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Analysis of the Technology and Development Status of Indoor Positioning

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Abstract. RFID technology is an automatic identification technology that can accurately read and write tags through the radio frequency signals emitted by its equipment. At present, this technology has been widely used in various fields. It also has advantages over other positioning technologies in indoor positioning. This article analyzes and compares eight mainstream indoor positioning technologies including RFID technology in terms of accuracy, anti-interference, etc. At the same time, it also analyzes and compares the algorithms applicable to RFID indoor positioning, and focuses on the analysis and use of neural network technology. Combined with RFID technology to achieve positioning algorithms with strong environmental adaptability.

Keywords: RFID; indoor positioning; review; neural network;

1. Overview

In recent years, as Beidou, GPS and other technologies use synchronous satellites to provide people with global, high-precision, and time-efficient positioning, positioning technology has become more and more popular in people's daily lives. Related technologies can be used in the user's location information is fed back in a short time, and people's lives, travels, and various production activities are greatly facilitated. However, due to the updating and iteration of technology, people's requirements for positioning technology are continually increasing, and GPS and other technologies cannot be used indoors to achieve positioning functions due to the influence of building shading and outdoor weather. To meet the goal of combining indoor and outdoor positioning to make anytime and anywhere positioning, indoor positioning technology came into being.

To further understand the current development status of typical indoor positioning, this article summarizes and compares eight standard indoor positioning technologies in terms of accuracy, anti-interference, penetration, and power consumption. Then, seven common RFID indoor positioning algorithms are compared and analyzed in terms of algorithm complexity and positioning accuracy. Finally, the application of neural networks in two-dimensional and three-dimensional positioning is described.

2. Common Indoor Positioning Technologies

2.1. Wi-Fi Positioning

WIFI indoor wireless positioning technology can achieve positioning, detection and tracking tasks in complex environments [1]. The WIFI positioning technology is mainly divided into two types: a ranging method that uses multiple sensors to get coordinates and a method that builds a location fingerprint database, and then analyzes the algorithm to obtain location information. [2]

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WIFI positioning technology has the characteristics of simple operation, high universality, and excellent scalability [3], but WIFI signals are easily affected by other signals during the propagation process, positioning performance will be reduced, and positioning results will be weakened. [4]

2.2. Zigbee Technology

ZigBee technology needs to place more sensors in the positioning area and arrange it as a small network with sensors as network nodes. After the positioning object enters the positioning area, the node transmits data to the destination sensor, and the destination sensor realizes indoor wireless positioning after receiving the information. [1]

ZigBee technology has the characteristics of high reliability, high capacity, and high security, but the transmission rate of ZigBee is too low, the transmission is greatly affected by indoor obstacles, and its stability and accuracy are restricted by the external environment. [5]

2.3. Bluetooth Technology

Bluetooth technology is that when the target object enters the positioning area, the stations around the area will return the signal to the Bluetooth local area network, analyze the Bluetooth signal obtained by each station to varying degrees, and convert it to the coordinate position of the target object. There are two main types of Bluetooth indoor positioning technology: detecting the strength of the signal of the propagation model and the position fingerprint method. [2]

Bluetooth technology has the characteristics of low power consumption, high security, and small device size, but the signal anti-interference ability is weak. [2]

2.4. Infrared Technology

Infrared technology generally has two forms: one is to install an optical Sensor at a fixed point indoors, the person to be positioned wears an infrared transmitter, the Sensor receives and records signals, and uploads and analyzes to obtain the positioning position; the second is to install enough infrared transmitters and indoors Sensor, the person to be positioned will hinder the straight-line transmission of infrared rays in the room, so the position can be determined after analysis based on the signal changes of the Sensor to different degrees.[5]

Infrared indoor positioning technology has high positioning accuracy and fast response speed, but the positioning result is greatly affected by light and temperature, and the cost of arrangement is high, which makes it difficult to cope with a complex indoor environment. [3]

2.5. Ultrasound Technology

There are two principles of ultrasonic technology: one is to record the time from the generator to the receiver and the time for the acoustic wave to rebound and combine the acoustic wave velocity to obtain the distance between the two. The other is to mimic the method of communication between bats. [2]

