the location of the mobile station. In the two-dimensional plane, the triangle positioning method requires at least two base stations to determine the location of the mobile station, and the positioning schematic is shown in Figure 3.

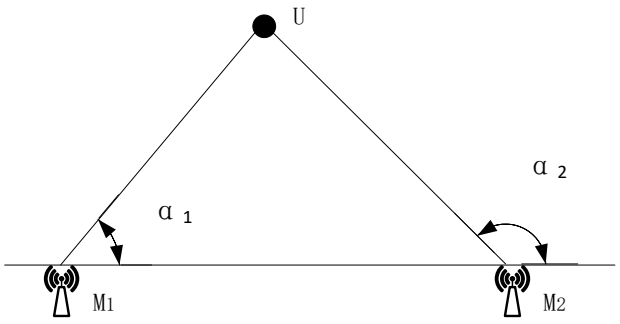

Figure 3: Positioning Principle Based on AOA

2.5. Proximity detection method

The proximity detection method, also known as the CoO (Cell of Origin) method or the Cell-ID (Cell Identification) method, judges whether the mobile device appears near a certain launch point by receiving some physical signals with limited scope. The positioning accuracy of this method depends on the layout density of the transmitting point and the coverage range of the signal coverage[4]. Although this method can only provide approximate positioning information, but its layout cost is low, easy to build, suitable for some of the positioning accuracy requirements are not high applications, such as automatic identification system for company employees check in.

2.6. Centroid method

The centroid localization method[5] calculates the centroid coordinates of all known beacons within the range of received signals of mobile devices as the coordinates of mobile devices (platforms needed). Accordingly, the weight of the corresponding beacon can also be set according to the received signal strength indicator (RSSI) to obtain the weighted centroid as the coordinate of the mobile device. This method is easy to understand and has small amount of calculation. The positioning accuracy depends on the beacon layout density[6].

2.7. Fingerprint positioning algorithm

The standard quantity of fingerprint positioning acquisition is radio frequency signal, but fingerprint positioning method can also use sound signal, optical signal or other wireless signal. Fingerprint positioning usually includes two stages. In the first stage, the off-line calibration stage, the fingerprint map is established through actual collection or calculation analysis, and multiple location points in the indoor scene are selected to collect the intensity of the signal emitted by multiple base stations and added to the fingerprint database. In the second stage, in the positioning stage, the best matching parameters are found by comparing the real-time received signal with the signal characteristic parameters in the fingerprint database. The corresponding position coordinates are considered to be the position coordinates of the target to be measured.

2.8. Dead reckoning

The dead reckoning method obtains the current position by calculating or calculating the known velocity and time on the basis of the previous position. This method is widely used in missile or rocket navigation, but there are cumulative errors in this method, and the positioning accuracy deteriorates with time. In the indoor scene, the location of pedestrians has the corresponding pedestrian dead reckoning (Pwdestrian Dead Reckoning, PDR). The step size and direction of each step of pedestrian walking are calculated by the sensors carried by pedestrians, so as to iteratively calculate the current position from the previous position[7].

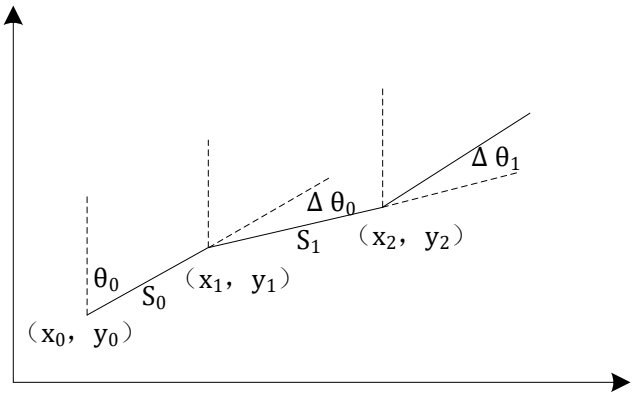

Figure 4: Chart of dead reckoning

3. Indoor positioning technology

3.1. WiFi Positioning Technology

WiFi positioning has become a widely accepted technology due to its low cost. The advantage of WiFi positioning is that no additional equipment is needed, and positioning is usually completed based on fingerprint positioning method and triangle positioning method. Triangular positioning based on RSSI observations. Fingerprint-based localization method includes offline acquisition and online localization[8]. The main purpose of the offline acquisition stage is to establish a location fingerprint database to represent the AP signal strength characteristics of each reference point in the location area. The purpose of online positioning stage is to obtain the final location information of mobile terminal equipment.

