ISSN: 2710-0588

Research on Path Planning of Handling Robot in Chinese Medicine Factory

Fayi Liao, Zhi Qiu, Chuanqing Pang

School of Mechanical and Electrical Engineering, Southwest Petroleum University, Chengdu 610500, China

Abstract

The path planning of handling robot in Chinese medicine factory is the key problem to improve production efficiency and reduce labor cost. In view of the complex layout characteristics in the handling process of Chinese medicine plant, this paper studies and improves the existing path planning algorithm. Firstly, through the analysis of the production environment of the Chinese medicine factory, a suitable map model was established. Then, combined with the operation environment of the handling robot in the Chinese medicine factory, the handling robot has A large number of nodes and many kinds of paths. The improved A* algorithm is used to plan the moving path of the robot. The effectiveness and practicability of the proposed path planning algorithm are verified by Matlab simulation test. Finally, the path conflict problem is solved.

Keywords

Chinese Medicine Factory Handling Robot; Path Planning; Improved A* Algorithm; Path Conflict.

1. Introduction

With the continuous vigorous development of China's economy and people's yearning for a healthy life, traditional Chinese medicine, as a unique advantageous industry in China, has a broad market prospect. In the Chinese medicine production industry, raw material transportation is an indispensable part of factory production.

Handling mobile robot (AGV) has been favored by many enterprises in need of logistics transportation system because of its good flexibility, reliability and efficiency. The raw material transportation logistics system of Chinese medicine factory is similar to the modern industrial and agricultural AGV logistics system in application, both of which are transported by mobile robots and then transported to a fixed point.

The smooth progress of logistics transportation not only depends on the control performance of AGV, but also needs path planning to guide AGV to complete transportation. In foreign countries, Matos[1] used TEA* path planning algorithm to find the position where AGV conflicts may occur, and used simulated annealing algorithm to optimize the task assignment scheme with the least path conflicts. In China, in terms of AGV path planning research, Yuan Zhiheng [2] proposed A two-layer path planning algorithm to solve the path conflict problem during scheduling. The first layer uses A* algorithm to carry out the shortest path planning in the global network, and the second layer uses RRT algorithm to solve the local path planning with conflicts. Li Yiming [3] proposed a chaotic sparrow algorithm based on the falling mechanism, which introduced variable scale chaos algorithm to improve the diversity of the initial population, used the falling mechanism to improve the randomness of the SSA algorithm, and finally used the Emmert difference to complete the smoothing process of path planning.

At present, the difficulty for small and medium-sized Chinese medicine factories to establish an automated handling robot material transport system is how to quickly build a logistics and transportation scheduling system for the Chinese medicine factory workshop, and use information and intelligent transportation scheduling schemes to replace manual recording of material information, so as to achieve stable, reliable, safe and efficient transportation of goods by handling robots. To solve this problem, the production situation of the Chinese medicine factory was analyzed, and A map model was built. On the basis of the map model, the improved A* algorithm was used to complete the order path instruction generation for the robot, and the path planning function was tested with Matlab software.

2. Map Construction

The section headings are in boldface capital and lowercase letters. Second level headings are typed as part of the succeeding paragraph (like the subsection heading of this paragraph). The planning and task allocation of the scheduling system cannot be separated from the detailed description of the production environment, and it is also the path required by the handling robot to carry out the handling task. Therefore, in the current production environment, it is necessary to establish a suitable map model. The commonly used map modeling methods include geometric method, grid method and topological method [4,5].

The geometric method is based on the actual environment, connecting all the obstacle boundary points, starting points, ending points, etc., and finally obtaining a set of edges, but its disadvantage is that it does not add factors such as the volume of the handling robot, and often the planned path is not practical.

The grid rule divides the entire production environment into a series of grids, each grid holds the map information, 1 represents obstacles, 0 represents no obstacles. Its advantage is that it is easy to save to the scheduling system for path planning, but the disadvantage is that the partition of the grid size will change the map accuracy.

