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RFID positioning equipment of track-and-field athletes based on VIRE algorithm

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Abstract. With the rapid development of the Internet of things technology, radio frequency identification (RFID) technology has been applied more and more widely. In this paper, for faster and accurate position of track-and-field athletes in track test, we proposed a VIRE algorithm using quadratic interpolation. The improved VIRE algorithm has good positioning effect. In addition, we applied the algorithm to a timing system design scheme based on active RFID, to determine the end point timing, and according to the system error analysis, we obtained effective error accuracy.

Key words. Radio frequency identification technology, VIRE algorithm, timing system.

1. Introduction

The concept of the Internet of things (IOT) was proposed by the Massachusetts Institute of Technology Auto-ID research center (Auto-ID Labs) in 1999. Its original meaning referred to connect all the items through radio frequency identification (RFID) and other information sensing equipment with the Internet, to realize intelligent identification and management [1, 2]. In order to meet the needs of modern logistics industry, it is continuously developed and considered as the third wave of the world information industry after the computer and the Internet [3]. With the popularization and development of mobile Internet, cloud computing, big data and so on technologies, the Internet of things technology has been applied in the warehouse management, security management, logistics management and other fields, making people's life more convenient, automatic and intelligent. It is also the core of technical reform in China's educational reform to make educational examination reform by means of information technology [4]. In consequence, the Internet of things technology is also expected to become the core technology means to support the education strategy.

In the practical examination in sports, whether it is 100-meter track and 800-

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meter track, or shot game or three steps, are involved in a large number of outdoor positioning. These positioning can be personnel positioning, and also the test equipment positioning. This positioning is conducive to the management of the examination room, exercise time and so on. The RFID technology is a non-contact automatic equipment technology, having the characteristics of small volume, wide range of reading and writing, long service life, strong anti-interference ability and so on, and the applications of supporting fast reading, mobile identification, multi-target identification, and unique identification [5, 6]. Compared with GPS and other mature positioning technologies, RFID is more suitable for small local and low-cost positioning systems. At the same time, the active RFID labels, compared to passive label recognition, the distance is farther and the storage capacity is also greater. We can see that the research of positioning system based on active RFID helps realizing more real-time and accurate personnel management, object positioning and other functions in sports skill examination, so as to achieve fair and just sports skill examination, having great social significance in the selection of personnel.

2. Method

2.1. VIRE algorithm

It is assumed that the coordinate of virtual label is (p, q), and the coordinate of actual reference label is (a, b). RSSI value of the label of the coordinate (x, y) is defined as $S_k\left(T_{x,y}\right)$, and then RSSI of the label can be calculated using formulae.

$$S_k\left(T_{p,b}\right) = S_k\left(T_{a,b}\right) + p \times \frac{S_k\left(T_{a+n,b}\right) - S_k\left(T_{a,b}\right)}{n+1}\,, \tag{1}$$

$$S_k\left(T_{a,q}\right) = S_k\left(T_{a,b}\right) + p \times \frac{S_k\left(T_{a,b+n}\right) - S_k\left(T_{a,b}\right)}{n+1}\,. \tag{2}$$

The coordinates of the label to be measured are calculated by weight.In order to improve the accuracy of VIRE algorithm, two weighting factors are introduced, the weighting factors w_{1i} and w_{2i} being given as

$$w_{1i} = \sum_{k=1}^{k} \frac{\left|S_k\left(T_i\right) - S_k\left(R\right)\right|}{k \times S_k\left(T_i\right)}\,, \tag{3}$$

$$w_{2i} = \frac{p_i}{\sum_{i=1}^{n_a} p_i} = \frac{n_{ci}}{\sum_{i=1}^{n_a} n_{ci}}\,. \tag{4}$$

In the above equations, k represents the reader, $S_k\left(T_i\right)$ suggests the label RSSI value remained to be measured read by the reader k, and $S_k\left(R\right)$ refers to RSSI value of virtual reference label. As a result, w_{1i} indicates the relationship between the virtual reference label RSSI value and the actual label RSSI value to be measured; n_a is all the selected virtual reference label areas, and n_{ci} represents the selected virtual reference label continuous area (the area connected together in the grids).

