PATH PLANNING AND MANAGEMENT OF URBAN INTELLIGENT PARKING LOT BASED ON RFID TECHNOLOGY

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*At present, the parking problem is common in urban parking lot. In order to solve the parking problem of urban parking lot, this study analyzed the management of intelligent parking lot. In the experiment, based on radio frequency identification devices (RFID), the algorithm of LANDMARC was improved to realize the location in the intelligent parking lot. In the path planning, the classic A * algorithm was used. Then, a simulation environment with 4 readers, 49 reference labels and 8 labels to be located was established in MATLAB, and the designed algorithm was tested. The experimental results showed that the location algorithm and path planning algorithm based on RFID technology involved in this study had smaller error and better reliability. In the future research, the intelligent parking lot management method designed in this study will be further improved, and its practical application effect will be more studied.*

Keywords: radio frequency identification devices, intelligent parking lot, positioning, path planning, LANDMARC algorithm, A* algorithm.

1. Introduction

Few parking spaces [1] and hard to find parking spaces are common problems in many cities, which have a great impact on urban traffic [2] and brings great trouble to people's life [3]. The construction of parking lot has been paid attention to by shopping malls, hotels, stations, etc., and they start to build large parking lot. However, due to the limited land resources, the scale of parking lot is always limited, and the current management method of parking lot is not conducive to the full use of parking lot resources. The intelligent parking lot can provide the information of free parking space for car owners and make reasonable planning for the route of finding parking space, which is helpful to solve the problem of parking difficulty, and the key technology has been widely concerned by researchers. Yeh et al. [4] designed the urban parking system combining cloud computing and intelligent terminal. The cloud server could provide users with the latest five parking lots which had parking space for selection and display the

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information in the parking lot on mobile devices through radio frequency identification devices (RFID). Huang et al. [5] studied the GMR sensor and realized the positioning control of parking lot. Roman et al. [6] developed a supervised learning algorithm to estimate the parking space, measured the distance between the car and obstacle using the mobile sensing unit, and verified the effectiveness of the method through experiments. Bogoslavskyi et al. [7] put forward a MDP based planning program for minimizing the time for searching parking space and arriving the parking space and verified the reliability of the method by the experiment in the real parking lot. In this study, the positioning and path planning were studied, the LANDMARC algorithm in RFID was improved, A * algorithm was used for path planning, and the reliability of the method was verified through simulation experiment. This study provides some references for the design of the intelligent parking lot and also makes some contributions to solve the urban parking problem.

2. RFID based positioning technology for intelligent parking lot

2.1 LANDMARC algorithm

RFID based positioning algorithms include angle of arrival (AOA) [8], time of arrival (TOA) [9], Received Signal Strength Indicator (RSSI) [10], etc. At present, the most widely used algorithm is LANDMARC algorithm [11], and its principle is as follows:

Suppose that there are M readers, N reference labels, and L labels to be positioned. The signal strength matrix of the reference label received by the reader is $\theta \in R^{M\times N}$, the signal strength matrix of the label to be positioned is $S \in R^{M\times N}$, and the correlation matrix of labels to be positioned and reference labels is $E \in R^{L\times N}$. The Euclidean distance can represent the actual distance between two points. The Euclidean distance between the label to be positioned i and reference label j can be expressed as:

$$D_{ij} = \sqrt{\sum_{k=1}^{M}\left(S_{ki} - \theta_{kj}\right)^2} . \tag{1}$$

Values of N D_{ij} are compared using K-nearest neighbor method to find k nearest neighbors of the label to be positioned. The calculation formula of the coordinate is:

$$(x, y) = \sum_{i=1}^{k} \omega_i (x_i, y_i) , \tag{2}$$

where $\omega_i = \frac{\frac{1}{D_{ij}^2}}{\sum_{i=1}^{k} \frac{1}{D_{ij}^2}}$.