The topology rule takes the current obstruction-free environment as the basis, sets multiple nodes, and the lines between nodes represent paths. The topology map can express the current environment more comprehensively, but its disadvantage is that the information of each node is too much, which is relatively abstract.

To sum up, according to the comparison between the production environment of the Chinese medicine factory and different map modeling, this paper adopts the raster-topology two-layer map model, uses the topology structure to complete the description of the global environment of the factory, and uses the raster method to complete the binary processing of the map information on the basis of the topological map as the walking path of the handling robot. The scheduling system uses the raster map in path planning and scheduling task optimization, and then extracts the topological path from the raster map after obtaining the result, and sends the information in the topological path to the handling robot, so that the robot can realize the handling task.

This paper takes the production environment of a Chinese medicine factory as the research object. openTCS software is used to draw the production environment [6], and the environmental diagram is shown in Figure 1. In the figure, T1 and T2 respectively represent different raw material pick-up points of the Chinese medicine factory, S1 and S2 represent the starting position of the handling robot 1 and 2, and C1 and C2 are the charging position of the handling robot. D1, D6 and D2 are the raw material placement points of stations 1, 2 and 3 respectively, and T9, T4 and T5 are the finished product pick-up points of stations 1, 2 and 3 respectively, among which D7 is the freight elevator of the factory, and all the finished products need to be transported to D7, so D7 is simplified as the storage point for finished products.

ISSN: 2710-0588

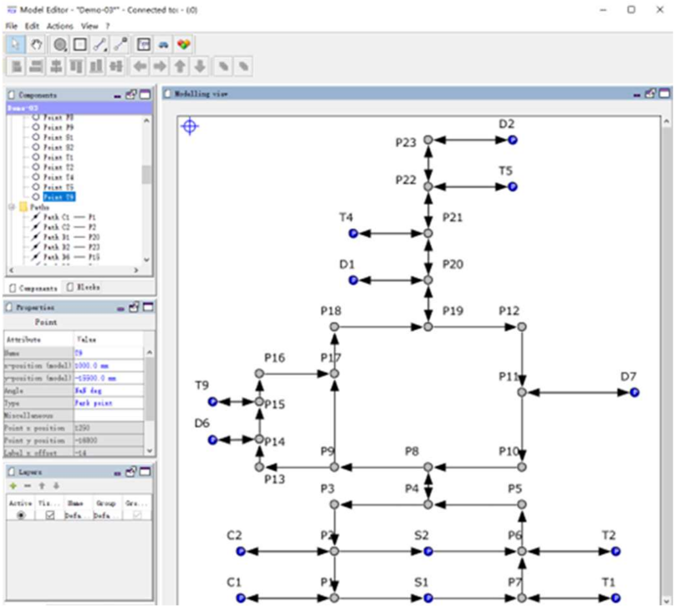

Figure 1. Robot transportation path diagram

3. A* Path Planning Algorithm

Path planning plays A relatively important function in the scheduling system. In the current research on path planning algorithms, many domestic and foreign scholars have studied it and proposed such path planning algorithms as Dijkstra algorithm, artificial potential field method, neural network, A* algorithm, fuzzy logic method [7]. Several methods are shown in Table 1.

Table 1. Comparison of several methods for robot path planning

algorithm	advantage	shortcoming
Dijkstra's algorithm	The optimal solution of the shortest path can be obtained	It requires a lot of computation and is not suitable for scenes with large maps
Artificial potential field method	The planned path is smooth and secure	If the potential field equation is not reasonable, it will lead to local optimality
A* algorithm	The search operation efficiency is high	Not applicable to path planning in unknown environments

Combined with the operation environment of the handling robot in the Chinese Medicine factory, it can be seen that the handling robot runs on a large number of nodes and a large variety of paths. If the Dijkstra path planning algorithm is adopted, it will make Dijkstra's algorithm traverse all nodes, resulting in slow planning efficiency and affecting the real-time performance of the system. If A* algorithm is adopted, because A* algorithm can complete path planning [8,10] by combining some information of current road conditions, the planning efficiency is greatly increased. Therefore, A* algorithm is chosen to realize the path planning of the transport robot.