In consequence, w_{2i} suggests the ratio of virtual label continuous area to the whole selected area. And the weight $w_i = w_{1i} \times w_{2i}$, and the coordinate of the final label to be measured can be calculated as

$$(x, y) = \sum_{i=1}^{n_a} w_i (x_i, y_i) . \tag{5}$$

Although the VIRE algorithm improves the positioning accuracy and does not improve the system equipment cost, there are also shortcomings: VIRE uses linear interpolation method, and in the actual environment, electromagnetic wave RSSI exists loss, and it is not proportional to the distance; secondly, two weighted factors introduced by VIRE algorithm will be affected by the threshold set by removing the wrong coordinate.

2.2. Improved VIRE algorithm

The improved algorithm is based on the deficiency of VIRE algorithm. VIRE algorithm adopts a linear interpolation method in the reference label, which has a large error in practice, because the actual distance loss of RSSI is nonlinear. To this end, this paper uses the nonlinear interpolation method - quadratic interpolation (parabolic interpolation).

First of all, we assume that the coordinate of virtual label is (p, q), and the label RSSI value of the coordinate (x, y) is defined as $S_k (T_{x,y})$, then the label RSSI value can be calculated with the following steps.

Assuming that in the rectangular coordinate system, the coordinates of three actual reference labels with the same known vertical coordinate are (x_1, b), (x_2, b), and (x_3, b). Then RSSI values of the reference label are $S_k (T_{x_1,e})$, $S_k (T_{x_2,e})$, and $S_k (T_{x_3,e})$. Construct parabolic equation $f (x) = ax^2 + bx + c$, then we can get the column equation groups:

$$\begin{cases} S_k (T_{x_1,e}) = ax_1^2 + bx_1 + c, \\ S_k (T_{x_2,e}) = ax_2^2 + bx_2 + c, \\ S_k (T_{x_3,e}) = ax_3^2 + bx_3 + c . \end{cases} \tag{6}$$

The overall relative error of the quadratic interpolation is less than that of linear interpolation, and the interpolation error is smaller near the actual reference label. In some places, there will be an error greater than linear interpolation error, but those places with greater errors is usually found to be the places where the RSSI attenuation is particularly severe, and the impact on the system positioning is smaller.

3. Results

3.1. System design

When the athletes start to run, there will a corresponding starting sensor or directional antenna to sense athletes starting, and record the starting time; when the athletes reach the end point, and enter the antenna range, it will be perceived by the system and recording the perception time, so as to calculate the time performance of athletes. But for this kind of timing systems, the antenna requires to provide directional function, so the antenna cost is too high, the deployment of the antenna is more complicated, and the antenna is vulnerable to damage. In this paper, a RFID timing system for track-and-field athletes based on VIRE algorithm is proposed. The system does not need to deploy the array antenna. The system structure of the timing system is shown in Fig. 1. The whole system is divided into five modules: data storage module, positioning algorithm module, configuration management module and device communication module, and application API interface module.