Ultrasonic positioning has the advantages of simple structure, small error, and strong anti-interference ability, but because it requires strict time measurement analysis, the hardware cost is high, which is not conducive to large-scale use. [2]

2.6. Ultra-wideband (UWB) Positioning

Ultra-wideband (UWB) is a pulse communication technology. It uses the technology of transmitting short-wave energy pulses to obtain its sequence. It allocates modulation and sequencing through orthogonal channels, expands the bandwidth to a certain frequency range, and performs data transmission to obtain position information. [2]

Ultra-wideband technology has the advantages of high reliability and strong anti-interference ability [3], but in indoor environments, the distance is short, the flight time is too short, it is not easy to measure, resulting in less use.

2.7. Optical Positioning Technology

Visible light positioning is positioning using visible light communication. The current optical positioning technology is divided into two types. One is an optical sensor installed on a moving object and calculates a

position based on a captured image. The other is that the optical sensor is mounted on a stationary object and calculates the position of the dynamically moving object in the field of view. [6]

The visible light positioning method has excellent characteristics such as stable positioning and no RF interference, but it is still susceptible to obstruction by obstacles. [7]

2.8. RFID Indoor Positioning Technology

RFID positioning is a signal transmitted by the reader to a certain range. When the RFID tag (here a passive tag) enters the radio frequency range of the reader, the tag antenna receives the signal and generates an induced current to power the tag. The chip and the information stored in the chip will be transmitted to the reader in the form of a radio frequency signal through the built-in antenna, and the reader will demodulate and decode the received signal, and finally calculate the position of the tag by a suitable algorithm.

RFID-based indoor positioning technology has the characteristics of low cost, low power consumption, high accuracy, and wide range of applications. It has a wide range of applications in areas such as warehouse management, logistics transportation, and library management.

We have summarized the above eight indoor positioning technologies, as shown in Table 1.

Table 1: Comparison of indoor positioning technology methods

technology	Accuracy	Transmission distance	Anti-interference	Penetration	Power consumption	cost	application scenarios
Wi-fi	High accuracy average error:1-3m	wide	Weaker	strong	low	low	Various areas of life, hotels, stations, etc.
Zigbee	average error:2-4m	Wider	weak	stronger	low	high	wireless personal area networks
Bluetooth	short distance, average error is 4-5m	narrower	weak	weak	lower	low	Handheld devices phones, players, etc.
infrared	High accuracy, millimeter level	narrow	weak	no	high	high	Small and spacious interior
Ultrasonic	High accuracy, sub-meter	narrow	strong	strong	high	high	Small area room
UWB	High accuracy, sub-meter	Wider	strong	strong	low	higher	Large places/high-precision positioning scenarios
Optical localization	High accuracy, millimeter level	narrow	weak	weak	low	high	medical field
RFID location	Centimeter	wide	strong	strong	low	lower	Library traceability, etc.

3. The Common RFID Indoor Positioning Algorithm

3.1. LANDMARC Algorithm

LANDMARC algorithm is a classic indoor positioning algorithm based on active RFID. The main idea is the nearest neighbour approximation method. The core idea is a centroid algorithm based on RSSI. This algorithm emits power through the reader, excites the tag, and then feeds back the power to the reader. The signal power obtained from the feedback combined with the indoor wireless channel model can roughly calculate the distance between the tag and the reader. The algorithm system has low cost and strong anti-interference ability. The theory is also easier to understand. Compared with other positioning algorithms, the algorithm has higher accuracy and better stability. However, it does not make good use of the powerful data reading capabilities of RFID, nor does it sufficiently organize the time series data effectively; in a dense environment, it is susceptible to multipath effects. [8, 9]

3.2. VIRE Algorithm

The VIRE algorithm is an improvement on the LANDMARC algorithm, which improves the accuracy and can obtain more accurate data. The virtual reference coordinates of the grid can reduce the cost while eliminating redundant position information. The VIRE algorithm does not require additional RFID readers and

tags, and can better adapt to changes in the environment. The addition of the Virtual Reference Tag increases the positioning performance of the entire system. However, the VIRE algorithm uses a linear interpolation method, which easily introduces additional errors. [9, 10]