The search range of the A* algorithm is the rasterized interval of the map, in which each step of the A* algorithm runs in one raster. Starting from the specified starting grid, the A* algorithm will first establish an open and close set table, and the open set table needs to first add the starting point, and find the grid points adjacent to the starting point. The methods of finding adjacent grid points can be divided into four and eight expansion at present, based on the fixed path in this paper. Therefore, we choose up, down, left and right four-way extension to search adjacent nodes.

When A* algorithm finds adjacent nodes, it will put them into the open set table, and delete the start node from the open set and put them into the close set table. By calling the evaluation function, the points in the open set table will be evaluated. The qualified points will be set as the parent node by A* algorithm. At this time, the A* algorithm completes the first round of search, and before opening the next round, it also needs to put the parent node into the close combination table, indicating that the current grid point meets the requirements.

In screening points in the open set table to the close table, the correctness and rationality of the evaluation function determine whether the A* algorithm can effectively find the optimal path. The expression of the fitness evaluation function of the A* algorithm is as follows:

$$f(n)=g(n)+\omega(n)\cdot h(n) \tag{1}$$

$g(n)$ ——The actual substitution value from the starting point to the current node n;

$h(n)$ ——The estimated substitution value from the current node to the target point;

$\omega(n)$ ——Evaluate the weight of substitute value in fitness $f(n)$.

The proxy value of g(n) is generally calculated by Manhattan distance, while the proxy value of h(n)heuristic function can be calculated by Manhattan distance, Euclidean distance, diagonal distance, etc. The three calculation formulas are shown in equation (2), (3) and (4).

$$L(i,j)=\left|x_i-x_j\right|+\left|y_i-y_j\right| \tag{2}$$

$$L(i,j)=\max(|(x_i,y_i),(x_j,y_j)|) \tag{3}$$

$$L(i,j)=\sqrt{(x_i-x_j)^2+(y_i-y_j)^2} \tag{4}$$

(2) The Manhattan distance is calculated as the sum of the absolute values of the vertical and horizontal distances between two points. Formula (3) Diagonal distance is suitable for eight-way search, and the robot can walk up, down, left, right and diagonal to find the shortest distance between two points. Formula (4) Euclidean distance is generally not used in grid maps, but is more used in geometric and topological maps, and the linear distance between two points is used to obtain the substitute value.

w(n), as the weight of the node estimate, can indirectly affect the fitness value of $f(n)$ and ultimately lead to different effects of A* algorithm. Therefore, many scholars will study w(n) and achieve corresponding optimization effects when improving A* algorithm. The effect of w(n) on the A* algorithm is as follows: When $w(n)*h(n)=0$ happens, the A* algorithm degenerates into Dijkstra's algorithm, from a heuristic search to a global search. When $w(n)*h(n)<g(n)$ the A* algorithm can find the shortest path, its search speed gradually slows down as it becomes smaller. When $w(n)*h(n)=g(n)$ the result of the path found by A* algorithm is more accurate and faster, but it is difficult to implement. When $w(n)*h(n)>g(n)$ A* search speed is accelerated, but the path it seeks is not necessarily the shortest path, by sacrificing accuracy in exchange for search speed.

According to the raster map established by the factory, the substitution value calculation function of the A* algorithm adopts Manhattan distance, and the weight w(n) is 1, which makes the calculation result of fitness $f(n)$ accurate and fast.

ISSN: 2710-0588

By calculating the values in the open set table repeatedly, the A* algorithm continuously puts appropriate nodes into the close set table. When the target point appears in the open set table of the A* algorithm, the A* algorithm ends the cycle and outputs the values in the close set table to a raster array. That is, a shortest driving path is formed, and the whole path planning algorithm is completed. Figure 2 shows the flowchart for planning A* paths.

