A Novel Approach for Indoor Positioning Based on RFID and UWB

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Abstract—In recent years, with the rapid development of mobile communication network, wireless network technology and pervasive computing, the demand of location-based service, especially indoor positioning, is becoming increasingly urgent. Indoor positioning based on Ultra wideband (UWB) is one of the most accurate indoor positioning technologies; however, due to its high cost, it is difficult to cover the large indoor environment completely. In view of the limitations of the existing indoor positioning technology, this paper designs and implements an indoor positioning algorithm and prototype system based on RFID, which could assist the existing indoor positioning based on UWB and reduce costs on the premise of positioning. Experiments show that the algorithm in this paper has better effect than other methods.

1. INTRODUCTION
In the 1940s, RFID technology was created and used in the military field to identify enemy’s aircrafts and our aircrafts [1], and it also played an important role in logistics and transportation management [2], but it was still in exploration stage. Its real rise was in the 1990s [3]. In recent years, with the development of communication technology and Internet, especially the vigorous, extensive deployment of the internet of things, the growth of indoor positioning technology is having an increasingly fierce trend [4]. Compared with other positioning technologies, RFID technology has such characteristics as high security, high data rate, high precision, high anti-interference ability and the ability to locate multiple targets at the same time [5], which makes RFID indoor positioning technology still has obvious advantages in the common development of various mainstream indoor positioning technologies [6].

2. RELATED WORK
Utilizing RFID indoor positioning technology, there are distinctions in positioning effect when choosing different positioning algorithms and different equipments and its layouts. In general, the positioning method can be divided into ranging-based and fertilizer distance measurement-based, as shown in Fig. 1.
Fig. 1 Classification RFID indoor positioning methods

There are three most commonly used location algorithms as follows.

1. **RFID location method based on ranging (AOA)**

   The orientation of RFID reader antenna based on AOA is relatively strict. The algorithm designed by AOA to infer the direction of active tag mainly uses the antenna array with directivity [7]; In order to locate accurately, the requirements for the incident angle information of electromagnetic wave used for operation processing are comparatively high. The specific method is to arrange multiple RFID readers (BS) at different positions. When the starting point direction is known, every time the information in two readers with different positions is obtained, two straight lines in different directions of the same active tag can be inferred. Then, the intersection point is the possible coordinate position of the target tag (MS).

2. **RFID positioning technology based on Received Signal Strength Indication (RSSI)**

   In the environment where the indoor positioning is desired, at least three RFID readers should be arranged in triangle orientation, and then the reader receives the RSSI signal strength information from the target tag [8]. At the same time, the RSSI signal strength information is transformed into the linear distance information between the RFID reader and the target tag by using the algorithm: taking the location of the reader as the center, and distance between the reader and the target tag as the radius [6]. Through the different combination of the intersection lines between circles, the coincidence positions of the intersection lines between three circles represented by three readers are deduced by using the algorithm equation, so as to obtain the position information of the target label.

3. **RFID location technology based on Time of Arrival (TOA)**

   This positioning principle is similar to that of RSSI positioning technology [9]. The difference is that RSSI positioning obtains the distance value between reader and tag from signal strength signal, while TOA positioning reaches time through signal strength [10]. In order to realize TOA positioning, it is necessary to follow the strict time synchronization principle when receiving and sending signals between readers and tags. When the readers and writers receive tag information, they compare the sending and receiving time of messages, and calculate the transmission distance of messages in this period of time by algorithm to get the distance between them. Finally, the three-sided algorithm could determine the target tag location.

   In this paper, the RFID algorithm proposed in this paper will be introduced from the following aspects: location trajectory algorithm based on Kalman filter, database design, UDP server design and system test.

3. **OUR APPROACH**

   In the system, due to the limitation of the hardware equipment, RFID antenna sometimes fails to receive the tag information, resulting in the lack of positioning information at a certain time, which has a negative impact on the realization of positioning and moving track view [12]. To make the
positioning track move more smoothly, the system designs and implements the positioning track algorithm based on Kalman filter [8].