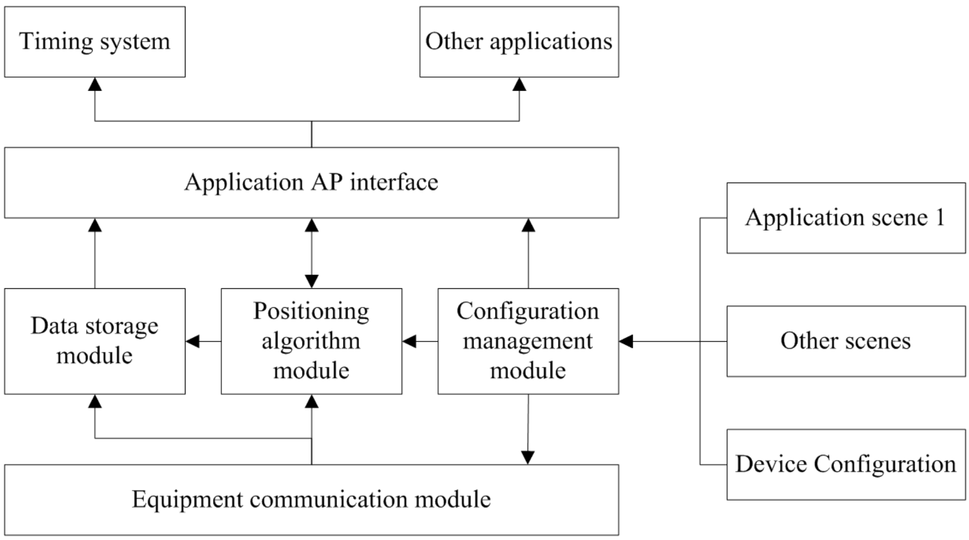

Fig. 1. Structure of timing system

3.2. Determination of the terminal point

How to determine the time at which the player is at the finish line is what a system needs to consider. When the athletes will arrive at the end point and enter the reader reading and writing range, according to the transmitting frequency of active RFID label signal, the system will continuously record a plurality of time and location information of the active RFID label into the scope of the reader, until the label leaves the read range of the reader, or when the reader collects enough reading and writing times and does not need to read any more.

As shown in Fig. 2, assuming that the t-moment label location is the solid point $P(x, y)$. In the following coordinate system, the distance d from the label to Y axis (the end line) is $|x|$, and the dotted line is the possible position locus of the label. In the process of athletes running to the destination, the location P of athletes will correspond to a moment t. While what the timing system requires is the moment of athletes at the terminal line, namely the moment of $d = 0$ (horizontal coordinate of P is 0).

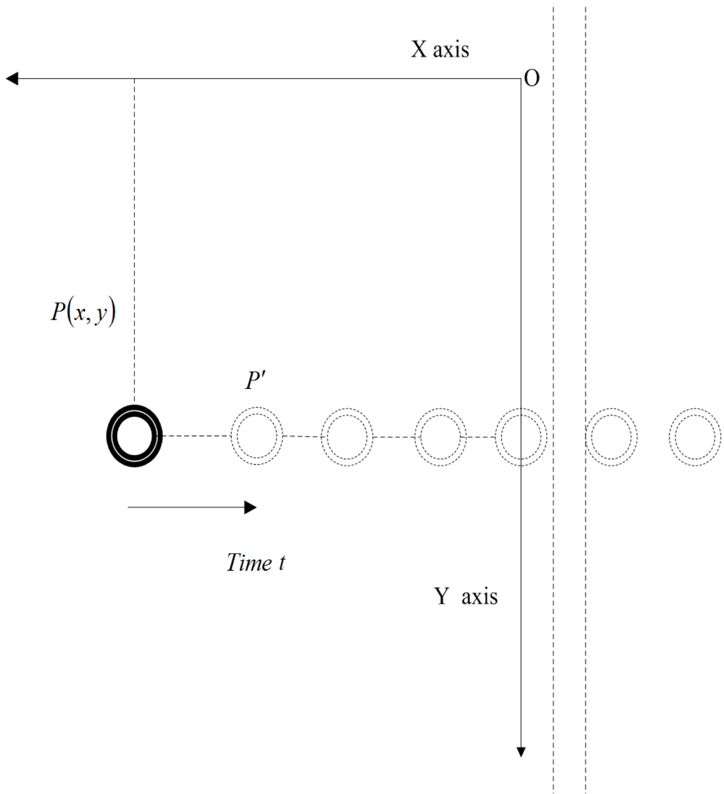

Fig. 2. Locations of athletes

From the above analysis, there is a certain functional relation between the label position P and distance $d\,(|x|)$ of the end line and the time t, and the continuity is maintained. Through the reader, although we can collect some points on the curve function, because the process of athletes before running to the end point is not a uniform motion (deceleration process), it is difficult to get a clear function equation. The approximate function curve is shown in Fig. 3. Symbol Δt is the emission time interval of the label (the reciprocal of the transmitting frequency).

For determining the time t of $d = 0$, in allusion to different cases, adopt the following methods:

The closet distance threshold $d_{\min}$ was selected, and in the position and time data read by the reader, choose the one whose distance is less than or equal to the set threshold $d_{\min}$ and the one with the minimum distance, then the time that the distance corresponds to is the time for the label to arrive at the terminal point; in this way, because the time for athletes carrying labels to enter the reader reading range is not fixed, it may occur the situation that it does not exist points less than the threshold. In view of this situation, the second method is proposed.

