AGV PATH PLANNING BASED ON SMOOTHING A* ALGORITHM

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ABSTRACT

The path consumption of the digital map in the grid as the environment expression way is discrete, for Automated Guided Vehicle(AGV) to achieve low consumption and smooth path planning target, the A algorithm is applied to the path planning based on grid, and the optimal path is realized. A path smoothing method is proposed and applied to the path of A*. The smoothing method satisfies the AGV turning radius, makes the path smooth transition at the break point, and realizes the smooth path deviation. The simulation results are verified by using the grid method, and the path of the proposed method is smoother, the path consumes less and the path error is less than that of the A*.*

KEYWORDS

Automated Guided Vehicle (AGV), A Algorithm , Smooth Path*

1. INTRODUCTION

Path planning technology is one of the key technologies of AGV. Its task is to find a path from the initial state (including position and attitude) to the target state (position and attitude) in the environment with obstacles. The A* algorithm is based on the grid map, and the grid map is a way of environmental expression which can be obtained by the discretization of the actual environment. In the cell interior, the path is the same, and the path between the adjacent grid and the grid is not continuous [1-2].

Because the path of each unit cell is discrete, each grid is used as a whole to participate in the path planning algorithm, such as A* algorithm, the final design of the path is composed of a representative unit grid (or center) endpoint connection, the path direction changes the increment only is pi / 4, so the design path are usually not the actual environment optimal, smooth path [3-4].

A* algorithm can achieve the continuous path, but the path of the change is usually not continuous, which is due to the approximate expression of the path. The design of the final path must meet the dynamic characteristics of AGV itself, such as: the initial speed direction, turning radius and so on, the algorithm needs to calculate the path of smooth [5]. According to the information around the obstacles, this paper presents a tangential smoothing method based on A* algorithm, to realize continuous change of the direction of the path. The proposed smoothing method is applied to the path planning algorithm, the path of the final path is optimized and the smooth transition of the path is satisfied.

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2. PRINCIPLE OF A* ALGORITHM

The search space is described as a set of nodes and the edges are connected to each side, each side length is given to the path value, so that the path of the search can be represented by the nodes in the space. A* searches for the shortest path by selecting the node sequence of the path between the start node and the destination node. The AGV path search area is required to be grid, and the AGV runtime environment map is partitioned into a set of size uniform squares, each of which represents a certain position in the environment (as shown in Figure 1). The core part of the A* algorithm is the evaluation function:

$$f^*(n) = g^*(n) + h^*(n) \tag{1-1}$$

In the formula: n represents the current node to search; $f^*(n)$ is the evaluation function, which means that the cost of the optimal path from the initial position to the target position after the node n is reached; $g^*(n)$ represents the actual value of the minimum path from the initial position to the node n, if n is the starting point, then the $g^*(n) = 0$; $h^*(n)$ is the cost value of the optimal path to "estimate" from the node n to the target location.

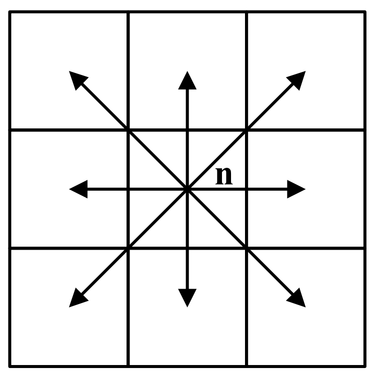


Figure 1. A* algorithm development node orientation map

An evaluation function of $h^*(n)$ is the type (1-2), the current node n coordinates (x_1, y_1), and the target node coordinates are (x_2, y_2):

$$h^*(n) = \sqrt{[(x_1 - x_2)^2 + (y_1 - y_2)^2]^2} \tag{1-2}$$

Then the evaluation function is:

$$f^*(n) = g^*(n) + \sqrt{[(x_1 - x_2)^2 + (y_1 - y_2)^2]^2}$$

The A* algorithm is extended from the 8 directions of the starting node, and the direction is shown in Figure 1. We select the node as the $h^*(n)$ value of the second nodes in the 8 nodes, and then expand the sequence of second nodes. This way, the path can be simply iterated until the destination node is searched. The A* algorithm is set up to two lists: one is open list (OPEN), the other is closed down list (CLOSED). When the node is expanded, the existing obstacles and the existing node direction will not be extended, and stored in the closed list.