3.3. Triangular Centroid Algorithm

The triangular centroid algorithm is used to solve the situation where the signal coverage is not accurate due to the complex indoor environment, and the three circles do not intersect. In the circular positioning model, using the physical distance of the three beacon nodes, with the node as the centre and the distance as the radius, the mobile nodes should have intersected at one point. Still, due to the influence of noise and the signal encountering obstacles, the Circles do not intersect at one point. The triangle centroid algorithm is used to take the centroid of the triangle formed by the intersecting three points to determine the position. The triangle centroid algorithm is intuitive and simple, and the positioning accuracy is high. [11]

3.4. PDOA Algorithm

PDOA ranging is based on the principle of multi-frequency radar ranging. By measuring the phase difference between the transmitted and reflected signals, the round-trip propagation time of the signal is calculated, and the distance between the two points is calculated. There is an error in the actual operation of the PDOA algorithm. However, through the improvement of the PDOA algorithm, the errors in ranging are corrected and reduced, and the accuracy of ranging is improved. [12]

3.5. TOA Algorithm

The TOA algorithm is a way to obtain the time when the signal transmitted by the transmitter reaches the target and then returns to the transmitter, and then calculates the distance based on the time. The algorithm requires at least three reference points to locate a two-dimensional target. If more than three reference points are available, the least square method can be used to improve the positioning accuracy. The positioning accuracy of the arrival time positioning method is high, but the algorithm requires that the tag and the reader be synchronized in time. Due to the multipath effect caused by the complexity of the positioning environment, the positioning accuracy of the system will be reduced. Tiny errors may also have a great impact on the entire positioning. [13]

3.6. TDOA Algorithm

TDOA is an improvement on the TOA algorithm. It simultaneously transmits signals at different measurement points and locates the target by calculating the difference in distances from different nodes to the target object. The positioning accuracy of this method is as high as the arrival time method, and it also requires that all participating readers have strict synchronization in time. Using the hyperbolic equations to obtain the specific position of the target to be located can better overcome the need for the synchronization Problem. Otherwise, the algorithm cannot complete the tracking and positioning of the target. In addition, due to the complexity of the space, the reader may not receive the signal from the tag and is also vulnerable to multipath and noise. [14]

3.7. RSSI Algorithm

This algorithm uses the transmission loss model to calculate the distance of the tag from the power received by the reader. Using the signal strength positioning method, it is easy to build an RFID positioning system, but

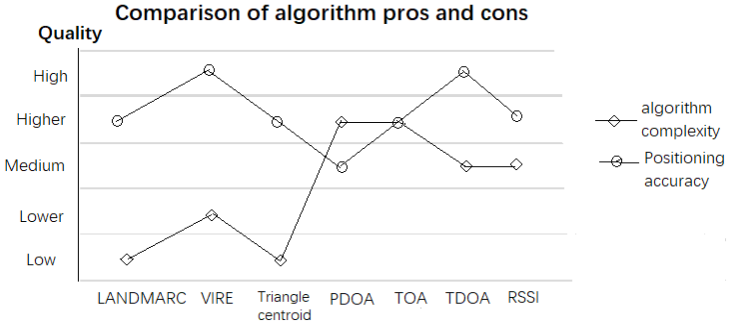

Fig. 1: Comparison of the advantages and disadvantages of the algorithm

the accuracy is not high enough, and it is not suitable for applications with high positioning accuracy. Therefore, the positioning method is suitable for deployment in situations where positioning accuracy is not high. Because there are many obstacles, there is a serious non-line-of-sight effect, and the reader is vulnerable to interference when receiving signals. [11] The advantages and disadvantages of the seven algorithms are shown in Figure 1.

4. Combined with Neural Networks to Achieve Positioning

Each of the seven positioning algorithms described above has advantages and disadvantages, which can be reasonably selected for different application purposes. Recently, the algorithm combining RFID technology and the neural network has shown advantages in positioning accuracy. This article will focus on analyzing and introducing such algorithms.