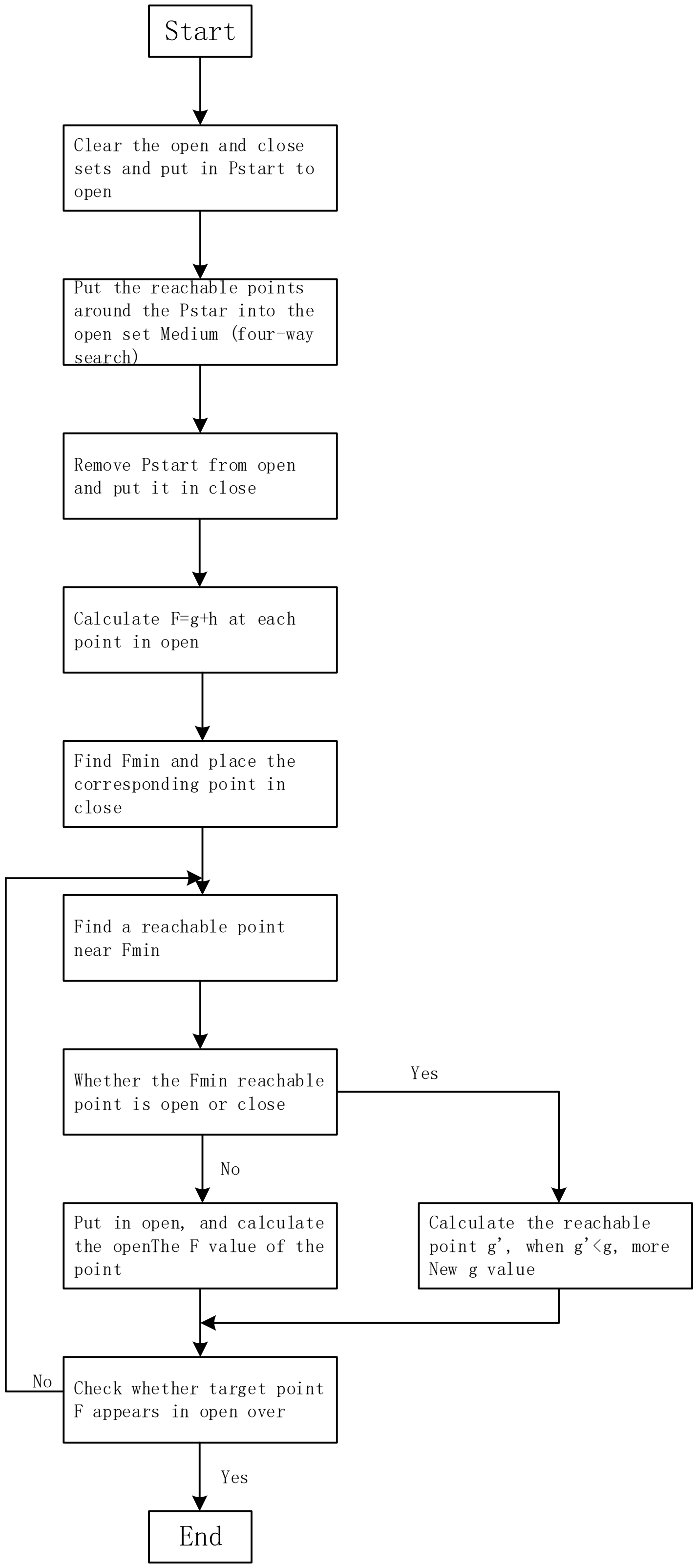

Figure 2. Path planning flowchart of the A* algorithm

ISSN: 2710-0588

4. Improved A* Algorithm and Simulation Test

The traditional A* algorithm has A good effect when applied to the fixed path. However, because the factory path planning stipulates that some roads can achieve two-way driving and some roads can only one-way driving, the wrong path planning often occurs when the A* algorithm is used for path planning. For this fixed path with single and double direction, it is necessary to optimize and improve the A* algorithm to solve the problem of wrong path planning.

By observing the map in Figure 1 for modeling, and intercepting a short section of single and double paths for research, as shown in Figure 3.

