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A Comprehensive Method to Combine RFID Indoor Targets Positioning with Real Geographic Environment

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Abstract. Nowadays RFID indoor targets positioning results display methods are simplified. The positioning results visual effect is also unsatisfied. To solve this problem, we design and realize a comprehensive method to implement RFID indoor localization algorithms in a geographic information system. In our method, the RFID indoor targets positioning results can display in the real geographic environment, which can improve the application value of the results. First, we establish the geographic environment using geographic information system in order to combine RFID indoor positioning results with the real environment. Then we design a distributed system architecture to filter the useless data and implement the positioning algorithm. In this way, indoor targets real-time positioning and the results visualization display are realized. And the positioning results can also be combined with the real geographic information environment. System test results indicate that this method achieves ideal indoor positioning data display effect under well indoor-positioning precision.

Keywords: indoor localization algorithm, geographic information system, data visualization display.

1. Introduction

With the rapid development of network technology and sensing devices, IOT(internet of things) plays a more and more important role in people’s live. As an important part of the Internet of things technology, RFID (Radio Frequency Identification) technology with the advantages of short time delay, high precision, non-contact, non-line of sight, low cost, and large range of transmission, has gradually formed a wide range of practical applications, such as the second generation ID card, bus card, Olympic tickets, ETC and the like [1].

So far, the research of RFID indoor localization technology has got widely attention [2]. But most of the existing RFID indoor positioning systems had only demonstrated the positioning data in simple graphics, or only in a simple form. These methods make detrimental visualization effect of the RFID positioning data. At the same time, the

RFID positioning data lacks effective combination with the real geographical information, which hinders researchers to analyze the data deeply and affects indoor positioning results' practical application. So the RFID indoor positioning data visualization display method has become one of the focus research fields of the indoor positioning technology [3-4]. The goal of this research is to build a RFID indoor positioning system based on the real geographical environment information. The system can realize indoor targets positioning and the visualization display of the positioning data as well. The system uses a distributed architecture and some data filter methods to achieve LANDMARC indoor localization algorithm. In this way, we combine the indoor localization algorithm with Geographic Information System (GIS).

To achieve the goals mentioned above, we mainly solve problems in three aspects and our contributions are as follows:

(1) We use GIS to build geographical environment information for real application environment and complete conversing the physical space data into the geographic information space data.

(2) We design and deploy a distributed architecture for the RFID indoor positioning system. And we realize a large number of RFID data accessing, transmission and filter reliably under the distributed architecture.

(3) We implement the RFID indoor positioning algorithm in the system and combine the indoor targets positioning results with the geographic environmental information. In this way, we enhance the data display effect and improve the practical application value of the results.

The structure of the paper is as follows.

In Section 2, it's related works and background. We introduce the current widely-used RFID indoor localization algorithms and analyses their practical application situation. And there is also a detailed introduction to the indoor localization algorithm-LANDMARC.

In Section 3, there is a brief introduction to GIS. It introduces geographic information systems' concepts, features and the important effect in RFID positioning data visualization. And we offer the specific explanation for the method of real geographical environment information's construction.

In Section 4, the paper elaborates the RFID indoor positioning system's architecture, which is based on the real geographical environment. Besides that this part also introduces the RFID data filter method and the implementation of LANDMARC localization algorithm in the distributed system.

In Section 5, this paper analyses the indoor positioning accuracy under the system structure and tests the implemented system's architecture. And we also test the fusion of geographical information with positioning data and verifies the visualization effect of RFID indoor positioning data.

In Section 6, we conclude our work and discuss the future research direction.

2. Related Works and Background

2.1. Related Works

At present, there are a great variety of RFID indoor localization algorithms, such as Angle of Arrival (AOA), time of arrival (TOA), time difference of arrival (TDOA), Location identification based on dynamic Active RFID Calibration (LANDMARC) algorithm and the like. The features of each localization algorithm are summarized as shown in Table 1. Location systems based on TOA/TDOA algorithm need reader to convert the signal strength values based on path loss model into the distance information. The location system brings the distance information into the model of TOA/TDOA solution for calculation and then makes the results.

Table 1. Summary of RFID indoor localization algorithm

name	Accuracy	Real-time performance	Equipment performance requirements	Environment adaptability	cost
AOA	better	poor	higher	poor	higher
TOA	better	poor	higher	poor	higher
TDOA	better	poor	higher	poor	higher
WCL	better	poor	lower	better	lower
Sub-triangle	better	poor	lower	better	lower
LANDMARC	better	better	lower	better	lower

According to the positioning algorithm mentioned above, RFID indoor location systems can be divided into two categories: non-real-time locating systems and real-time locating systems. Typical non-real-time locating systems include the Energy probability map matching positioning system [5] and the multi-sensing distance measurement positioning system [6]. Typical real-time locating systems include 3D-ID, Spot-ON and the LANDMARC location system. With the increasingly-improved requirement of timeliness in location results, real-time location systems have become the main development trend in RFID indoor location systems.

