Research on Path Planning of Mobile Disinfection Robot Based on Improved A* Algorithm

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Abstract. The traditional A* algorithm uses Euclidean distance as the heuristic function in the path planning of mobile disinfection robot. This method may lead to the generation of a certain number of useless nodes, which makes the search time longer. To solve this problem, this paper proposes an improved A* algorithm, starting from the heuristic function, adding additional value to the heuristic function, using the cosine value of the angle as the additional parameter. This method effectively reduces the comparison of useless points with the same F value, and significantly reduces the number of visited nodes. The simulation results show that the improved A* algorithm can significantly improve the path planning efficiency of mobile disinfection robot.

1.introduction
With the progress of science and technology in the last 20 years, robots are no longer only used in manufacturing industry, but also play a strong role in other fields such as scientific research, life, medical treatment and education[1]. Especially since last year novel coronavirus pneumonia has occurred, in the material transportation, safety disinfection and other links, there has been a non-contact, fully automatic mobile robot, which has made great contributions to fight against the epidemic situation. Mobile disinfection robot can realize contactless distribution and protect people's lives. In high infection areas, it can also replace manual disinfection, measurement, cleaning and other work to reduce the risk of human infection[2]. In the field of robot, path planning has been a hot topic at home and abroad [3]. Path planning means that the mobile robot obtains the global information of the environment through the sensor, and plans an optimal path through the path planning algorithm, which can make the mobile robot move from the starting point to the target point safely and quickly [4]. As an intelligent heuristic algorithm, A* algorithm has a wide range of applications due to its strong portability and plasticity [5], such as aerospace, agriculture, manufacturing, warehousing and logistics [6]. But the traditional A* algorithm also has many shortcomings. Euclidean distance is used as the heuristic function in traditional A* algorithm, which may lead to the generation of a certain number of useless nodes, thus making the search time longer. Therefore, improving the heuristic function to reduce the number of useless nodes is also the focus of research. In order to solve the problem of multiple visits to useless nodes in the process of searching path, this paper adds the angle
cosine added value as a new heuristic function on the basis of Euclidean distance. Under the premise of selecting appropriate weights, the A* algorithm reduces the number of visits to useless nodes in the process of searching path. Compared with the traditional A* algorithm, the efficiency of path planning of mobile disinfection robot is significantly improved by this method.

2. Principle and improvement of A* algorithm

2.1. The principle of traditional A* algorithm

A* algorithm is a typical heuristic search algorithm for finding the optimal path in a static environment. It can quickly find the path to the target point in a known environment [7]. Its working mode is to evaluate the surrounding nodes from the starting point and select the low cost point for expansion, the corresponding heuristic functions are as follows:

\[ f(n) = g(n) + h(n) \]  
(1)

\[ g(n) \] is the actual cost from the starting point \( s \) to the evaluation point \( n \), while \( h(n) \) is the estimated cost from the evaluation point \( n \) to the target point \( g \). The estimation function of the basic A* algorithm is generally calculated by Euclidean distance formula (2) and Manhattan distance formula (3).

\[ h_E(n) = \sqrt{(x_n - x_g)^2 + (y_n - y_g)^2} \]  
(2)

\[ h_M(n) = |x_n - x_g| + |y_n - y_g| \]  
(3)

There are two lists, open list and close list in A* algorithm's route finding process. The route finding process is as follows:

- Initialize the open list and close list, make sure that the close list is empty, and then put the starting point into the open list.
- Determine whether the open list is an empty list. If it is, the pathfinding fails. If there is a target node, the pathfinding succeeds.
- Select the node with the lowest F value in the open list as the parent node, and then put it in the close list. Put the node that can reach the current node into the open list, calculate the F value of each reachable node of the current node, and take the node with the lowest F value as the new expansion node.
- Skip to the second step until the end point is found.

![Figure 1. An example of A* algorithm.](image)

The algorithm flow chart is shown in Figure 2:
Figure 2. Flow chart of A* algorithm.

From the steps of A* algorithm, we can see that the actual cost is constantly updated with the iteration of the algorithm, and the algorithm expands from the current point to the surrounding, forming a large number of unnecessary redundant nodes. In the process of route planning, we only need one optimal route, but when some feasible routes have the same F value, all routes will be searched. A* algorithm will compare the nodes with the same F value one by one, which will lead to long search time and low search efficiency.

2.2 Improvement of A* algorithm
In order to improve the search efficiency, this paper chooses to start from the heuristic function, add additional value to the heuristic function, and choose the cosine value of the angle as the additional parameter. Let there be vectors $\vec{O AJ}$ and $\vec{O BJ}$ in the plane. The angle between vectors $\vec{O AJ}$ and $\vec{O BJ}$ is $\alpha (0 \leq \alpha \leq 180)$. The angle between vectors is shown in Figure 3.