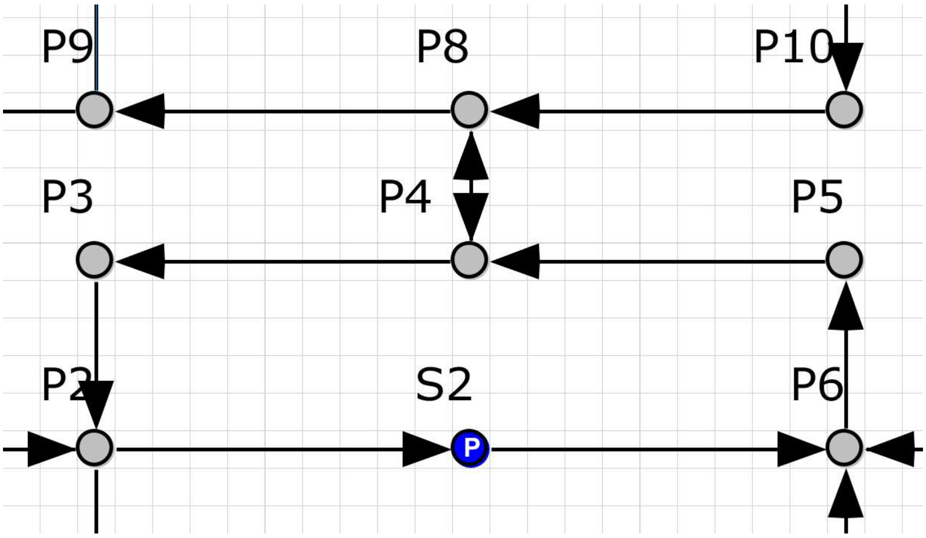

Figure 3. Part of the map modeling diagram

In the partial path map shown in Figure 3, P5-P4, P4-P3, P6-P5, etc. are all one-way paths. When the robot needs to reach P6 from P10, the traditional A* algorithm will plan the path of P10->P8->P4->P5->P6 according to the principle of shortest path, as shown in Figure 4. This violates the rule of one-way driving, and the reason for the error is that when the grid at P4 node searches for adjacent nodes, the adjacent nodes on the right side are not restricted. Therefore, this paper starts with the substitution value of g(n). When the A* algorithm takes P4 node as the parent node, the g(n) value of the adjacent nodes on the right side of P4 is set as the obstacle node value. Then the fitness value of the node on the right is infinite and will not be selected to enter the close set. At this time, the adjacent points on the left of P4 node will be selected, that is, the directional selection improvement of the A* algorithm has been completed. The improved path planning effect is shown in Figure 5.

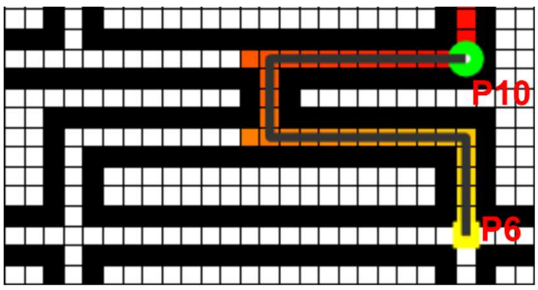

Figure 4. The A* algorithm path planning diagram is not improved

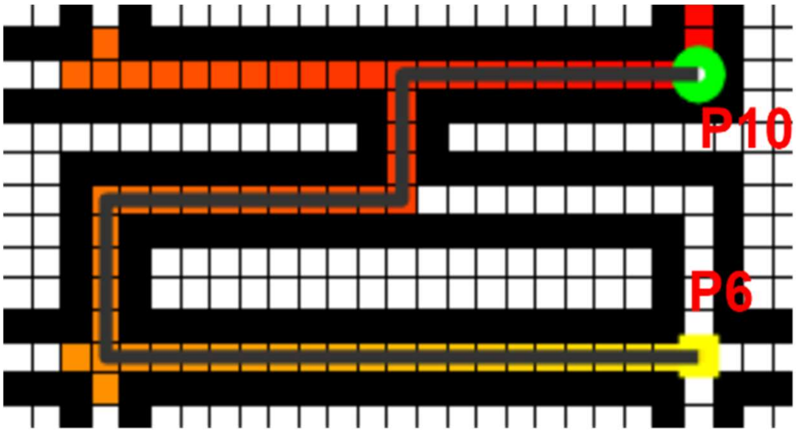

Figure 5. Improved A* algorithm path planning diagram

As can be seen from the comparison between Figure 4 and Figure 5, the improved A* algorithm does not search to the right at the inflection point, which not only speeds up the search speed of the A* algorithm, but also meets the path planning with single and double directional fixed paths.