2.2 Improved LANDMARC algorithm

Under the interference of complex environment, RFID signal may be affected by reflection, diffraction and so on, which will affect the positioning accuracy. In order to improve the positioning performance of LANDMARC, it was improved in this study. Firstly, the position of the label to be positioned is estimated by triangle positioning, and the distance between the estimated result and the reference label is calculated and set as judgement distance d_m. Then the matrix of signal strength difference is calculated:

$$\mathbf{T}_m = \begin{bmatrix} t_{m11} & t_{m12} & \cdots & t_{m1L} \\ t_{m21} & t_{m22} & \cdots & t_{m2L} \\ \vdots & \vdots & \vdots & \vdots \\ t_{mN1} & t_{mN2} & \cdots & t_{mNL} \end{bmatrix}, \quad (3)$$

where $t_{mnl} = |s_{ml} - \theta_{mn}|$. t_{mnl} which is not within the judgement distance is set as inf (infinite number), and the nearest neighbor label matrix on every reader can be expressed as:

$$\mathbf{T}_m = \begin{bmatrix} t_{m11} & t_{m12} & \cdots & t_{m1l} & \cdots & t_{m1L} \\ t_{m21} & t_{m22} & \cdots & t_{m2l} & \cdots & t_{m2L} \\ t_{m31} & t_{m32} & \cdots & t_{m3l} & \cdots & t_{m3L} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \text{inf} & \text{inf} & \cdots & \text{inf} & \cdots & \text{inf} \\ \text{inf} & \text{inf} & \cdots & \text{inf} & \cdots & \text{inf} \end{bmatrix}. \quad (4)$$

i_{ml} is set as the number of the nearest neighbor labels of the labels to be positioned on every reader, i_l is set as the total number of reference labels of labels to be positioned, i.e., $i_l = i_{1l} + i_{2l} + \cdots + i_{ml}$, and the correlation matrix is:

$$\mathbf{E}_m = \begin{bmatrix} d_{11} & d_{12} & \cdots & d_{1l} & \cdots & d_{1L} \\ d_{21} & d_{22} & \cdots & d_{2l} & \cdots & d_{2L} \\ d_{31} & d_{32} & \cdots & d_{3l} & \cdots & d_{3L} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \text{inf} & \text{inf} & \cdots & d_{i_l l} & \cdots & \text{inf} \\ \text{inf} & \text{inf} & \cdots & \text{inf} & \cdots & \text{inf} \end{bmatrix}. \tag{5}$$

Weight $\omega_i = \dfrac{\frac{1}{t_{mnl}^2}}{\sum_{i=1}^{N} \frac{1}{d_{il}^2}}$ is calculated, and then the coordinate of the label to be positioned is $(x, y) = \sum_{i=1}^{i_l} \omega_i (x_i, y_i)$.

The improved LANDMARC algorithm is applied to the intelligent parking lot positioning, and its process is shown in Fig. 1.

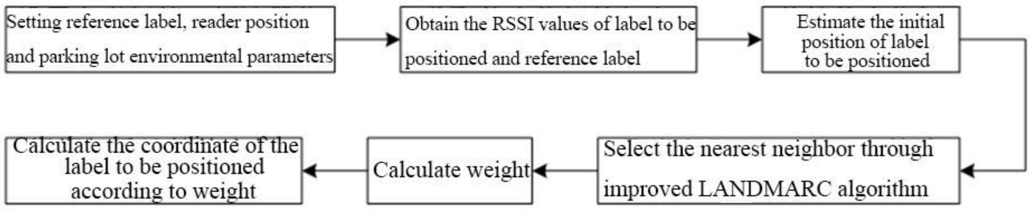

Fig. 1. The algorithm of the intelligent parking lot positioning

3. Path planning algorithm

On the basis of RFID positioning, the path planning of vehicles in parking lot is studied. In this study, A * algorithm was used as the path planning algorithm of the intelligent parking lot. The evaluation function of A * algorithm is: $f(n) = g(n) + h(n)$, where $g(n)$ represents the actual cost from initial node to node n and $h(n)$ represent the evaluated cost from node n to the end point.

In the A * algorithm, two lists need to be updated continuously: OPEN list and CLOSE list. The detailed process is shown in Fig. 2.