Figure 3. The angle between vectors

According to the cosine theorem of vector angle, as shown in equation (4), the cosine value of
angle $\alpha$ can be obtained. Suppose point $A(x_1, y_1)$, point $B(x_2, y_2)$, then the cosine value of the angle can also be expressed as equation (5).

$$
\cos \alpha = \frac{x_1 x_2 + y_1 y_2}{\sqrt{x_1^2 + y_1^2} \sqrt{x_2^2 + y_2^2}}
$$

Before selecting a point in the next step, take the current point as the coordinate and the end direction as the positive direction of x axis and y axis to build a coordinate system. Through this coordinate system, we can build a vector for analysis and judgment, as shown in Figure 5.

![Figure 4. Angle diagram](image)

It can be seen that there are four points A, B, C and D in the figure above. The angle between a and B and the positive direction of x axis is greater than 180°, so this point is obviously inconsistent. When selecting, this kind of points can be directly excluded without operation, and the angle between C, D and y axis is between 0 and 180°. We can judge by setting the angle between vectors $\overrightarrow{SC}$ and $\overrightarrow{SD}$ and y axis as $\alpha$ and $\beta$. According to the cosine formula of vector angle, we can get the following formula:

$$
\cos \alpha = \frac{\overrightarrow{SC} \times \overrightarrow{SN}}{|\overrightarrow{SC}| |\overrightarrow{SN}|}
$$

$$
\cos \beta = \frac{\overrightarrow{SD} \times \overrightarrow{SN}}{|\overrightarrow{SD}| |\overrightarrow{SN}|}
$$

According to the property that the cosine value is monotone decreasing from 0° to 180° and the range of its value is -1 to 1, the monotonicity of the heuristic function is constrained as follows:

$$
h(n) = h_0(n) + h_{\cos}(n)
$$

$$
h_{\cos}(n) = -\omega \cos \theta
$$

Taking C and D into the formula, the following equation is obtained:

$$
h_{\cos}(C) = -\omega \cos \alpha
$$

$$
h_{\cos}(D) = -\omega \cos \beta
$$

$$
h_{\cos}(C) < h_{\cos}(D)
$$

In the improved a* algorithm, we assume that the F values of C and D are the same:

$$
f(A) = g(A) + h(A) + h_{\cos}(A)
$$

$$
f(B) = g(B) + h(B) + h_{\cos}(B)
$$

$$
f(A) < f(B)
$$

It can be concluded that after the improvement, if point C is in the optimal path, for the subsequent node $x$ after point C, there is $f(x) < f(D)$, then point D will not judge before the completion of the search, which effectively reduces the comparison of useless points with the same f value, and improves the efficiency of the algorithm.
3. Simulation experiment

The simulation experiment is carried out in the environment of Matlab R2016b, and a 64 × 64 simulation map is built. By establishing a rectangular coordinate system, the lower left corner coordinates of the simulation environment map are defined as (1,1); the upper right corner coordinates are defined as (64,64). After using the angle cosine formula as the added value to improve the heuristic function, we can choose the appropriate weight $\omega$ to reduce the number of visits to invalid nodes in the search process of A * algorithm. In the experiment, the weights of 5 and 10 are selected to test, and the experimental data as shown in Table 1. are obtained.

| Experimental group number | Number of access nodes | The number of access nodes after improvement ($\omega=5$) | The number of access nodes after improvement ($\omega=10$) |
|---------------------------|------------------------|-------------------------------------------------------|-------------------------------------------------------|
| 1                         | 320                    | 286                                                   | 260                                                   |
| 2                         | 147                    | 114                                                   | 101                                                   |
| 3                         | 262                    | 231                                                   | 205                                                   |
| 4                         | 81                     | 79                                                    | 78                                                    |
| 5                         | 408                    | 370                                                   | 354                                                   |
| 6                         | 636                    | 504                                                   | 465                                                   |
| 7                         | 218                    | 164                                                   | 133                                                   |
| 8                         | 122                    | 105                                                   | 98                                                    |
| 9                         | 720                    | 564                                                   | 501                                                   |
| 10                        | 486                    | 398                                                   | 364                                                   |

From the above experimental data, we can further analyze the angular cosine as a heuristic function, as shown below:

![Comparison chart before and after improvement](image)

Figure 5. Comparison chart before and after improvement

From the comparison results in the above table, it can be seen that the improved A * algorithm can significantly reduce the number of access nodes.

4. Conclusion

In this paper, the path planning algorithm of mobile disinfection robot is studied. The traditional A * algorithm uses Euclidean distance as the heuristic function, which leads to the generation of a certain
number of useless nodes and makes the search time longer. It adds cosine correlation value to the heuristic function and reduces the comparison of useless points with the same F value. The experimental results show that the improved A* algorithm is faster than the traditional A* algorithm, and with the increase of the number of search nodes, the optimization range is more obvious. The next step is to verify the algorithm through physical testing.

Acknowledgments
Thanks to Mr. Sun's careful guidance, Mr. Sun gave me suggestions on many questions. The work presented in this paper is supported by the Plateau Disciplines in Shanghai.

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