5. Path Conflict Problem and Solution

When multiple robots are scheduled by the scheduling system, due to the fixed path, it is bound to cause the contradiction of path conflict during the operation of robots [11], which can be classified into the following three types:

As shown in Figure 6, when robot 1 and robot 2 are on the same path, robot 1 will first stop and rotate when entering the station point. At this time, the path is blocked by robot 1, causing robot 2 to be unable to pass this path. Although each robot has an obstacle avoidance device, robot 2 still has the possibility of collision with robot 1.

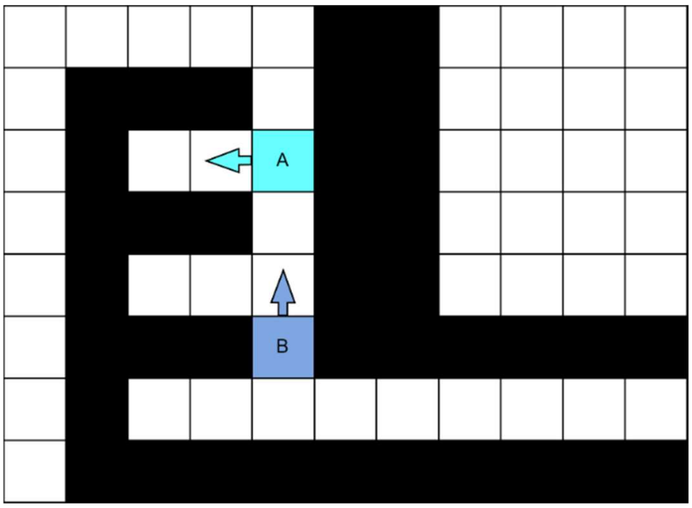

Figure 6. Schematic diagram of simultaneous pursuit collision

Robot corner conflict is shown in Figure 7. When robots meet at corners composed of different directions, due to the possibility of obstacle avoidance blind area, robots fail to take corresponding obstacle avoidance measures before collision, resulting in mutual collision between robots.

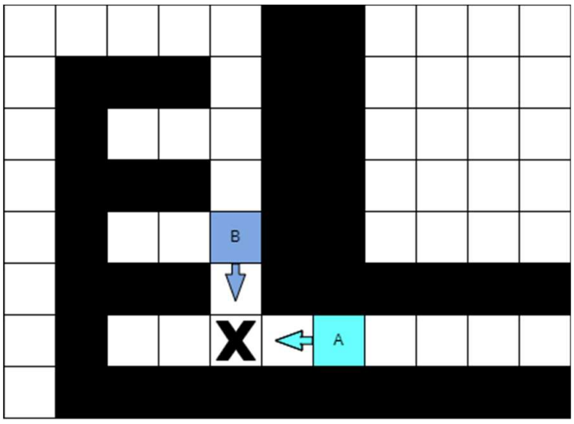

Figure 7. Corner collision diagram

As shown in Figure 8, this conflict is basically related to bidirectional path planning. The appearance of bidirectional path makes robots more flexible, and it also leads to bidirectional conflict when multiple robots use this path together.

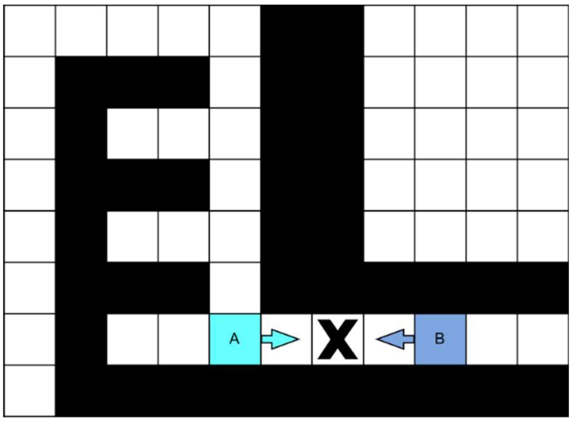

Figure 8. Diagrammatic collision

In view of the above three situations, this paper chooses to introduce the idea of traffic lights to solve the robot collision problem, and the solution flow chart is shown in Figure 9.