3.2. Zigbee Positioning Technology

ZigBee technology is mainly used for short-range data transmission between various electronic devices. The data transmission module of ZigBee is similar to the mobile network base station[9]. ZigBee network can provide wireless data transmission function for users. Zigbee positioning is usually based on proximity detection and multilateral positioning. Zigbee technology forms a network between the test node and the reference node. When the test node sends information, it collects the data of each reference node, transmits the data to the positioning terminal, and analyzes the position of the test node.

3.3. Bluetooth Positioning Technology

Bluetooth is a short-range communication wireless technical standard using ISM band of 2.4 ~ 2.485 GHz, which can realize fixed and mobile information equipment interconnection network at low cost[10].Bluetooth positioning is based on RSSI positioning principle. The Bluetooth positioning accuracy is related to the density of Bluetooth beacons. The more beacons are, the higher the accuracy is. Bluetooth positioning is usually based on RSSI, triangle positioning method, centroid method, fingerprint positioning method.

3.4. RFID Positioning Technology

RFID (Radio Frequency Identification) technology is a rapidly developing wireless communication technology, which is usually based on proximity detection method, fingerprint positioning method and centroid method to complete positioning. RFID positioning is composed of RFID tags and readers. The tag is used as the only recognition feature of the object, and the spatial position is measured according to the received signal strength indication (RSSI) of wireless communication between the reader and the tag installed on the object[11].

3.5. UWB Positioning Technology

UWB ultra wideband technology is a carrier-free communication technology, which uses nanosecond non-sinusoidal narrow pulse to transmit data, so it occupies a wide spectrum range. UWB broadband positioning technology is the most commonly used trilateral positioning method, TOA and TDOA algorithm to accurately calculate the coordinates of the label. Compared with other technologies, UWB positioning technology is easy to integrate positioning and communication, so it is more suitable for complex indoor space[12].

3.6. Inertial Positioning Technology

Inertial positioning technology realizes positioning through dead reckoning method, which is first applied to space technology. Usually, inertial measurement unit (IMU), namely gyroscope and accelerometer, is used to measure the target velocity, attitude and other information for positioning and navigation.

3.7. Visual Positioning Technology

Visual positioning technology uses UAV, camera and other equipment to image processing and scene analysis through the background computer, and then uses fingerprint positioning method to establish fingerprint database. The pre-calibration image is matched with the building structure data in the fingerprint database to locate[13]. According to the number of cameras in the system, it can be divided into monocular vision, binocular vision and multi-camera vision.

3.8. Infrared Positioning Technology

Infrared positioning technology is used in the field of intelligent robot positioning by image processing and proximity detection. Infrared indoor positioning system is mainly composed of three parts : infrared positioning label, fixed position sensor and positioning server. The main realization method of infrared positioning[14] is to attach the positioning object with an electronic tag that emits infrared rays, and measure the distance or angle of the signal source through multiple infrared sensors placed in the room, so as to calculate the position of the object. In this way, it is necessary to ensure that at least three effective infrared receivers are available, and the infrared positioning results are accurate. If the infrared receiver cannot receive the light emitted by the infrared transmitter due to indoor occlusion, the positioning results will be inaccurate.

3.9. Ultrasonic Positioning Technology

Ultrasonic positioning technology is based on ultrasonic ranging technology, and its basic principle is trilateral measurement positioning method[15]. Ultrasonic ranging technology is divided into reflective ranging method and unidirectional ranging method according to the installation of ultrasonic sensors. According to the principle of ultrasonic ranging is divided into TOA method, TDOA method and phase method[16].

3.10. Data fusion Location Technology

Data fusion positioning is also called combination positioning. Through the fusion of a variety of positioning technologies, the information of a variety of sensors is fused for comprehensive positioning. The combination of positioning technologies with complementary characteristics is often selected according to the application scenarios, so that it is not limited by a single positioning technology. It is the main research direction of indoor positioning today. The most representative combination is the combination of GNSS and INS, which has developed maturely. At present, GNSS and INS and multi-sensor combination are a hot research direction.

ISSN: 2664-9640

3.11. Comparative Analysis

Table 1 compares and analyzes the above indoor positioning technologies from the perspectives of positioning accuracy, coverage range, power consumption (divided by high, medium and low levels), whether affected by NLoS (non-line-of-sight propagation), difficulty of deployment and maintenance, and respective defects.