The 3D-ID indoor positioning system is proposed by Pinpoint Company, based on GPS positioning algorithm. The positioning accuracy of 3D-ID is about 1M to 3M. It has a better environmental adaptability. The system is mainly used in indoor environments such as hospitals, supermarkets but it is difficult to promote largely due to its high construction cost [7].

The Spot-ON system, proposed by Jeffrey and his colleagues is also a typical RFID indoor location technology. Its principle is similar to the ad-hoc network. Wireless devices associated with each other are the system's location targets. The system gets the target's position by using aggregation algorithm based on signal strength analysis. But so far the complete Spot-ON system is still in the validation test stage and it has no real large scale deployments and applications [8].

The LANDMARC system is sponsored by Michigan State University and the Hong Kong University of science and technology. The system captures dynamic environmental information by introducing fixed-position reference tags. It determines the exact position of the targets [9] by using reference tags' position and the residual weighted algorithm.

Nowadays as the wireless sensor technology develops and popularizes, including RFID (Radio Frequency Identification, RFID) technology [10-12], Bluetooth, WLAN (Wireless Local Area Networks, wireless local area network) [13-15], positioning technology has been rapidly developed and improved. It can be well applied to complex indoor environment deployment and data collection, which makes it possible to get a large number of moving objects indoor track data [16]. At the same time, as the further study of indoor positioning algorithms for moving target it can better meet the positioning precision requirements of indoor location services. The Best Paper in SIGCOMM 2014 use RFID technology to improve the positioning accuracy to the millimeter level for indoor targets [17].

But most of the indoor targets positioning system pay little attention to the data visualization display and their visual effect is poor. To solve this problem, we build a real geographic environment and design a distributed architecture for data processing. In our system, we combine the indoor targets positioning technology with real the geographic environment, which can obviously improve the actual application value of the results.

2.2. Background

A RFID indoor location system usually includes four parts: labels (Tag), readers (Reader), detect antennas (Antenna), RFID applications [18]. The system structure is shown in Figure 1. Currently most of the RFID indoor location systems are based on network environment [19]. RFID tags in the RFID location system have high portability, no function of communication between each label and low system cost [20].

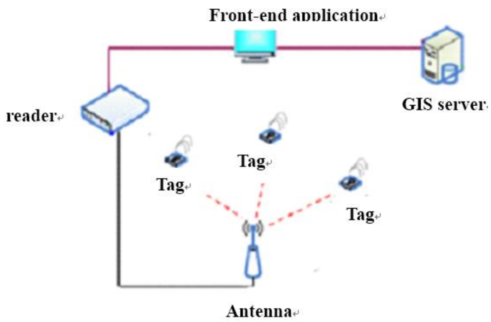


Fig. 1. RFID indoor location system architecture

In this research, we use Active RFID tags to positioning targets. The work principle of Active RFID system is: Tags transmit signals according to the preset frequency.

When tags enter the detection range of the antenna, tags establish connection with the reader through detection antennas and send the RFID data to the reader, including tag number (ID), sending time (Time), and signal strength indicators (RSSI), etc. Therefore, researchers can use the data above to measure the tags' position.

Compared to the TOA/TDOA algorithms, we can directly use RSSI values to realize the LANDMARC algorithm. The LANDMARC algorithm also reduces the requirement to reader synchronization mechanism and the performance demands of the hardware which makes LANDMARC algorithm have better applicability. Based on the above analysis, we use the LANDMARC algorithm to achieve the capability of indoor positioning. The layout of LANDMARC system is shown in Figure 2.

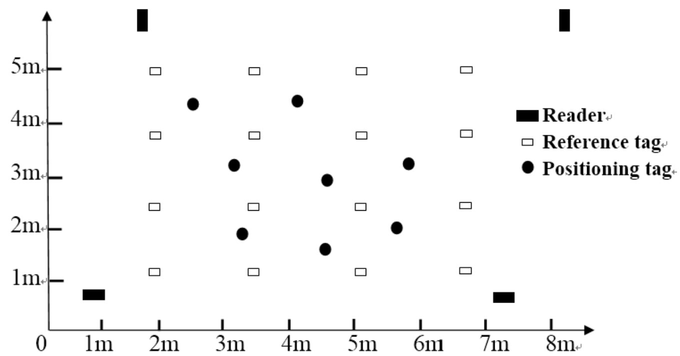


Fig. 2. RFID indoor location system architecture

The main idea of LANDMARC algorithm is inverse distance weighting ratio algorithm. This approach can date back to the 1960's. It is mainly used in the calculation of coordinates. With the introduction of the concept of reference tags, the algorithm determines the position of an unknown point. The LANDMARC algorithm uses fixed-position reference tags as reference points.

