An Improved RFID Localization Algorithm Based on Layer By Layer Exclusion

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Abstract—Most of existing RFID indoor localization algorithm is based on the signal strength values, reference tags and ranging location. After these algorithms are applied to the occasions of large space and complex environment such as exhibition hall, hospitals and prisons they are facing some problems such as high system cost, deploying difficulties and detecting difficulties of working state of readers. Aiming at the network reader, we present an improved localization algorithm which is implemented by tracking real-time objects and detecting the reader’s working state, and the system can still work when there are abnormalities in the reader. The experiment results show that the proposed methods can be used in the large space and complex environment.

Index Terms—multi-layer environments, RFID, layer by layer exclusion, parallel reading

I. INTRODUCTION

The rapid development of the mobile computing devices, wireless technology and the internet technology makes people more interested in location-aware service system. In many applications, we need the exact location of an object. The GPS[1] which is used to locate outside objects is the most famous and widely used technology. Taking into account the positioning accuracy, cost and feasibility, the GPS is not suitable for indoor localization[2]. RFID localization technology has become the preferred indoor localization technology and is concerned by more and more people because of its advantages such as non-contact, non-line-of-sight, high sensitivity and low cost[3].

Nowadays, RFID (Radio Frequency Identification) technology which has the ability of carrying information and reliable transmission is most widely studied in the indoor environments. The tag of each object has unique identification code which is used by the RFID localization system, and the receiver gets the location information of the electronic tags by receiving the signals transmitted by the electronic tags.

The RFID localization technology implements the localization of the object based on received signal strength values, angle values and the time interval. Currently, there are several commonly used localization methods such as DOA-based localization methods, RSS (Received Signal Strength) and TOA (Time of Arrival). The principle of using angle values to locate is to compute an angle of incidence using the phase difference of the received single of adjacent antenna. However, this method requires antenna arrays and large cost of hardware. The localization method based on received signal strength values requires a tag reader which receives the signal strength value as the localization basis. Its advantages of lower power and lower cost make it used in more and more practical systems such as LANDMARC[4] (Location Identification Based on Dynamic Active RFID Calibration) and SpotOn[5]. The LANDMARC system has good system expandability, but it has the localization error of 1 meter. It can handle more complicated environments. But the system has the shortcomings such as the necessary time-consuming, influenced localization accuracy by the density of the hardware system and distributions of the tags, so the LANDMARC system has the limited application filed. The localization algorithm based on field strength values mainly includes analytic algorithm, estimation algorithm and nearest neighbor algorithm which are based on the reference tag[6-10].

These algorithms which are applied in the limited space occasions take the single reader as the study object and can’t detect the working states of the reader. Take the algorithm which is based on the reference tag for an example, we simulate a large space such as exhibition hall, hospitals and prisons, and set up the experimental environment in the 10m*10m space. In order to implement the localization of objects, the algorithm need deploy a large number of reference tags which makes the cost very high, and it is difficult for workers to complete the deployment of reference tags because of large workload. Moreover, once the environment changes, reference tags need to be redeployed[7-12]. It can be seen that the algorithm is poorly adaptive. If the localization
algorithm which is based on signal strength value is used in the bad environment, the signal is often subject to interference which results in the production of larger errors.

In this paper, a localization algorithm which takes the reader network as the study object will be introduced to solve these problems. Though the localization accuracy is lower than algorithms which are based on the reference tags and high signal intensity, its accuracy can also meet the requirements of the large scale systems. The methods can not only monitor and real-timely track the objects, but also detect the working state of reader.

The rest of the paper is organized as follows. In Section 2, we present the system structure of RFID, analyze the characteristics of traditional localization algorithm based layer by layer exclusion, and put forward an improved localization algorithm based layer by layer exclusion. Besides, we discuss the execution process of the improved algorithm in detail. Section 3 gives the simulation results aiming at the four-tier shelf with readers, and the results shows the effectiveness of proposed method. Finally, a brief summary are discussed in Section 5.

II. COMPOSITION AND WORKING PRINCIPLES OF RFID SYSTEMS

A. The Composition of RFID Systems

The RFID is non-contact identification technology and is different from the traditional bar code which is based on optical principle. The RFID tag doesn’t need manual operations, and uses the radio frequency communications to identify, track and manage objects automatically. The whole RFID system are composed of three parts: the reader, electronic tag (TAG) which is also called transponder and application software systems[13].

The block diagram of RFID is shown in Figure 1.