3. AGV MOTION MODEL

Single steering wheel is a common AGV wheel structure types, including a main navigation wheel, two driven wheel, and a plurality of universal auxiliary supporting wheel, its structure is shown in figure 2. This structure of the AGV turning radius is small, and the movement is flexible. Among them, the main navigation wheel is both the driving wheel and the steering wheel, which is driven by different servo motors. A driven wheel is fixed on the lower part of the support body after landing fork, do not rotate about the direction can be realized. According to the kinematic model of AGV and the return data of the encoder, it can be used to solve the position and attitude of AGV, and then realize the real-time positioning of AGV.

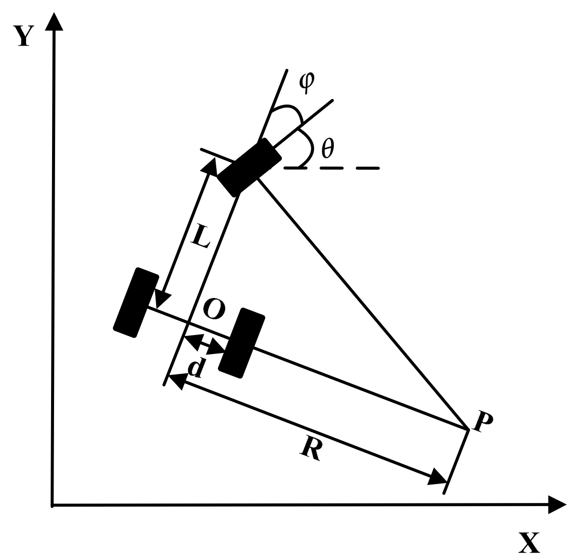


Figure 2. The kinematics model of single wheel AGV

Considering the minimum turning radius as AGV kinematic constraints in the running process, figure 2 is a simplified model of the single wheel AGV [6].

Assume that AGV's posture is (x, y, θ), the x, y is the position coordinates of the AGV, θ is the direction angle of the AGV, φ is the central axle and the front wheel of the AGV driving direction angle, known as a steering angle. AGV wheel steering mechanism has the mechanical characteristics of the constraint:

$$\varphi \leq \varphi_{\max} \tag{1-3}$$

There is an upper bound of the path curvature ρ of the path of AGV:

$$\rho \leq \frac{1}{R_{\min}} = \frac{1}{L \cot \varphi_{\max}} \tag{1-4}$$

In the formula, L is the front and rear wheel axis distance, as shown in Figure 2, the minimum turning radius is:

$$R_{\min} = L\cot\varphi_{\max} \tag{1-5}$$

Therefore, when the AGV turn, we take the minimum turning radius as its kinematic constraint. We will use it as a path to smooth processing.

4. SMOOTH PATH PLANNING METHOD

4.1. Inscribed circle smoothing method

The inscribed circle smoothing method is independent of θ, the inscribed circle to achieve the smooth transition of the path, with the radius of the arc is $R_{\min}$ we replace the original line in the corner, the arc tangent to two lines, as shown in Figure 3, and then the broken line S_1Q 、 QS_2 will be replaced by $\overset{\frown}{S_1S_2}$.

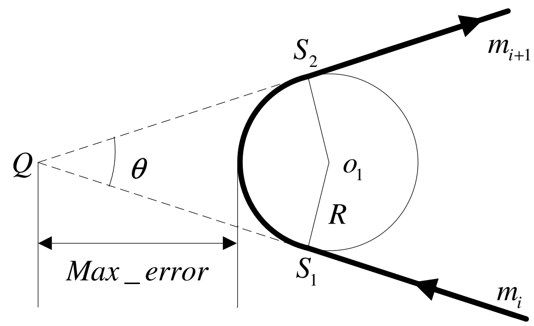


Figure 3. Inscribed circle smoothing method

The path is smoothed:

$$\overset{\frown}{m_iS_1}S_2m_{i+1} = R\angle S_1O_1S_2 \tag{1-6}$$

The maximum error deviation from the original route is calculated as follows:

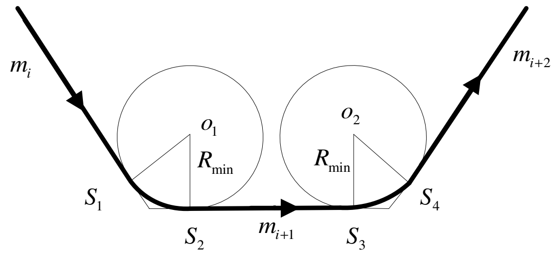
$$Max\_error = \frac{R}{\sin(\frac{\theta}{2})} - R = R(\frac{1}{\sin(\frac{\theta}{2})} - 1) \tag{1-7}$$

In the selection of the path smoothing method, we first determine whether it can meet the requirements of security, here to determine the maximum deviation of the path of the path of the unit path. When the path of the bias point is far greater than the discount of the unit path, that is, the deviation can be regarded as an obstacle, and then the smoothing method cannot be applied to the smooth [7-9].

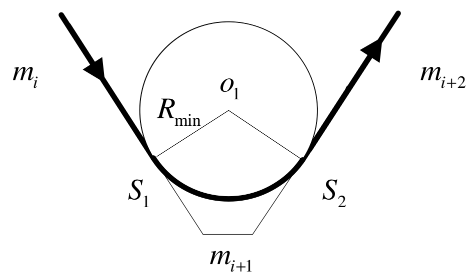
For the inscribed circle smooth method, when the angle θ between the connected paths is smaller, and turning radius R is larger, smoothed path of maximum deviation Max _ error is bigger, so we take the minimum turning radius of AGV is $R_{\min}$, the smooth two section path angle is θ.

4.2. Special Case 1

If the corner is sufficient for two smooth arc tangent to the path, as shown in Figure 4 (a), we draw Inscribed circle with m_i and m_{i+1} 、 m_{i+1} and m_{i+2} respectively, tangent point is S_1 and S_2 、 S_3 and S_4 respectively, and the new path is $m_i + \overset{\frown}{S_1 S_2} + m_{i+1} + \overset{\frown}{S_3 S_4} + m_{i+2}$. If the corner is not enough for the two smooth arc tangent to the path, as shown in Figure 4 (b), we draw Inscribed circle with m_i and m_{i+2}, tangent point is S_1 and S_2, and the new path is $m_i + \overset{\frown}{S_1 S_2} + m_{i+2}$.



(a)

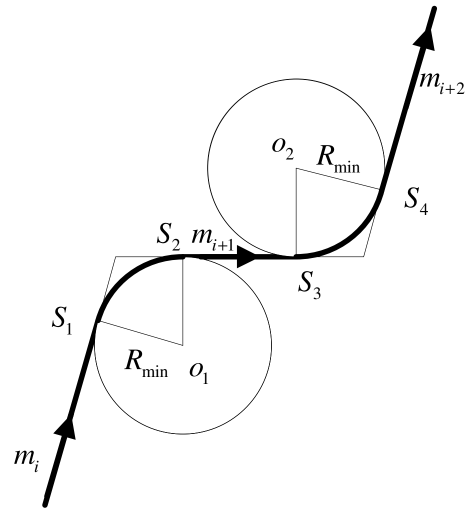


(b)

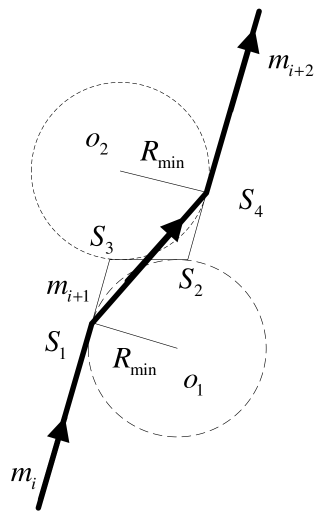
Figure 4. Special case 1

4.3. Special Case 2

If the corner is sufficient for two smooth arc tangent to the path, as shown figure in Figure 5 (a), we draw Inscribed circle with m_i and m_{i+1} 、 m_{i+1} and m_{i+2} respectively, tangent point is S_1 and S_2 、 S_3 and S_4 respectively, and the new path is $m_i + \overset{\frown}{S_1 S_2} + m_{i+1} + \overset{\frown}{S_3 S_4} + m_{i+2}$. If the corner is not enough for the two smooth arc tangent to the path, as shown in Figure 5 (b), we draw Inscribed circle with m_i and m_{i+1} 、 m_{i+1} and m_{i+2} respectively, tangent point is S_1 and S_2 、 S_3 and S_4 respectively, and we draw Inscribed circle with m_i and S_1S_2 、 S_1S_2 and m_{i+2}, the final processing method is shown in Figure 5 (a).