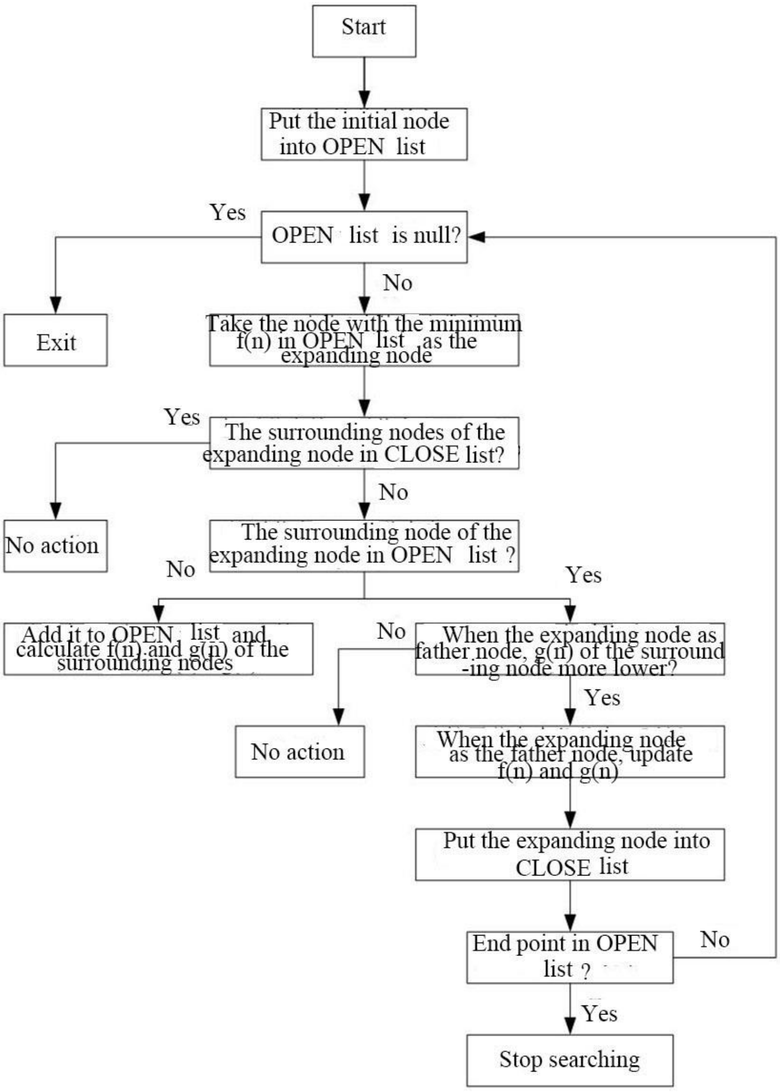

Fig. 2. The path planning process of the A* algorithm

As shown in Fig. 2, the specific steps of the algorithm are as follows.

(1) Firstly, the initial node is put into the OPEN list.

(2) Whether the OPEN list is null is determined. If the OPEN list is null, exit directly. If not, it turns to the next step: the node with the smallest value of $f(n)$ in the OPEN list is taken as the expanding node.

(3) Whether the expanding node of the node is in the CLOSE list is determined. If it is, no action will be taken; if not, then whether it is in the OPEN list is determined.

(4) If it is not in the OPEN list, it is added to the OPEN list, the expanding node will be regarded as the father node of the surrounding nodes, and $f(n)$ and $g(n)$ of the surrounding nodes are calculated.

(5) If it is in the CLOSE list, then whether the $g(n)$ of the surrounding nodes is smaller when the expanding node is taken as the father node is determined. If it is, then the expanding node is taken as the father node, and $f(n)$ and $g(n)$ are updated; if not, no action is taken.

(6) The expanding node is put into the CLOST list and whether the end point is in the OPEN list is checked. If not, then it returns for researching, and if it is, the searching stops.

(7) It moves from the end point along the father node to the initial node. Finally the route planning result is obtained.