![Figure 1. The block diagram of RFID](image)

Its working process includes the emission and receiving of the information. First, the readers encode the information, modulate with specific frequency carrier signal, and sent out the information by the antenna. Once the electronic tag enter into the work areas of the transmitting antennas, it receive the RF signal emitted by reader[14-16]. The circuit of the chip on the tag can not only implement demodulation, decoding and decryption of the received signals, but also send the command requests, passwords, and permissions.

Then, through the modulator, the receiver adds the relevant information which has been stored in its chip as the feedback signals to reader. Electronic tags sent the signal of some fixed frequency back to the readers using the energy which is obtained by the induced current. The receiving antenna of the readers gets the carrier signals from the Electronic tags and the information is transmitted to the reader after the demodulation of the antenna controller.

The Block diagram of Reader is shown in Figure 2.

![Figure 2. The block diagram of Reader](image)

After the received signals are demodulated and decoded by the readers, then they are sent to the central information system for the relevant data processing. The central information system judges the legitimacy of the electronic tags according to the logic operations results and makes the corresponding settings and control for different treatment, such as data recording, the display of the relevant information or instructions, and signal controls by the executing agency. In the end, they are sent to the application software systems so as to make a corresponding processing.

The reader is information controlling and processing center of the RFID system and it can be read by read/write devices based on the different technology and structures[17].

The reader is usually constituted by coupling modules, transceiver modules[18], control modules and interface modules. The reader and transponder usually use the mode half-duplex communication to exchange information. At the same time, the reader provides energy and timing to passive transponder through the coupling devices. The collection of the object identification information, processing and management functions is realized via remote transmission such as Ethernet or WLAN. The RFID transponder is the information carriers of the systems. Most of the current transponders are composed of original passive elements of microchip and coupling devices.

The Block diagram of Tags is shown in Figure 3.

![Figure 3. The block diagram of tag](image)
The RFID Localization algorithm based on layer by layer exclusion is derived from hierarchical thoughts. In the box or shelf environment, there embed HF RFID reader antennas at the bottom of the cabinet drawer or shelf partitions, the antennas must be designed scientifically so that it can only read the tag of objects which is placed in this layer of the objects, and the lower adjacent layer of the objects. When system works, it starts to read from the reader antennas of the bottom layer, and it doesn’t stop reading until the highest layer is read so that it implements the layer by layer localization. The localization algorithm based on the layer by layer exclusion uses multi-antenna reader, and the embedded antenna of each layer is controlled by one reader.

The specific scheme of the localization algorithm based on layer by layer exclusion is shown in the Figure 4

![Figure 4](image)

Figure 4. Shelf equipped with readers

In the following, we first present the working process of the RFID localization algorithm based on layer by layer exclusion.

Shown as Figure 4, the system reasonably controls the upper and lower reading range of each layer’s reader antenna, i.e., the embedded antenna reader of the first layer can only read the electronic tags of the first layer, the embedded antenna reader of the second layer can read the electronic tags of the second layer and the first layer, the embedded antenna reader of the third layer can read the electronic tags of the second layer and the third layer. Furthermore, the localization based on layer by layer exclusion can start to read from the first layer’s embedded antennas in the bottom, then sequentially read the embedded antennas of the second layer and the third layer.

Among the tags which are read by the second layer’s embedded antenna, only the tags which are not read by the antenna of the first layer can be kept the reading result of the second layer. Similarly, until the tags of the top layer are read, among the tags which are read by the third layer’s embedded antenna, only the tags which are not read by the antenna of the second layer can be kept the reading result of the third layer.

For the localization of the same level’s tags, we could rationally set the horizontal reading range of reader antennas through the test, and locate tags by the coverage range of the embedded antennas of this layer. The antenna reader reads all the tags from left to right or from right to left in each layer, we could directly select the one of the tags which lies in the overlapping area. The localization accuracy depends on the reader antenna’s coverage range. The greater the coverage range is, the smaller the localization accuracy is. Conversely, the higher the localization precision is, the more the antennas are required. Thus, that will increase the cost of deploying RFID systems[19].

In the RFID system, each reader has its own address number as its identity number, we denote it as “Reader”. Each antenna has an identity “An” as its sub-address number, the reader and antenna constitute the complete tag’s address <Reader, An>. Thus the location of each antenna in the shelf has its own unique address number [20-22]. After the reader reading the tag ID, the detecting antenna passes its own address number to the reader, and the reader pass it to the server through the network. In this way, the unique address number is programmed into RFID back-end database system, so we can determine which layer the object is, and implement the localization of object by querying the relation of the antennas’ address and their physical location.