Assuming there is N readers, M reference tags and U positioning tags. N readers read signal strength value of M reference tags and U positioning tags which they send to the readers. The calculating process is:

First, we define the signal strength value of reference tag as follows. S_{Ri} indicates the value of a reference tag on reader-i.

$$S_R = (S_{R1}, S_{R2}, \ldots, S_{RN})$$

The signal strength value of positioning tags is defined as follows. S_{Ti} indicates the value of positioning tag on reader-i.

$$S_T = (S_{T1}, S_{T2}, \ldots, S_{TN})$$

Thus, the Euclidean distance between them is shown as follows.

$$E_j = \sqrt{\sum_{i=1}^{N} (S_{Ti} - S_{Ri})^2} \quad j \in (1, M) \tag{1}$$

Lower E indicates the closer between the reference tag and the positioning tag. Then k reference tags whose signal strength value is closest to the positioning tag are selected to calculate the tag's position. The positioning coordinates are calculated as follow.

$$(x, y) = \sum_{l=1}^{K} W_l (x_l, y_l) \quad \textbf{(2)}$$

W_l is the l reference tag's weight in its neighbors (l=1,2,3,...,K<M). Based on the formula, it can be calculated as follow:

$$W_l = \frac{1/E_l^2}{\sum_{j=1}^{K} (1/E_j^2)} \quad \textbf{(3)}$$

3. The Construction of Real Geographical Environment Information

In order to achieve the combination of the RFID indoor localization algorithm with real geographical environment information, we need to build the geographical environment first. The geographic information system owns completed functions of geographical data display, capture, conversion, processing and analysis. It can convert the real drawing of the geography into spatial data. In this study, we use the geographic information system to complete the construction of geographical information and the publication of map data.

3.1. Introduction of Geographical Information System

Geographic Information System (GIS) is also known as "geo-information system". It is a specific spatial information system. It is a system software which integrates geographical information analysis with map visual effects. GIS can capture, storage, manage, operate, analysis, display and describe the whole or part of the Earth's surface‘s geographic data. Geographic Information Systems (GIS) and Global Positioning System (GPS), Remote Sensing System (RS) are known as the 3S System. Geographic Information System has five main features: Data Display, Data collection, Data transformation, Data processing, and Spatial analysis.

Using GIS's function constructs the system's geographical environment information. It completes the conversion from physical space to geo spatial data and the publication of the real geographic environment data. In this way, the system provides a full environmental platform for the combination of RFID positioning data with real geographical information and helps to realize positioning data visualization.

3.2. The Construction Method of Geographical Information

We use ArcGIS products to complete the construction of geographical information and the publication of map data. To achieve the construction of geography environment, we need to complete the transformation from physical spatial data coordinates to geo spatial data coordinates. The coordinate system of data in geographic information system is the Mercator projection coordinate system. Mercator projection is the projection whose angle is unchanged and is also known as an isometric cylindrical projection. Suppose there is a cylinder which cuts in the equator. It makes the projection of the intersection of the Equator and Prime Meridian as the origin coordinate. The Equatorial projection is horizontal x axis. The Prime meridian projection is the vertical y axis. They constitute the Mercator Planar rectangular coordinate system. The long axis of the Earth ellipsoid is a, short axis is b, as shown in Figure 3.

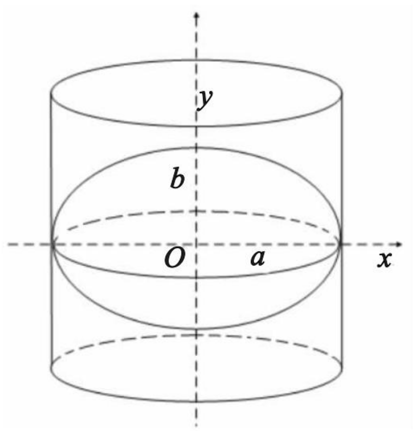


Fig. 3. Mercator projection model

According to the condition of isometric projection, it brings out the formula [21] of Mercator projection such as (4), (5).

$$x = a \times \theta \quad \textbf{(4)}$$

$$y = a \times \left[\ln \tan\left(\frac{\pi}{4} + \frac{\varphi}{2} \right) + \frac{e}{2} \ln\left(\frac{1 - e \times \sin \varphi}{1 + e \times \sin \varphi} \right) \right] \quad \textbf{(5)}$$

θ (-π, + π) is longitude, east longitude gets positive, West longitude gets negative, (-pi/2,+ Pi/2) is latitude, north latitude gets positive, South latitude gets negative. e is the first eccentricity of the earth ellipsoid. The calculating formula is shown in (6). According to the projection formulas, Mercator projection can convert coordinates of latitude and longitude （θ，φ）into plane coordinates (x, y).