According to the Kalman filter principle, the system needs to define two variables $X_0$ and $P_0$, where $X_0$ is the position information of the initial state, also known as the position information of the previous state, and $P_0$ is the uncertainty parameter of the initial position information, the so-called covariance of the previous state. In the system, if the RSSI strength of the label received by the server for 5 consecutive times continuously changes greatly, the label is considered to be in the state of uniform motion with the moving distance per second as $X_s$; if the RSSI strength of the label received by the server for 5 consecutive times is basically unchanged, the label is considered to be in the state of static motion with the moving distance per second $X_s = 0$. If there is a predicted uncertainty parameter $P_1$ and the last time uncertainty parameter $P_k$ in the current environment, then the position information $X$ predicted at the current time and $P^2$ of the uncertainty parameter $P$ predicted at the current time can be obtained.

\[
X = X_0 + X_s \\
P^2 = P_0^2 + P_s^2
\]

At this time, the system could get the Kalman gain coefficient $K$.

\[
K = \frac{P^2}{P^2 + P_k^2}
\]

Then the label position information $X(i+1)$ required at the current time and the uncertainty parameter $P(i+1)$ are obtained.

\[
X(i+1) = X + K_s*(X_n - X) \\
P(i+1) = (1-K_s)*P^2
\]

When the system runs to this stage, it has completed the positioning trajectory algorithm based on Kalman filter. When the next moment comes, the system parameters $X_i=X(i+1)$, $P_i=P(i+1)$, so as to start a new round of positioning trajectory algorithm calculation.

Through the algorithm of positioning track based on Kalman filter, the next moving track of the tag can be predicted. When the tag data cannot be received at a certain time due to hardware reasons, the positioning track of the tag will move towards the positioning track point predicted by the system, so that the positioning track can move more smoothly.

1. Database Design

The function of database is data storage and data processing. In this system, the design of database table mainly meets the requirements of user login, device registration storage, current label positioning coordinate storage and historical label positioning storage.

2. UDP Server Design

In this system, UDP server establishes data link with RFID tag through socket communication to complete the transmission of positioning data. The UDP communication flow chart is shown in Fig.2.

3. System Test

The system test includes signal field strength stability test and distance calibration test. RFID signal strength is the basic and most important data of the system. The system tests the stability of signal strength at different distances. In this paper, through the measurement of five signal strength stability, it is verified that the signal strength from the antenna to the tag is relatively stable, and with the increase of distance, the signal strength gradually weakens, the weakening trend is obvious, which meets the needs of RFID indoor positioning technology for data change trend.
4. Function Test

Function test is divided into user registration classification test and device registration test. User registration test is divided into two main points.

1. In the registration interface, after the user enters the user name and password to be registered, the user needs to enter the second password for confirmation, and then can register only after confirmation.
2. In the login interface, the user needs to enter a user name and password to log in.

In the device registration test, the antenna address code, antenna X coordinate and antenna y coordinate are needed in the device registration interface, and then register the device.

4. EXPERIMENTAL RESULTS

Figure 3 positioning display interface is also the main interface of the system, where the user can view positioning information and parking vacancy. The specific implementation process of system positioning is as follows.

After the system is successfully logged in, it starts to receive the information returned by RFID reader, and matches with the device registration information in the database. After successfully matching, it carries out the classification and filtering of the information, extracts useful information, and then converts the signal strength information into the distance value through the RSSI value transformation distance algorithm.

According to the change table of signal strength when the distance between the tag and the antenna increases gradually, the average value of signal strength can be obtained when the distance between the
tag and the antenna increases from 0m to 13m, and the nonlinear fitting function chart as shown in Fig.4 can be obtained by nonlinear fitting with MATLAB.

![Fig. 4 Nonlinear fitting function diagram](image)

Figure 4 the function prototype used in the non-linear fitting function chart is a quadratic equation of one variable. The specific formula is as follows after MATLAB operation:

$$F(x) = 0.004604 \times x^2 + 0.03119 \times x - 1.285$$

At the same time, the unknown parameters $A$ and $\alpha$ can be obtained by using MATLAB to evaluate the traditional signal strength formula $RSSI = A - 10 \log \alpha$ through the least square method, $A = 17.2712$ and $\alpha = 3.6551$ can be obtained by the least square method. Finally, the two distance values needed can be gained by the two formulas obtained by the nonlinear fitting and the least square method, and then the average value can be acquired to get the distance value with smaller error value.

5. CONCLUSION AND FUTURE WORK

In this paper, we propose an indoor positioning algorithm based on Kalman filter and RFID, and based on this algorithm, we design a positioning application system using ultra wideband (UWB), and carry out experimental verification. Experimental results show that our algorithm and system have good accuracy, RFID algorithm and equipment assistance, reduce the cost of indoor positioning based on ultra wideband. In the future, how to improve the efficiency of the algorithm [11], and make the seamless connection of different location signals to achieve the indoor location algorithm and system of multi-source fusion, is worthy of further research [13].

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