The RFID localization algorithm with layer by layer exclusion has the followings deficiencies. When the antennas of the first layer are in working condition, the second layer’s antennas are idle. Only the antennas of the first layer are read completely, the second layer’s antennas start to be read. When the working range of antennas at different levels does not intersect, only one antenna is working at one time, so the reading of data has low efficiency. The data of each layer has redundant part, and need be compared with the lower adjacent layer’s data so as to filter the redundant data in the end, but the comparison of the redundant data in these data is meaningless, but costs much time, the efficiency of filtrating redundant data is not ideal. When the amount of data tag is large, it will take us lots of time to filter the redundant data and locate the tags. It can be seen that the efficiency of the algorithm is also very low.

B. An Improved Localization algorithm with Layer By Layer Exclusion

We design the antenna reader’s reading domain from top to bottom, so that the embedded antenna reader of the first layer can read the tag of this layer. The embedded antenna reader of the second layer can read the tags of this layer and the first layer. The embedded antenna reader of the third layer can read the tags of this layer and the second floor, but it can not read the first layer’s tag.

Shown as Figure 4, the RFID system can be divided into three layers, and each layer has a reader with four antennas. In the system, the reader’s ID is denoted as “Reader”, the antenna ID is denoted as “An”, and the tag’s ID is denoted as “Tag”. Then the logic location of an object is denoted by a triple tracking vector <Reader, An, Tag> which is also the data sent to the background management system. The different layers’ readers should have different ID, but the antennas maybe have the same ID. However, the antenna in the same layer couldn’t have the same ID. When the RFID system is on the working state, the background system sends the data reading command to a reader, the reader start to read antennas after each reader receiving the reading command.

Supposed that all readers read the tags in 4 seconds, the time of readers reading the tag is shown in Figure 5. The time of the localization algorithm based on layer by layer exclusion is shown in Figure 6.
Compared with the two figures, we know that it takes 12 seconds for RFID localization algorithm based on layer by layer exclusion, however, the improved algorithm only needs 4 seconds, and the efficiency is twice higher than localization algorithm based on layer by layer exclusion.

Most of the background system uses high-performance computer, the computing speed and storage capacity is much greater than the reader. When the RFID system is working, the antenna of the first, second and the third layers is read from left to right or right to left, the readers only take the charge of data reading, data transmission and anti-collision, and the filter of the redundant data of and the localization of tags is assigned to the background, so the efficiency of this algorithm depends on the time of reading data read from the antenna. When the system filters the redundant data, the redundant data of each layer are first filtered. Then the redundant data between the adjacent layers are filtered. This avoids the match of redundant data between adjacent layers because the comparison of redundant data between adjacent layers is meaningless.

For example, shown as Figure 1, there is a three-tier shelf, each tier has a reader with four antennas, the ID of the first layer’s reader is denoted as Reader1, the antenna’s IDs from left to right are respectively denoted as An1, An2, An3 and An4; the ID of the second layer’s reader is denoted as Reader2, the antenna’s IDs from left to right are respectively denoted as An1, An2, An3 and An4; the ID of the third layer’s reader is denoted as Reader3, the antenna’s IDs from left to right are respectively denoted as An1, An2, An3 and An4. Supposed that the antenna reader need take 1 second to read tag, <Reader1, An1, Tag1> Represents the Reader1’s antenna can read the Tag1. At one time, we could have the following data: <Reader1, An1, Tag1>, <Reader1, An2, Tag1>, <Reader2, An1, Tag2>, <Reader1, An2, Tag2>, <Reader2, An1, Tag1>, <Reader2, An1, Tag3>.

The improved localization algorithm based on layer by layer exclusion requests readers to transmit data to the background database, the background system use filtering algorithm to filter the tag data by three-dimensional tracking vector <Reader, An, Tag>. The Filtering principle is that we first filter the redundancy data of each group, then filter the redundancy data between adjacent groups. The process of filtering the redundant data is also called matching of data.

The computation of filter is shown in Figure 7 for the example.

Firstly, we divide the three-dimensional tracking vectors into groups according to Reader, then each group is sorted by An. In the upper example, the data is divided into two groups, after sorting each group, one group is {<Reader1, An1, Tag1>, <Reader1, An2, Tag1>, <Reader1, An2, Tag2>, <Reader2, An1, Tag1>}, the other is {<Reader2, An1, Tag1>, <Reader2, An1, Tag3>.

Then <ReaderN, An1, TagX> of each group is regarded as a valid data, <Reader1,An1,Tag1><Reader2 An1,Tag1> is the valid data in this example.

Next, compared <ReaderN, An2, TagY> with the valid data <ReaderN, An1, TagY>, if TagY=TagX, then delete the <ReaderN, An2, TagY>. Similarly, we filter the data in each group. In this example, after filtering the data in each group, one group is {<Reader1, An1, Tag1>, <Reader1, An2, Tag2>}, the other is {<Reader2, An1, Tag1>, <Reader2, An1, Tag3>.