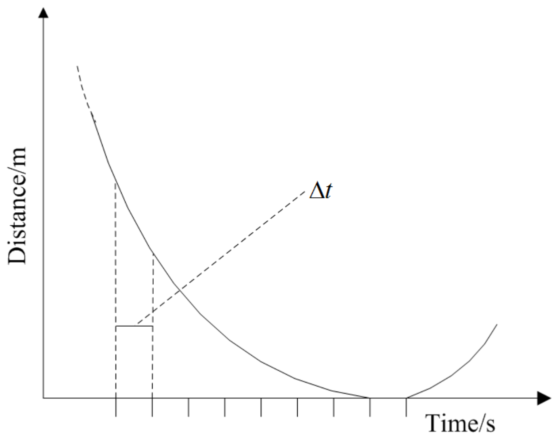

Fig. 3. Function relationship between distance and time

3.3. Theoretical error analysis

VIRE algorithm in the environment of $3\,\mathrm{m} \times 3\,\mathrm{m}$, when the label is divided into the grid 30×30, at the same time, the environment of the algorithm is bad, and in the case of severe impact on positioning accuracy, the average error of the VIRE algorithm is about $0.5\,\mathrm{m}$. As a result, we assume that the positioning error E after using the algorithm is $0.5\,\mathrm{m}$, then E is the distance between the actual location of the label and the measured position of the system. Theoretical error analysis is shown in Fig. 4.

In the above figure, the center is the actual position, and the error is taken as the radius to make a circle, the error distributed in it. It can be seen that the point with the maximum distance to the actual position error is in a circle, the closer to the center, the closer to the actual position distance, but this is not our focus for analysis. The key point is the vertical distance from the error point to the terminal line. As can be seen from the figure, the two blue ends of the circle are perpendicular to the terminal line. The distance to the terminal line is equal to the radius, which is the maximum.

4. Conclusion

According to the shortcomings of great actual error of VIRE algorithm using linear interpolation to calculate the virtual label RSSI value, we used nonlinear

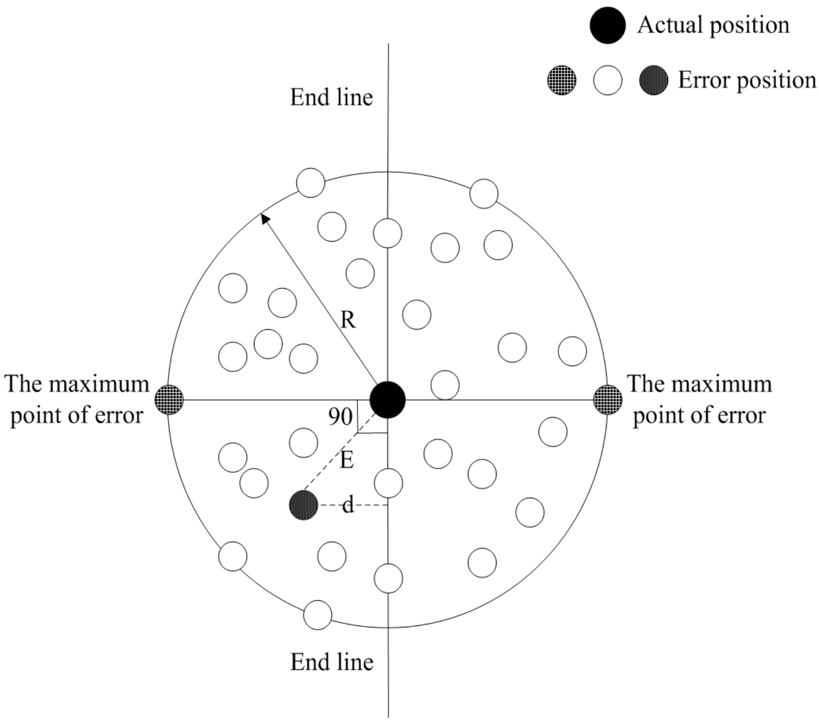

Fig. 4. Timing system error analysis

quadratic interpolation VIRE positioning algorithm, to helpto improve the accuracy of positioning, and combined with active RFID positioning technology, apply it to track-and-field athletes track timing system. First of all, we introduced the general structure of the timing system, then determined the timing method of the final position by the positioning algorithm, and finally gave the theoretical error analysis of the system. At last, the timing precision can reach 0.065 up to 0.09 seconds, suitable for 100-meter race with timing accuracy of 0.01 s.

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