In the fixed path of this paper, due to the unidirectional and bidirectional path, it is still necessary to formulate some rules carefully when using the solution in Figure 9 to avoid collision. The supplementary rules are as follows:

According to the position of the current node and the next node during robot transportation, determine whether the road section occupied is horizontal or vertical, so as to prevent the robot from occupying two roads at the same time when it is in the horizontal and vertical nodes, such as nodes P9, P17 and P15 in Figure 3-4.

The bidirectional section of P4-P8 connects four unidirectional sections. In order to prevent two robots from appearing at P8 and P4 nodes at the same time, P3-P4-P5-P9-P8-P10 is synthesized as a section. When the robot runs to P10 or P5, it represents the possession of all nodes of the section. When it reaches P9 or P3, it means that all nodes in the section are released. If robot a and robot b arrive at P10 and P5 at the same time, respectively, the principle of the high priority of P5 is occupied.

P18-p19-P12-p20-p21-p22-p22 is synthesized as a path, where P18 nodes represent the beginning of occupation and P12 nodes represent the end of occupation, and the node occupation priority is P20>P21>P22>P22>P18.

ISSN: 2710-0588

The priority of the main path node is greater than that of the station node.

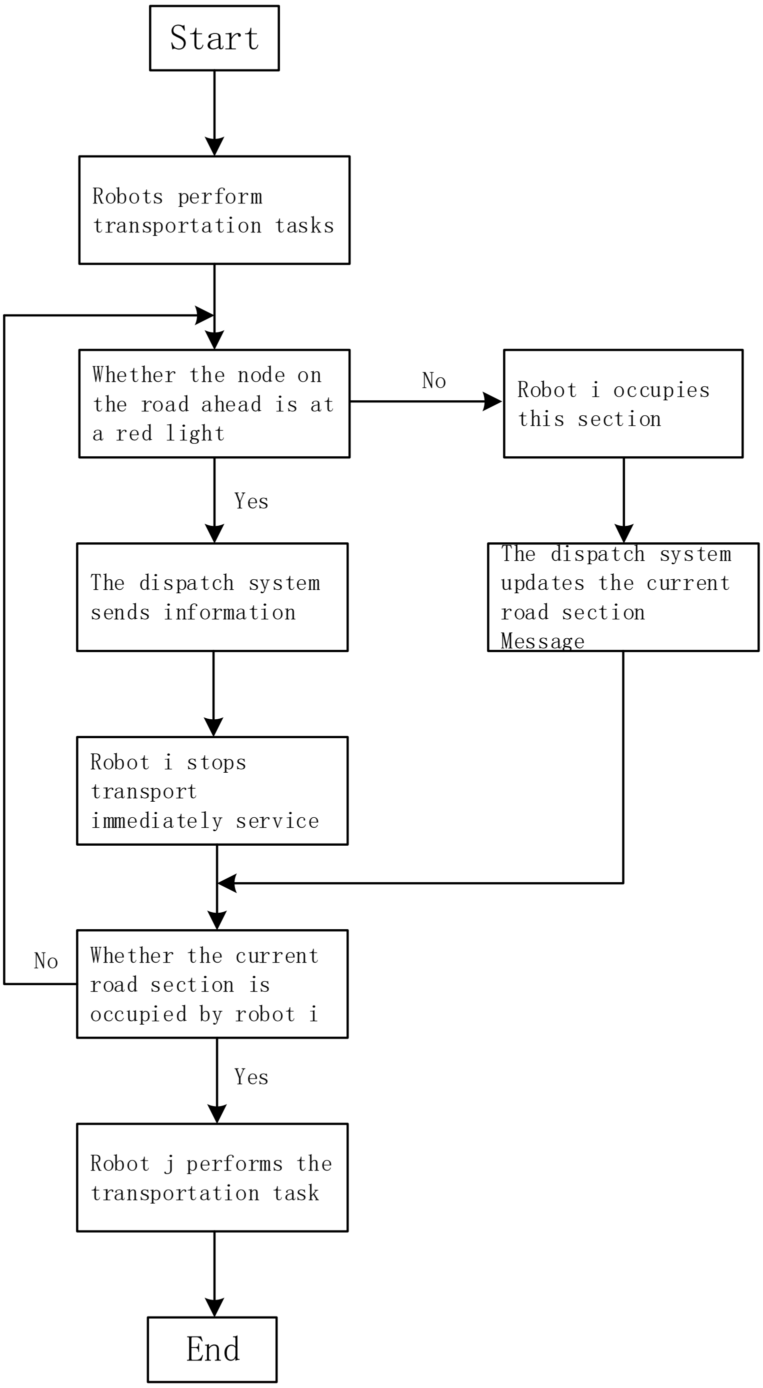

Figure 9. Robot collision avoidance solution strategy

6. Conclusion

Starting from the actual production demand, this paper constructs the map model and improves the path planning algorithm of A* algorithm. The path planning simulation based on improved A* algorithm is completed by Matlab software. Finally, the method of scheduling system to solve the path conflict problem is discussed. At the same time, Matlab GUI graphical interface is used to test the path planning. After testing, it is verified that the handling robot can execute the path instructions of the task scheduling system. The path planning strategy proposed in this paper is reasonable and meets the production requirements of the workshop.

ISSN: 2710-0588