After the filtering of each group, the first group of the elements <Reader1, AnX, TagY> is the valid data, compared <Reader2, AnW, TagZ> with the first group elements, if TagZ=TagY, then delete the <Reader2, AnW, TagZ>, else keep it in the second group. The third group and the second group are also compared like this way until the last group. So the rest of the data <Reader1, An1, Tag1>, <Reader1, An2, Tag2>, and <Reader2, An1, Tag3> are what we want to get in this example. <Reader1, An1, Tag1> represents the object with tag “Tag1” in the physical location of the antenna “An1” of Reader1.
In the following we describe the improved RFID localization algorithm based on layer by layer exclusion. First we group the tag data that come from the reader according to the tracking vector’s first element, and sort the groups according to the first element of each vector. The filtering of redundant data for each group is the data matching in the group. For the tracking vector, we sort them according to the second element of the vectors, take the first data vectors as the valid data, and put them into a useful data container. For each group, we filter the tracking vectors at the back according to the third element of these vectors. If the third element is same, then we delete the tracking vector, else they are the useful data and we save these in the data container. Then we use the second of the preserved tracking vectors as the base vector. According to the third element of tracking vectors, we match the remaining tracking vectors with base vector. If the third element is same, then we delete the tracking vector, else save them in the data container. We do the same work like this way until the third element of all tracking vectors is different. When the redundant data of each group is filtered completely, we take the first group as the base group and match it with the second group according to the third element. If they are same, we delete the vector, else we save it in the second group. The Algorithm works until the completion of the last group matches with the penultimate group, and the filtering algorithm ends.

In the matching process of localization algorithm based on layer by layer exclusion, the redundant data of each group participates in the matching, and this increases the workloads of data matching. As shown in this instance, the number of matching in improved localization algorithm based on layer by layer exclusion is four times, but the number for original algorithm is six times. Therefore, the efficiency of the improved filtering algorithm has been enhanced.

III. EXPERIMENTAL RESULTS AND ANALYSIS

We use the four-tier shelf to take the experiment. The space of bookshelf’s layer is 30cm, the height and the width of the shelf is 150cm and 90cm. We put the books with tags in the shelf, use Mifare read/write device with the USB interface reader DH3060U, all of the eight antennas are equally embedded in clapboards, DFC is the air tag, the system deployments is shown in Figure 8.

![Figure 8. Four-tier shelf with readers.](image)

The host sends the commands of reading tags to the readers, and the antenna start to read tags after the readers receive the commands. The readers send the tag data to the background management system, and store the useful data in the database after filtering the redundant data by filtering algorithms.

The number of each layer’s tags is the same. The different numbers of tags are adopted, and we get the reading data time and filter time as Table 1 and Table 2.

<table>
<thead>
<tr>
<th>The number of TAG</th>
<th>Reading time</th>
<th>Filtering time</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>2s</td>
<td>0.000004ms</td>
</tr>
<tr>
<td>300</td>
<td>6s</td>
<td>0.000015ms</td>
</tr>
<tr>
<td>400</td>
<td>8.5s</td>
<td>0.000018ms</td>
</tr>
<tr>
<td>1000</td>
<td>20s</td>
<td>0.00005ms</td>
</tr>
<tr>
<td>2000</td>
<td>40s</td>
<td>0.00009ms</td>
</tr>
</tbody>
</table>

We compute the average value of the data of two tables, the reading speed of the improved localization algorithm based on layer by layer exclusion is approximately three times higher than traditional localization algorithm based on layer by layer exclusion. The filtering time of redundant data of improved algorithm is also twice higher that of traditional algorithm. The Experiment results show that the efficiency of reading tag and redundant data filtering has been greatly improved.

IV. CONCLUSION

The traditional RFID Localization algorithm based on layer by layer exclusion exist some deficiency, so we make some improvement on data reading and the filtering of redundant data. The Experiment results show that the improved RFID Localization algorithm based on Layer By Layer Exclusion could reduce the system hardware and software cost, enhance the localization accuracy of objects, shorten the reader’s reading time and enhance the efficiency of removing the redundant data.

Because the improved algorithm is used in the environments with dense tags, so it needs the reading range to be scientifically designed and the parameters of the RF circuit is reasonably adjusted, but that will be a cumbersome and careful work. When the reader reads the data in parallel models, the range of the adjacent antennas is overlapping which affects the performance of the antenna, so there exits the phenomenon of missing reading data, and it needs a very strong support for anti-collision algorithm. In the future, our main research work...
is to solve the testing problem in the environment with dense tags.

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REFERENCES


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