Table 1: Comparison of Positioning Technology

Technology	Accuracy	Coverage	Power loss	Is it affected by Nlos	Deployment and maintenance	Defect
WiFi	1~5m	Generally	Low	Yes	Need to collect fingerprint data offline, regular maintenance	Building fingerprint libraries takes a lot of manpower
Zigbee	1~2m	1~50m	Low	Yes	One system deployment is required	A large number of nodes need to be deployed, and there are few applications
Bluetooth	＜10m	1~30m	Low	Yes	Regular maintenance is required	vulnerable to external noise signal interference
RFID	0.05~5m	1~50m	Low	No	Regular maintenance is required	Positioning accuracy needs to be improved, mainly depending on the density of tags laid to maintain accuracy
UWB	15cm	1~150m	Low	Yes	One system deployment is required	Limited by hardware, poor universality and high cost
Inertial navigation	2~10m	Very extensive	Mid	No	Need fusion positioning to eliminate accumulated error	Accumulate errors over time
Visual positioning	0.01~1m	1~10m	High	No	Local map building, regular maintenance	High cost due to high frequency change of scene and light interference
Infrared	5~10m	1~5m	High	Yes	One base station deployment, regular maintenance	poor penetrability and small label propagation range
Supersonic wave	1~10m	1~10m	Low	Yes	One base station deployment, regular maintenance	Affected by multipath and NLOS propagation

ISSN: 2664-9640

4. Application progress and challenges

4.1. Application progress

Since the advent of indoor positioning technology, it has developed rapidly. To some extent, it makes up for the shortcomings of traditional positioning technology and improves indoor positioning accuracy. At present, this technology has been applied in many fields and has achieved certain application results. The indoor positioning technology has good application scenarios :

1) Indoor Location Service

Indoor location service is widely used in large indoor scenes such as airports, museums, supermarkets and exhibition centers. In the airport, passengers can find the optimal flight route according to the service, including the processes of check-in, check-in and security check. In museums, exhibition centers, visitors can clearly know their location, to their own interested exhibition hall ;in supermarkets, they can not only provide services for users, but also provide information on passenger flow for merchants.

2) Public safety

Indoor positioning is of great significance for public safety. When encountering sudden safety accidents such as fire and collapse, accurate positioning information is needed for rescue. It is difficult for firefighters to determine the location of rescuers, especially when collapses and mudslides lead to great changes in the layout of surrounding buildings. The location service provided by indoor positioning technology can not only locate the trapped people, but also ensure the safety of rescuers at all times and reduce the rescue risk.

3) Personnel and goods management

Indoor positioning can be used for positioning and monitoring services for specific populations. For example, RFID and other positioning technology is commonly used in the company ' s employees to work card signing service ; UWB indoor positioning technology can be used to monitor prisoners in prison. There are also some positioning technologies used in schools to ensure the safety of students at all times. In addition, indoor positioning is also used in the logistics warehousing industry to provide all location information in the transportation process of warehousing goods to ensure that goods are not lost.

4) Intelligent transportation

The indoor positioning technology makes up for the deficiency of outdoor positioning technology in the sheltered environment. Through the seamless positioning and navigation service provided by the combination of the two, the whole navigation of the vehicle during driving can be realized, and the positioning and navigation distortion of the vehicle in the sheltered areas such as the tunnel and the parking lot can be effectively solved.

4.2. Application progress

Although the accuracy of indoor positioning technology continues to improve, it has not been popularized in all walks of life. There are mainly the following difficulties and shortcomings :

1) Environmental factors have great influence. Indoor positioning is easily affected by environmental factors. Due to the complexity of the indoor environment, the location change of large objects and a large number of pedestrians will have a certain impact on the positioning. In addition, environmental factors such as noise in indoor environment can also interfere with positioning.

2) Lack of indoor positioning scheme evaluation system. Nowadays, there are various positioning technologies with advantages and disadvantages, especially the emergence of combined positioning makes the selection of positioning schemes more diversified. Without a complete and authoritative indoor positioning scheme evaluation system, it is difficult to make

a comparative evaluation of the positioning methods studied by scholars. At present, only some scholars[17] systematically evaluate a positioning technology.

3) System deployment and maintenance is not convenient. Most indoor positioning equipment needs to be deployed and maintained regularly, which leads to inconvenient use and increased cost, and restricts the promotion and application of indoor positioning technology.

4) The algorithm needs to be improved. At present, although many scholars have improved the positioning algorithm, there are few algorithms that can be applied in practical applications, and the algorithms that can be recognized by the market are still classical algorithms.