4. Case analysis

In order to verify the effect of the improved LANDMARC algorithm in the parking lot positioning, the simulation environment shown in Fig. 2 was established in MATLAB. The coordinate of the label to be positioned was set as (x, y), the coordinate calculated by the algorithm was set as (x', y'), and the calculation formula of the positioning error was:

$$error = \sqrt{(x'-x)^2 + (y'-y)^2}\ . \quad (6)$$

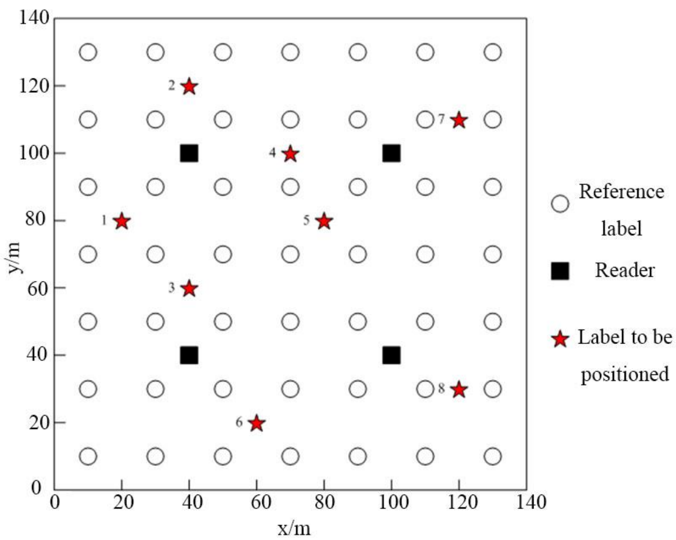

Fig. 2. Positioning distribution

The positioning results of LANDMARC and improved LANDMARC algorithms are shown in Table 1.

Table 1

Error comparison

Label to be positioned	Error of LANDMARC algorithm/m	Error of improved LANDMARC algorithm/
1	1.32	0.56
2	1.21	0.43
3	1.08	0.33
4	1.16	0.52
5	0.83	0.68
6	1.03	0.47
7	1.16	0.45
8	0.75	0.37
Average error	1.07	0.48

It was seen from Table 1 that the positioning error was relatively large when the traditional LANDMARC was used for positioning, the maximum error was 1.32 m, the minimum error was 0.75 m, and the average error was 1.07 m; the error of the positioning result obtained by the improved LANDMARC algorithm was relatively small, the maximum error was 0.68 m, the minimum error was 0.33 m, and the average error was 0.48 m, which was 55.14% smaller than that of the LANDMARC algorithm. It showed that the improved LANDMARC algorithm could significantly improve the positioning accuracy.

In the parking space positioning of the intelligent parking lot, there was generally one label to be positioned (i.e. the target parking space). Label 1 to be positioned in Fig. 2 was taken as the target parking space, the positioning errors of the two algorithms under different values of k were compared, and the results are shown in Fig. 3.

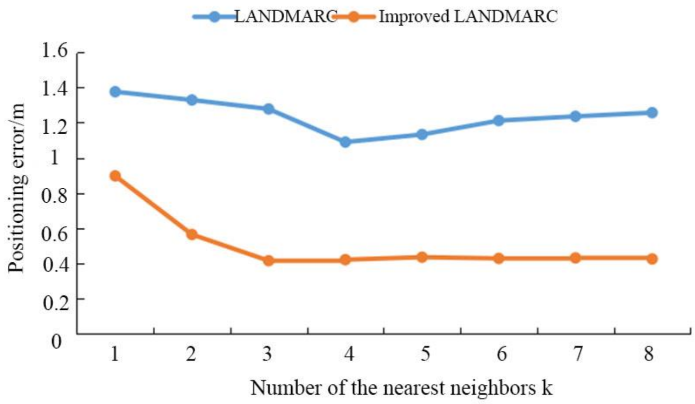

Fig. 3. Effect of k value on positioning error

It was seen from Fig. 3 that the error of the algorithms tended to be stable with the increase of k value. The error of the LANDMARC algorithm was stable at about 1.2 m, and it was optimal when the value of k was 4 (error = 1.089 m). The error of the improved LANDMARC was stable at about 0.4 m, and it was optimal when the value of k was 3 (error = 0.415 m).