4.1. Two-dimensional Positioning

For complex indoor environments, the positioning accuracy of various wireless devices often fails to meet expectations. Existing research results often use empirical path loss models to describe indoor wireless signal propagation characteristics [15]. By combining the RSSI value of the CQPSO-BP neural network to process the loss model of indoor wireless signal propagation, the corresponding distance value can be obtained [16]. Compared with the RSSI-d curves fitted by three neural networks, compared with The traditional LANDMARC positioning algorithm and the LAND-M ARC positioning algorithm based on the CQPSO-BP neural network have better and stable positioning results. The learning process of PSO-BP neural network is shown in Figure 2 [16]

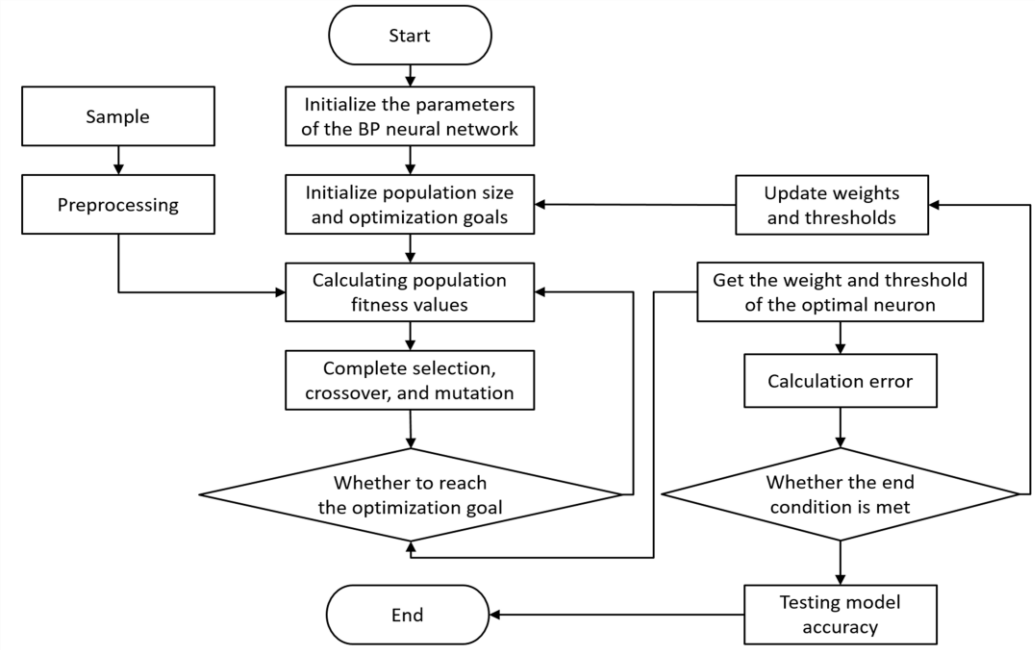

Fig. 2: Learning flow chart of PSO-BP neural network

But on the other hand, the BP neural network algorithm has obvious shortcomings, that is, it is easy to fall into a local minimum so that the entire network cannot converge to the global minimum [17]. To improve this situation Reference [17] proposed a solution that using particle swarm optimization and BP neural network to use the particle swarm algorithm to record the characteristics of the current global optimal solution instead of the gradient descent strategy in the neural network [17].

As the shallow BP neural network faces many limitations, drawing on the idea of fusion with multiple models, Longpeng Chen, Ning Ye, et al. [18] proposed an RFID indoor positioning method based on dual neural networks, established the BP neural network and DNN neural network. As shown in Figure 3.The dual neural network model takes the output of the BP neural network as the input of the DNN network model and outputs the precise positioning coordinates of the label to be tested. The dual-neural network model brings

more accurate positioning coordinates and more Short positioning time, leading in comparison with other algorithms in real-time and reliability.

Ningjia Song and Yinghua Cui proposed a fingerprint location algorithm based on genetic algorithm-generalized regression neural network (GA-GRNN) optimization.

GRNN network has stronger learning ability and learning speed, combined with a genetic algorithm to optimize the optimization efficiency of GRNN network; it solves the problem of low optimization efficiency when using the Drosophila algorithm to optimize neural network [19]. The prediction error of 0.34m is reduced in the model output after optimization. New attempts have been made in terms of overall algorithm complexity and positioning accuracy. Its network structure is shown in Figure 4.