$$e = \sqrt{\left(a^2 - b^2\right)} \times \frac{1}{a} \quad \textbf{(6)}$$

To achieve the construction of real geographical environment information and the RFID positioning data visualization, the system needs to overlay the indoor CAD map and the real geographic map by ArcGIS Desktop. CAD diagrams use the world coordinate which is also known as universal rectangular coordinate. The Geographic Map uses the geographic coordinate system. So before overlaying the CAD map and the geographic map, we need to convert the two coordinate systems to Mercator projection coordinate system which can be used by GIS data. According to Mercator projection coordinate system in GIS, indoor CAD map completes affines transformation and finishes the transformations of coordinate system through ArcGIS Desktop. The real geographic map completes the coordinate system transformation using the formula 3-1, 3-2 and the function of ArcGIS Desktop. After unifying the coordinate system, the indoor CAD map and the geographic map can be overlay together in GIS. In this way, the system achieves the conversion from physical space to geo spatial coordinates and finishes the construction of real geographical information. The drawing result is shown in Figure 4.

Fig. 4. Drawing effect in ArcGIS

4. The Method of RFID Indoor Positioning Data Visualization Display

To achieve the combination of RFID indoor localization algorithm with the real geographical environment information and complete the visualization of RFID data, we complete and improve the traditional RFID indoor positioning system. We propose a scalable hierarchical system architecture. Through the implementation of the system architecture, we finish the calculation of RFID indoor localization algorithm results and complete the combination of RFID indoor localization algorithm with the real geographical environment information. The system makes indoor positioning RFID data realize visual display on GIS map and improves the practical value of the positioning results.

4.1. Design of the system architecture

In allusion to the characteristics of RFID data and the demand for the flexibility, efficiency and robustness of complex event processing, the system architecture should be loose, scalable and distributed. It should be both C/S oriented and B/S oriented. The system structure is shown in figure 5.

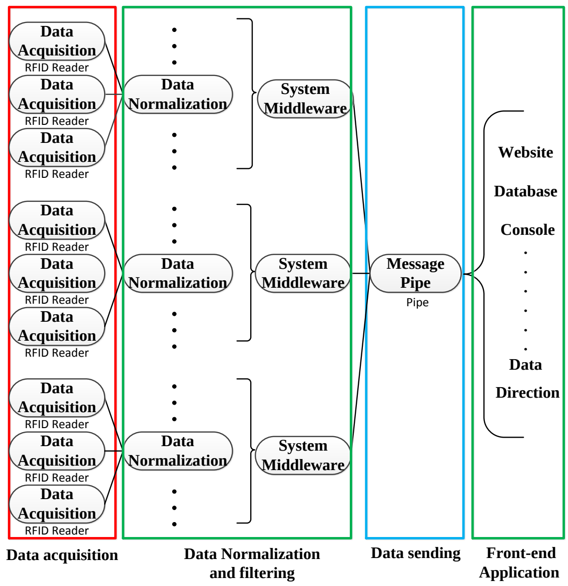


Fig. 5. The design of the system architecture

As shown in figure 5, various RFID readers collect real-time information into the system. First of all, the data are standardized and normalized. After the normalization processing, the data are sent to the middleware system, rather than directly sent to the front end application. In the message middleware, the data are filtered based on the setting rules and release the filtered data to the outside through the message pipeline. Data through the message pipes can flow to the database, Web server, console and other different front-end, application which is deployed. Message pipes can realize load balancing according to the requirements of the front-end application. At the same time, the user can also directly change the system middleware filtering rules and information for the complex event processing.

According to the purpose of the research and the unsolved problems, we make the system architecture refer to the current mainstream RFID system design. The system is divided into four levels: the sensing layer, the platform layer, the network layer and the application layer. The specific structure is shown in Figure 6.

The sensing layer collects the basic data through RFID readers and tags. It completes information transformation from physical space to digital space.

The platform layer preprocess the basic data which is collected by the sensing layer. The basic data will be converted into the specified format and delivered to the subsequent processing levels. The platform layer makes data normalized and standard. Because of the platform layer, it allows the system to access different kinds of RFID readers' data. The system architecture can be fully adapted to different hardware devices. It can effectively improve the scalability and flexibility of the system.

The main function of the network layer is to distribute data and balance load. It can provide data service guarantees for the specific implementation of application layer. In the implementation process of the network layer, it effectively separates acquisition data from back-end applications by message middleware technology. It greatly reduces the system's coupling and increases the system's scalability. Because of the message middleware technology, basic data which is acquired in front-end can be copied to multiple back-end applications. The network layer realizes the publish/subscribe pattern and improves the flexibility of the system.