5. Conclusion

In this paper, the current indoor positioning principle is briefly introduced, and the different types of positioning technology are introduced and analyzed in detail, and the common problems in indoor positioning are discussed. Through comparative analysis, the following conclusions can be drawn :

1) With the rapid development of indoor positioning technology, the demand for higher precision positioning is increasing.

2) There are many kinds of indoor positioning technologies, and different technologies have their own advantages and disadvantages. Wide-area and local positioning technologies are often complementary, but there is still no universally applicable indoor positioning scheme due to many combination schemes.

3) Combined positioning is the mainstream direction of indoor positioning research at this stage, which can effectively improve the positioning accuracy and positioning robustness ;

4) Integrated navigation and communication technology will provide new research ideas for future indoor and outdoor positioning technology to improve positioning accuracy and reduce costs, especially for integrated positioning.

With the continuous development of indoor positioning technology, high precision, low cost and universal indoor positioning technology is the direction of future research. Comprehensive utilization of various positioning technologies and information fusion positioning will be a feasible solution to the current indoor positioning difficulties.

References

[1] Guo X, Ansari N, Hu F, et al. A survey on fusion-based indoor positioning[J]. IEEE Communications Surveys & Tutorials, 2019, 22(1): 566-594.

[2] Fu S, Li Y, Zhang M, et al. Ultra-wideband pose detection system for boom-type roadheader based on Caffery transform and Taylor series expansion[J]. Measurement Science and Technology, 2017, 29(1): 015101.

[3] Wang Xin.Three-dimensional tracking and positioning technology of indoor targets based on UWB [D].Shandong University, 2021.Li. “Study on Traffic Access Evaluation of 26 Flag Counties in Hubaoe Urban Agglomeration”. Logistics technology， 2015,38(08):12-14.

[4] Harle R. A survey of indoor inertial positioning systems for pedestrians[J]. IEEE Communications Surveys & Tutorials, 2013, 15(3): 1281-1293.Statistics Bureau of Inner Mongolia Autonomous Region. “Inner Mongolia Statistical Yearbook”. China Statistical Press, 2020.

[5] Shi H. A new weighted centroid localization algorithm based on RSSI[C]//2012 IEEE International Conference on Information and Automation. IEEE, 2012: 137-141.

[6] Wang Yijian. Research and implementation of key technologies for Bluetooth indoor positioning [D].Southeast University, 2015.

[7] Qian J, Ma J, Xu L, et al. Investigating the use of MEMS Based Wrist-worn IMU for Pedestrian Navigation Application. 2013.

[8] Thewan, T.; Seksan, C.; Pramot, S.; Ismail, A.H.; Terashima, K. Comparing WiFi RSS Filtering for WirelessRobot Location System.Procedia Manuf. 2019, 30, 143–150.

[9] Li Y. Positioning and Ranging Process of RSSI Algorithm Based on ZigBee Technology[C]//Journal of Physics: Conference Series. IOP Publishing, 2021, 1846(1): 012082.

[10] Zhang Sheng, Jiao Cheng and Fu Yong. Overview of indoor positioning methods and technologies [J].Digital technology and applications, 2018,36 (10) : 73-74 + 76.DOI : 10.19695 / j.cnki.cn12-1369.2018.10.36.

[11] Wang D, Dong E, Shi Y, et al. Rfid indoor positioning method based on received signal strength indication[C]//Journal of Physics: Conference Series. IOP Publishing, 2021, 1748(4): 042018.

[12] Yavari M, Nickerson B G. Ultra wideband wireless positioning systems[J]. Dept. Faculty Comput. Sci., Univ. New Brunswick, Fredericton, NB, Canada, Tech. Rep. TR14-230, 2014, 40.

[13] Mautz R, Tilch S. Survey of optical indoor positioning systems[C]//2011 international conference on indoor positioning and indoor navigation. IEEE, 2011: 1-7.

[14] Li B, Tang S, Zhang Y, et al. Occlusion-Aware Path Planning to Promote Infrared Positioning Accuracy for Autonomous Driving in a Warehouse[J]. Electronics, 2021, 10(24): 3093.

[15] Liu Yan, Dong Kuan.Indoor robot positioning research based on ultrasonic sensor [J] information technology, 2015 (8 :) : 54-56.

[16] Li Changlu, Su Hansong. Research on ultrasonic positioning system [J]. Laboratory research and exploration, 2013, (02) : 39-44.

[17] Mannay K, Ureña J, Hernández Á, et al. Evaluation of Multi-Sensor Fusion Methods for Ultrasonic Indoor Positioning[J]. Applied Sciences, 2021, 11(15): 6805.