(a)



(b)

Figure 5. Special case 2

5. SIMULATIONS

We take $L = (\sqrt{2}+1)m, \varphi_{\max} = 45^\circ$, and then $R_{\min} = L\cot\varphi_{\max} = (\sqrt{2}+1)m$. Using the minimum turning radius circle to replace the key points of the broken line, combined with the analysis of the path of the above, the path is shown in Figure 6.In the graph, the black path is the path before the smooth, and the red path is the path of the process. It can be seen that the path of the process is much smoother than the previous path.

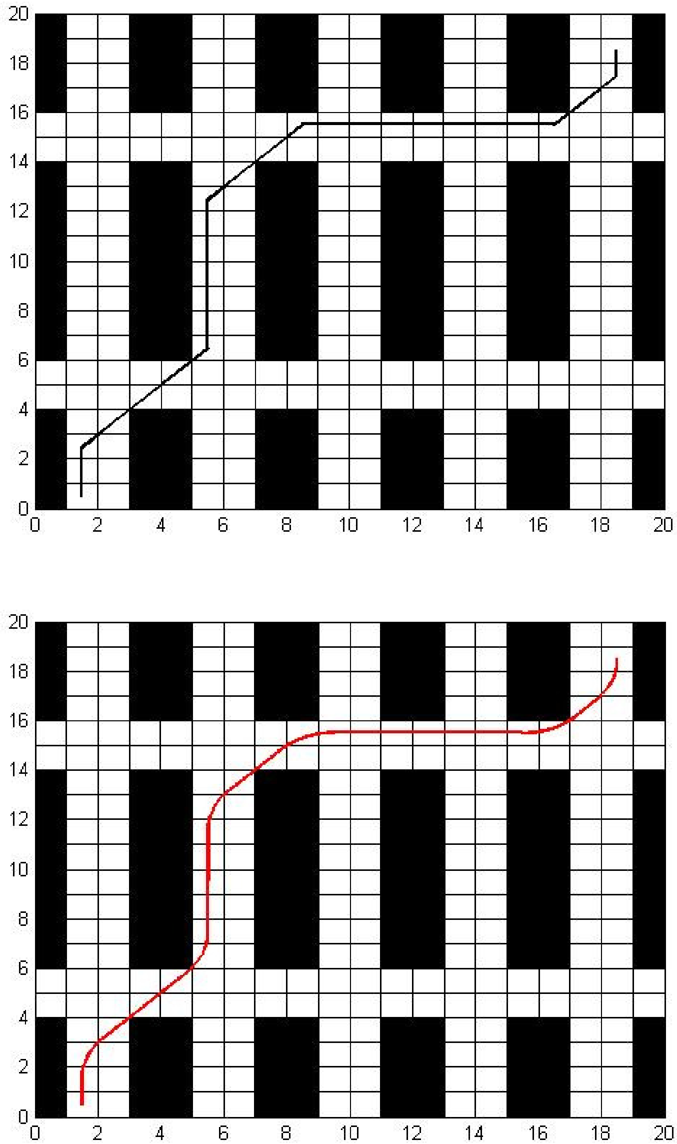


Figure 6. Simulation results

For the evaluation of the path can be used in the path of the consumption of the path as an evaluation index, the path is less consumption of the path is more excellent.

Table 1. Comparison of simulation results

	Path consumption (m)	**Maximum deviation (m)**
A* Algorithm	29.6	
Smoothing A* algorithm	27.8	0.21

6. CONCLUSIONS

When the A* algorithm searches path, each step is to the adjacent eight grid search, and then into the next grid. If the simple lattice to the grid is acceptable, but if it is a real experiment in particular the mobile robot which needs to smooth, which is unacceptable.

Taking into account the new path in the presence of some abrupt turning point and local area have jitter, combined with the AGV motion constraints, w extract the key points in the path, and follow the path to the smooth processing.

The path smoothing method proposed in this paper can be very good to meet the dynamic characteristics of AGV, especially to meet the AGV turning radius. In addition, the local path deviation is minimized by the judgment of the information of the obstacle, and the total deviation of the path is achieved.

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