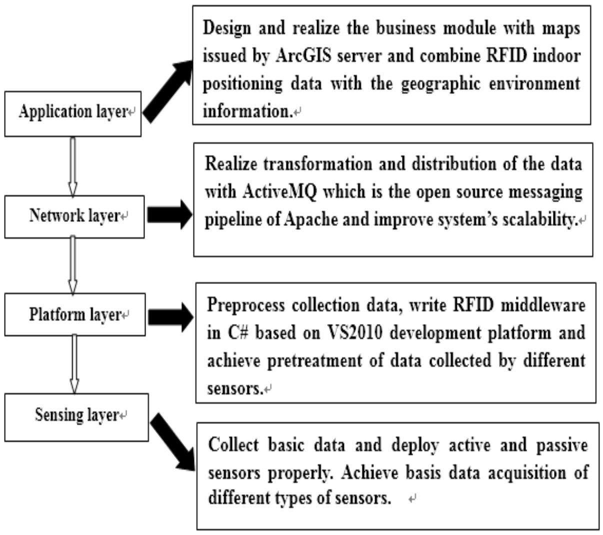


Fig. 6. The details in the system architecture

The application layer is mainly for the practical needs of users and uses the publish/subscribe model. User can realize their own defined functions by calling the data which the platform layer has dealt with. The application layer can complete many kinds of business functions. It also can realize the conversion of data from cyberspace to reality. In the system architecture, geographical mapping services offered by GIS are combined with indoor positioning data in the application layer. It achieves positioning results visualization and completes the combination of RFID indoor localization algorithm with the real geographical environment information.

In the system architecture, every layer is independent and finishes its own function. The data is collected by the sensing layer. It is processed and delivered layer-by-layer. Finally, it arrives to the top level for applications. Each functional module of the system is relatively independent. Coupling of the various parts of the system have been effectively reduced. In this way, we increases the system's scalability and ensures the system's performance. At the same time, the architecture of low coupled system design is benefit for distributed deployment. It also improves the flexibility and reliability of the system.

4.2. Realization of the system architecture

According to the system architecture and the corresponding functions of GIS, LANDMARC indoor localization algorithm is realized in the system. The visualization of the results is also completed. According to the system hierarchies, the original data turns through the sensing layer, the platform layer, the network layer and the application layer. Using the system, we complete the data collection, processing, transfer, display and other functions.

The function of the sensing layer is basic data collection and processing. According to the algorithm's real requirement, the system uses active RFID tags for positioning. The sensing layer receives radio signals from active tags through RFID readers and converts the received signals to real data. Then the sensing layer passes the underlying data to the platform layer for processing.

The platform layer receives the data from the sensing layer and normalizes the data. Because the data contents of a tag are too many, the system integrates and extracts the collected data in order to facilitate the realization of the localization algorithm. The system designs a four-tuple standardized format for data. It is shown as follow:

$$\boldsymbol{S}=\{TimeStamp,\ ReaderIP,\ TagID,\ RSSI\}$$

The TimeStamp indicates the time when the reader reads the data. The ReaderID is reader's network address to identify different readers during data acquisition. The TagID is a tag number. It is used to distinguish the different reference tags and positioning tags. The RSSI is the signal strength of tag which the reader receives and it is used for the calculation of the reference tags weighting in the LANDMARC algorithm. At the platform layer, the data is extracted by RFID middle ware which is written in C#. According to the standardization quaternion group forms, the data is consolidated for the uniform data format as follows.


```
<raw data>
    <producer>
      <timestamp>
         2015-5-13 22:28:06
      </timestamp>
      <sensor type="RFID Reader-passive">
         <sensor ID>
           10001
         </sensor ID>
         <tag ID>
           E20081818101010611 60A01E
         </tag ID>
         <IP address>
           192.168.0.100
         </ IP address >
         <RSSI>-84</RSSI>
      </sensor>
```

```
        <sensor type="RFID Reader-active">
          <sensor ID>
            20001
          </sensor ID>
          <tag ID>
            14055
          </tag ID>
          <IP address>
            192.168.0.178
          </ IP address >
          <RSSI>1058</RSSI>
        </sensor>
      </producer>
  </raw data>
```


Then the platform layer pushes the processed data to the network layer for the further processing. The network layer receives the data pushed by the platform layer and completes data transmission and distribution. The function is realized by message middleware. The system's message middleware is formed by the Apache ActiveMQ message bus. The message middleware completes the data delivery, distribution and other functions and realizes the system's basic requirements for load balancing. The architecture of the message is shown in Figure 7.

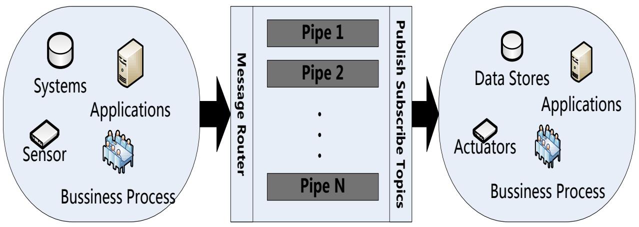


Fig. 7. The architecture of the message pipe

In this architecture, using the publish-subscribe pattern, front application can get the latest data from messages pipe. For example, if there are m data collection sensors and n front applications, in the traditional architecture, the system needs m * n data path for data transmission and distribution. But using the current architecture, we only need m + n + 1 pathway to complete each work. In this way, we make the front deployment pressure reduce greatly and improve the system's data real-time transmission capability. At the same time, the user can also directly connect to the system message middleware to manage the data transmission. It improves the system data transmission's adaptability.