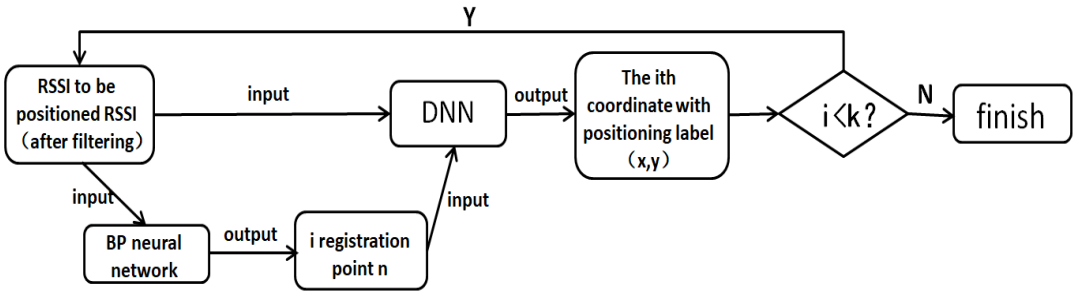

Fig. 3: Flow chart of RFID indoor positioning algorithm based on double neural network

4.2. Three-dimensional Positioning

Some scholars have tried to use neural networks to solve 3D problems. Min Liu, Yourui Huang, etc. proposed an improved multi-strategy particle swarm algorithm (IMSPSO), which uses this method to optimize the neural networks with significant errors, and uses improved three-dimensional weighted intersection points. The centroid algorithm dramatically improves positioning accuracy. In a three-dimensional space with a base area of $1m \times 1m$, using 4 Wi-Fi transmitting nodes and repeatedly taking experimental data for experiments, the results obtained are compared with GA-ANN and BP-ANN algorithms. The combined error range is minimal, and the fluctuations are gentle. At present, there are not many research reports on the combination of neural networks and indoor three-dimensional excellent positioning. The research of device and neural network positioning algorithms will be more and more in the future. [20,21]

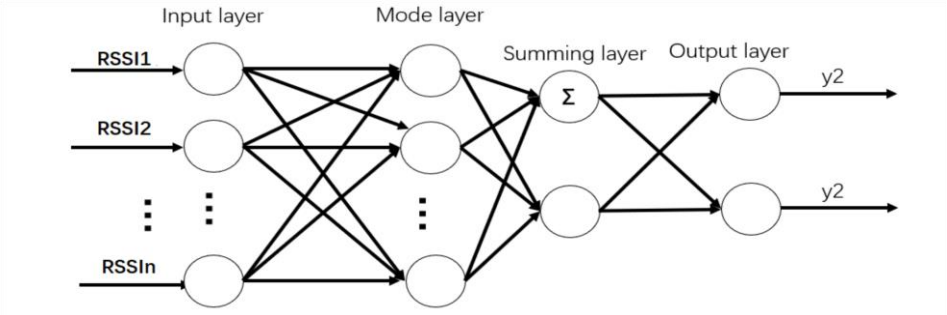

Fig. 4: GRNN network structure

5. Conclusion

This article briefly compares eight mainstream indoor positioning technologies. Through analysis and comparison, it is concluded that RFID technology has greater advantages in terms of cost, accuracy, anti-interference, and diversity of application scenarios. In terms of positioning algorithms, this article focuses on seven mainstream positioning algorithms and compares their advantages and disadvantages. Combining the rise of artificial intelligence, the combination of neural networks and traditional indoor positioning algorithms will surely enter the field of vision of researchers. This article lists and studies the initial research progress and classic methods of neural networks in indoor positioning. Comparing the existing research results, it can be concluded that the use of algorithms combining neural networks and RFID has generally achieved two-dimensional positioning. If a complete data set is obtained, three-dimensional positioning can also be achieved. Compared with other technologies, RFID technology has extremely strong development potential. The

combination of RFID indoor positioning technology and neural network related algorithms may bring new vitality to this field.

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