This paper provides a feasible solution for the path planning of the handling robot in the Chinese medicine factory, which can be applied in the actual production, improve the production efficiency and reduce the cost. At the same time, future research can further optimize the algorithm to improve the effect and intelligence of path planning.

If you follow the "checklist" your paper will conform to the requirements of the publisher and facilitate a problem-free publication process.

References

[1] Matos, D., Costa, P., Lima, J., et al. Multiple Mobile Robots Scheduling Based on Simulated Annealing Algorithm, Communications in Computer and Information Science, vol. 1488 (2021), p. 187-202.

[2] Yuan, Z.; Yang, Z.; Lv, L.; et al. A Bi-Level Path Planning Algorithm for Multi-AGV Routing Problem, Electronics, vol. 9 (2020), p. 1351.

[3] Y.M.Li,G.C.Wang. Chaotic Sparrow algorithm AGV path planning based on falling mechanism, Manufacturing technology and machine tools, vol. 727(2023) , p. 102-108.

[4] X.T.Qiu. Research on Multi-sensor fusion Omnidirectional mobile robot technology based on EtherCAT [D], Jiangnan University,2021.

[5] Liu Chang. Research on Dynamic Optimization of AGV Scheduling System [D], Shandong University, 2021.

[6] Wang Jiajun. Research on Parking lot scheduling Strategy based on Parking AGV [D]. Shandong University of Science and Technology,2020.

[7] C. Wang and J. Mao.Summary of AGV Path Planning[C].2019 3rd International Conference on Electronic Information Technology and Computer Engineering,2019, p. 332-335.

[8] Lu Yingying. Design of Multi-AGV Logistics System based on Wireless Scheduling [D]. Jiangsu University of Science and Technology,2015.

[9] F. Jia, C. Ren, Y. Chen, et al.A system control strategy of a conflict-free multi-AGV routing based on improved A∗ algorithm[C].2017 24th International Conference on Mechatronics and Machine Vision in Practice (M2VIP),2017, p. 1-6.

[10] Giuseppe Fragapane, René de Koster, Fabio Sgarbossa, et al.Planning and control of autonomous mobile robots for intralogistics: Literature review and research agenda[J].European Journal of Operational Research, vol. 294 (2021), p. 405-426.

[11] Sun Guijie. Research on Control System of Autonomous Mobile Robot [D]. Jilin University,2021.