Back-end applications get data from the message middleware of the network layer. After that, the data removes into the application layer. The main function in the application layer is that it realizes the calculation of LANDMARC algorithm and calls the geographic maps published by GIS. The application layer combines the RFID indoor localization algorithm with the geographical environment information and puts the final calculated results over the geographic map. In this way, the system completes the indoor positioning data visualization display.

4.3. The Method of the Redundancy RFID Data Cleaning

During the practical deployment of the RFID system, the RFID Reader collect data automatically and quickly. If a lot of dynamic targets appear within a certain time, the amount of information is very large. Such as a 10 medium-sized warehouse, RFID Reader can generate about 1.2 ~ 40000 data per second, about the size of the data for each of the 20 bytes, then every day can generate about 1.6 GB to 60 GB of data. In order to guarantee the dynamic target trajectory description is accurate and stable, we need to take reasonable and efficient data filtering discriminant mechanism and methods to ensure the high availability of data.

In RFID data collection system, the target remains or passes a certain monitoring area, the RFID Reader reads the tag many times in the same position and at the same time which we call it time redundancy. We use the finite state machine model in the platform layer to remove redundant data in time [22]. Finite state machine model consists of five parts as:

$$M = \left(S, \Sigma, f, S_0, Z\right)$$

S={State i}, S is a finite set, in which each element is called a state.

Σ ={Input char i}, Σ is a alphabet, which each element is called an input character, the scene in the laboratory, the new input character (TimeStamp, ReaderIP, TagID, RSSI), which contain a tag information: RFID tag number, location, space status information and time status information.

$f : S \times \Sigma \Rightarrow S$ is a state transition function. It said a state which accept a new input character transfers to another state. In this experiment, the state transition function is: if the previous status and the current state of the tag data input is not the same, then the RFID tag status changes to the current state, if the input data is the same as the previous status, it has preserved the original state.

$S_0 \in S$, S_0 is one of the element in S, S_0 is the only one initial state. In the experimental environment, the system sets the initial state to the monitored RFID tag, the state can be any value.

$Z \subseteq S$ 且 $Z \neq \Phi$, Z is a subset of the S, we call it the final state set. In the experimental environment, Z means the monitored RFID tag’s final state change’s state.

To clean up the time data redundancy and obtain valid data, we only need to record the monitored object’s (RFID tag) last state based on the theory of finite state machine. After RFID Reader read a new data, we compare the new data to the last state. If the status is consistent, the tag data is redundant, then drop the information, if the status is not consistent, that is, data is valid, and then update the status information of the RFID tag, and the RFID tag data is distributed to the database server, used to track description.

Using the above methods we can greatly eliminate the redundancy of the collected data and provide a good guarantee to calculate LANDMARC localization algorithm’s results.

4.4. The method of the useless RFID data filtering

During the real operations of system architecture, the collection data in the sensing layer has problems in asynchronous. The data in the network layer has problem with transmission time delay. These problems lead that the application layer's integrity of standard data cannot be guaranteed. Hence we need to make rules on the application layer and filter the data to ensure that the localization algorithm evaluates correctly. The data filtering method is: after the application layer obtains data from the message middleware at a certain time, the system arranges the data into two-dimensional array of L*4. L represents the product of the reader number and the number of the tags in the indoor environment. Because there are three readers, four reference tags and a positioning tag, in the real test L is 15. Each row in the array represents a complete four-tuple data. Each column in array represents each element in the quaternion group. The system uses the active RFID readers whose frequency band are 2.4GHz for real deployment and testing. The range of RSSI values in the collection data is from 0-65535, the whole data matrix form is shown in Figure 8.

Fig. 8. The whole data matrix form

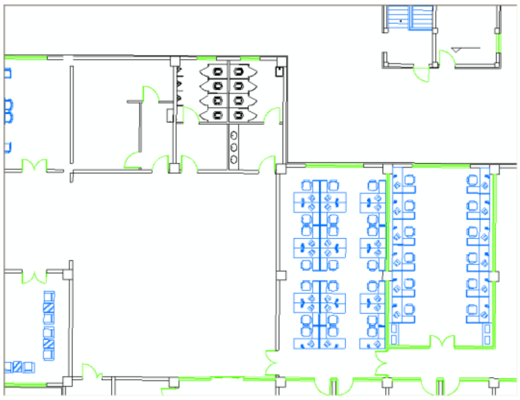
Each moment, system encapsulates a 2-dimension array matrix to a data package. Before calculating the localization algorithm, system tests the 2-dimension array matrix's integrity in the data package. If the matrix is integrated, it is used to calculate LANDMARC localization algorithm's results. If the matrix is missing, it will be dropped. In this way the system can guarantee the correctness of indoor localization algorithm and the reliability of the calculation results. In the real test, there are 3 Active RFID readers, 4 reference tags whose positions have been known and 1 positioning tag. The positioning tag's TagID is TagID1. Based on the data in each two-dimensional matrix, the application follows the steps of LANDMARC indoor localization algorithm and calculates the positioning tag's coordinates.