As for the path planning of parking lot, the same starting point and target point were set in the simulation environment. Twenty times of path planning was carried out to compare the performance of A * algorithm and Dijkstra algorithm [12]. The results are shown in Table 2.

Table 2

Comparison of path planning algorithms

	Dijkstra algorithm		A * algorithm	
	Search time/ms	Path length/m	Search time/ms	Path length/m
1	16	367	8	303
2	15	352	8	289
3	16	384	7	276
4	16	312	7	268
5	16	376	8	285
6	30	336	8	256
7	30	359	6	264
8	30	325	7	251
9	31	395	7	265
10	30	345	6	248
11	30	362	8	274
12	30	354	8	251
13	15	385	8	264
14	15	312	8	255
15	15	385	7	248
16	16	365	7	246
17	16	354	6	254
18	31	345	6	248
19	31	312	8	251
20	31	355	6	261
Average value	23	354	7.2	262.85

It was seen from Table 2 that Dijkstra algorithm had longer search time and longer path length, while the search time of A * algorithm was shorter than 10 ms, and the search path length was shorter. The average search time of Dijkstra algorithm was 23 ms, and the path length was 354 m; the average search time of A * algorithm was 7.2 ms, which reduced by 68.7%, and the path length was 262.85 m, which reduced by 25.75%. It showed that A * algorithm could help car owners find a shorter path to the parking space faster and had higher availability.

5. Discussion

The main problems of the traditional parking lot are: ① unable to give feedback to the owner of the car on how many vacant spaces are left, and if there are no vacant spaces, it will waste time; ② unable to provide the owner with the best way to find the parking space, which will cause the owner to spend a lot of time to reach his own parking space [13]; ③ the management personnel cannot reasonably allocate the parking space. How to find and arrive at the vacant parking space quickly [14] has been widely concerned. Intelligent parking lot can effectively solve the shortage of the traditional parking lot, ease the contradiction between the number of cars and parking lot, and reduce the waste of time and resources.

Finding out shorter path in the intelligent parking lost is the key to the path planning problem and also the topic of this study. This study mainly analyzed the positioning and path planning of intelligent parking lot. RFID technology was used for positioning, and the LANDMARC algorithm was improved. The coordinates of the label to be positioned was determined by the Euclidean distance between the label to be positioned and reference label. A * algorithm was used for path planning. It was found from the experimental results that the improved LANDMARC algorithm had a good improvement effect on the positioning accuracy. It was found from the comparison with the LANDMARC algorithm (Table 1) that the positioning error of the improved algorithm was smaller and more able to meet the needs of the actual parking lot application. In addition, the improved LANDMARC algorithm had the highest accuracy when the k value was 3. It was found from the experimental results of path planning (Table 2) that the search time of A * algorithm was 7.2 ms, and the planned path length was 262.85 m, which were better than Dijkstra algorithm, indicating that A * algorithm had better performance in path planning, was more convenient for car owners to find parking spaces, and was conducive to improving the satisfaction of car owners.

Although some achievements have been made in this paper, there are still some problems due to the limited level, which need to be solved in the next research:

(1) in RFID, label collision may reduce the identification rate for labels; hence the anti-collision algorithm of RFID needs to be studied in future works;

(2) only the simulation verification was carried out, and no experiment was carried out in the actual parking lot;

(3) the path planning algorithm still has the possibility of improvement.

6. Conclusion

Based on RFID technology, this study analyzed the intelligent parking lot, used the improved LANDMARC algorithm and A* algorithm, and carried out simulation experiments. The results show that:

(1) compared with the LANDMARC algorithm, the error of the improved LANDMARC algorithm was 0.48 m, which reduced by 55.14%;

(2) when the k value was 3, the error of the improved LANDMARC algorithm was the smallest, 0.415 m;

(3) compared with Dijkstra algorithm, the average search time of A * algorithm was 7.2 ms, 68.7% less, and the path length was 262.85 m, 25.75% less.

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