Because the real velocity of RFID data acquisition goes rapidly, the system cannot detect and filter the data packets every moment. Therefore the system needs the window technology to integrate the data first and ensure the system’s efficiency. The system sets 0.5s as a window time. One window time only detects the first data packet. If the data is integrity, then the data is used to compute with algorithm. If not, the data is dropped out of window. In this way, it can reduce the pressure of system and improve system's stability. Through the data filter in application layer and the realization of LANDMARC localization algorithm, the indoor positioning data visualization results are shown in Figure 9.

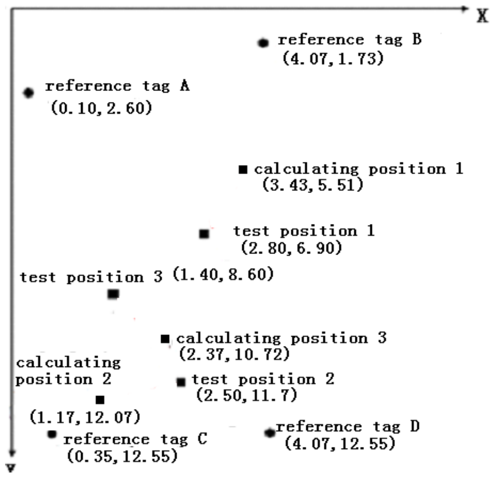
Fig. 9. Position effect diagram

5. Location Accuracy Testing and Result Analysis

We test the accuracy of indoor positioning with the achieved positioning function. The deployment diagram of the test is shown in Figure 10 (unit: m).The spatial data format needs to conform to the national standard GB/t 17798-2007 <geospatial data exchange format> but this data format is more complex. In order to simplify the expression, we select the corner of lab as the origin to establish a cartesian coordinate system. The West is the positive direction of x axis. The north is the positive direction of y axis. In this way, we convert the geo-spatial data into plane coordinates.



(a) Geographic deployment diagram



(b) Plane deployment diagram

Fig. 10. Testing deployment diagram

The specific test methods are:

(1) Place reference tags a, b, c, d in the coordinate system, measure the coordinates of the reference tags, mark them in the GIS system.

(2) Select 3 positions randomly in the coordinate system, as shown in Figure 11, respectively, for test 1, test 2, test 3, and place 3 positioning tags in the 3 positions.

(3) Open the readers, then receives the data from positioning tags and reference tags, record 1000 times of the tags' signal RSSI value, calculate the average RSSI.

(4) According to the formula (1), calculate Euclidean distance of the measuring tags 1, 2, 3.

(5) According to the formula (3), calculate the positioning tag and the reference tag a, b, c, d's weights. Choose the top three weight reference tags and calculate the coordinate results.

(6) Use standard errors (RMSE) to describe errors in coordinate, its calculation formula is shown in equation (7).

$$RMSE=E[(x-x1)^2+(y-y1)^2]^{1/2} \quad \textbf{(7)}$$

This method is repeated three times. We can get three results of every positioning tag. The test data is shown in TABLE Ⅱ. We compute the average of the coordinates for every positioning tag. The results are shown in Figure 11.

Table 2. Test data table

Number	Test position	Test position coordinate		LANDMARC calculating coordinate		errors
		X	Y	X	Y	
1	1	2.80	6.90	3.62	5.59	1.55
2	1	2.80	6.90	3.68	5.13	1.98
3	1	2.80	6.90	2.99	5.80	1.12
4	2	2.50	11.70	1.23	12.20	1.36
5	2	2.50	11.70	1.31	12.10	1.26
6	2	2.50	11.70	0.93	11.92	1.59
7	3	1.40	8.60	2.71	10.36	2.19
8	3	1.40	8.60	2.38	11.20	2.78
9	3	1.40	8.60	2.02	10.60	2.09
average						1.76

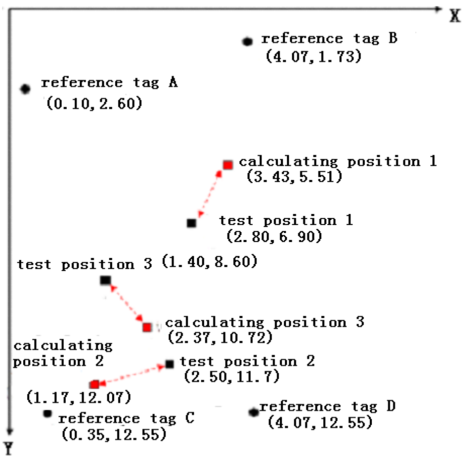


Fig. 11. Algorithm calculating results diagram

Positioning errors of traditional LANDMARC algorithm can basically reach around 1-2m.It can be seen on the test data shown in figure 12, if the system applies the algorithm for LANDMARC, the average location error is about 1.7m. Our test results are consistent with the algorithm error, but there is still room for further improvement.

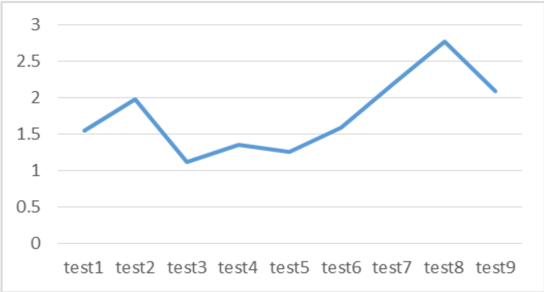


Fig. 12. Algorithm calculating results error diagram

Currently, most RFID indoor positioning systems still use relatively simple indoor map for visualization. The positioning also lacks of the combination with the spatial data. So the results can only show roughly location simply and users cannot quantify the precision of RFID positioning data. If multiple items appear in the same room, some items' diagram will overlap together in the visualization interface. Due to lack of space geographic information, it is difficult to achieve real-time switching of indoor positioning data and outdoor positioning data. Besides that, lack of space geographic information also affects the scalability of the system's position function. But in our designed system, GIS is combined with RFID technology through a distributed system architecture.

With GIS's strong processing capabilities of geographic data, we combine RFID positioning data with the real geographical information. As shown in figure 13, the system realizes graphical visualization of positioning results and avoids the phenomenon of multiple overlapping.

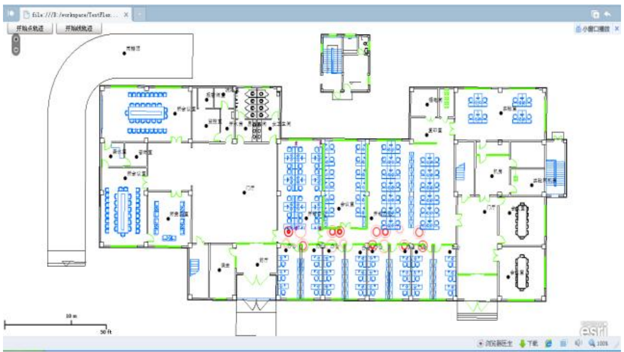


Fig. 13. Positioning data visualization display diagram

In this way, positioning results are shown more specific and imagery. The practical value of the positioning data is also improved.

Besides that, GIS can combine indoor with outdoor geographical information and it makes positioning results have the only real geographical coordinates, so the linkage of indoor and outdoor positioning can be achieved if needed. In addition, we uses a loosely distributed architecture in the system design. It has a feature of low coupling so it can be extended independently between the parts. This is benefit for improving the whole system's performance. The system's architecture allows the system to have the capacity to deal with large-scale RFID data collection in real time. It also ensures the stability and reliability of the system.

6. Conclusion and Future work

The research completes the conversion of physical spatial data and geographic spatial data with the GIS's data processing function. Besides, we combine RFID indoor positioning data with the real geographical information, which makes RFID positioning results have higher practical application value. Using GIS's powerful data-processing and data-presentation capabilities, the system gets RFID positioning data draw on real geographical environment more accurately. It can also enhance the visualization of positioning data and improve the practical value of positioning results. The indoor positioning data's visualization effect in our system is more specific. At the same time, under the distributed architecture we realize mass data's integration and filtering. So we can ensure the efficient implementation of LANDMARC algorithm in the system. In addition, the combination of RFID indoor positioning technology with GIS makes indoor positioning results have world unique geographical coordinates, which can realize seamless transformation of the indoor positioning and outdoor positioning. This achievement provides a reliable technical support for the spatial analysis of indoor and outdoor positioning data.

According to the system architecture and real requirements, the main direction of the research in the future is realizing the various sensor data's access such as GPS, BeiDou and so on. By using geographic information systems' services, the system can realize the RFID positioning data linkage inside and outside

At the network layer, we need to study how to make variety filter rules and realize event monitoring. Based on the large amount of data, we can build a data mining system using dynamic target data and use data analysis tools to research the model and the feature of RFID positioning data. At the same time, we need to know the security risks in the RFID system and improve the system's security in order to ensure important data transmission's safe and reliability.

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