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Study on Path Planning of Patrol Obstacle Avoidance Based on Robot NAO

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***Abstract*—Path planning is the core part of robotic patrol and obstacle avoidance ,which has been widely used. Considering about the family environment and the various factors of different path planning algorithms, artificial potential field algorithm is selected as the path planning algorithm. In addition to derive the traditional artificial potential field algorithm, this paper also introduced solutions such as how to solve the various defects of traditional artificial potential field algorithm, the simulation of traditional artificial potential field algorithm and verify the feasibility of modifying the algorithm. The integrity and superiority of the process are the hallmarks of this article.**

Keywords—Artificial potential field algorithm; taking straight line; setting middle target point; path optimization.

I. INTRODUCTION

At present, service robots gradually converge with daily life, which brings people convenient and reliable life experience. The first premise of service robot applied to home security is the optimization and realization of path planning algorithm. Path planning is the core part of the intelligent patrol module. The path planning directly affects the reliability of the NAO robot in performing tasks. Usually an excellent path planning method needs to meet the simplicity, logic, integrity, optimality, adaptability and the binding principles.

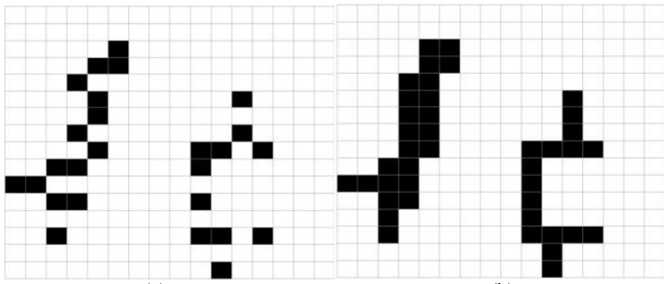
As a complex information system, large-scale network has So far series of path planning algorithms have been produced: artificial potential field method, grid method, neural network method, genetic algorithm and so on. The current path planning algorithms have their own advantages, but also have their shortcomings. Therefore, one direction for the future development of path planning technology is to optimize and improve the existing path planning algorithms.

II. DESIGN OF PATH PLANNING ALGORITHM

A. *Obstacle Handling*

For continuous obstacles (the distance between the obstacles is relatively close, while the number of obstacles is at least two) First of all, we use the mathematical morphology of binary images to classify them. Then the expansion of the obstacle operation to close together the obstacles into a large obstacle. In this way, the robot can solve the problem that the path can not be planned between two obstacles with very close distance.

Define an expansion operation: Set as a set of adjacent grids at the robot's motion space w, for a grid w belonging to a subset of obstacles and adjacent to the set of free grids, and populate the set with the elements in the set of obstacles. Figure 3-1 (a, b) shows the expansion process. The robot's motion space is divided into grids, so that the obstacles will be presented in the form of grids. The expansion operation of the barrier grids essentially means that the grids of obstacles occupy free grids between the obstacles, so that the obstacle assembly changes into a unit. In Fig. 1(a) shows the distribution of obstacles with a relatively short distance in the robot's motion space, and Fig. 1(b) shows the figure Fig. 1(b) after a large number of expansion operations in Fig. 1(a).



(a) (b)

Fig. 1. The distribution of obstacles.

Discrete obstructions refer to obstacles that are single and distant from other obstructions. In the traditional artificial potential field algorithm, the destination, obstacles and mobile robots are abstracted into a single particle. However, in this thesis, humanoid robot is working in a home environment, and obstacles in the family can not be regarded as particles, and the volume can not be ignored. If the volume is too large, it is very likely that the humanoid robot will cross the obstacle along the route established by the traditional artificial potential field algorithm, and the collision between the robot and the obstacle will occur, as shown in Fig. 2.

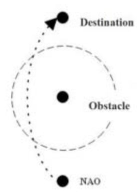


Fig. 2. Schematic diagram.

For discrete obstacles, this paper uses "puffing" approach to deal with different shapes of obstacles in the family, that is, with the smallest circle that can contain obstacles to represent obstacles, the size of the circle with the size of obstacles, as shown in Fig. 3.

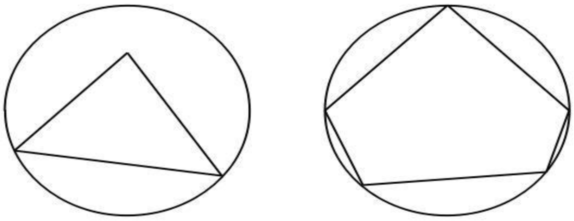


Fig. 3. Dispersion of discrete obstacles

B. Set the Middle Target Point

In order to solve the problem that the robot can not reach the destination when there is an obstacle near the destination and the robot falls into the local minimum and the obstacle before oscillation, this section adopts the method of setting the intermediate target point, that is, setting the intermediate target point in the middle of the path, It creates new traction, thus solving the above two problems, of which the number of intermediate target points can be set according to the actual situation.

When the robot is in the local minima and the obstacle frontal oscillation, the middle target point is set as follows: Once the robot is detected as local minima or obstacle frontal oscillation, the algorithm will set an intermediate target point The robot creates a new traction force that keeps the robot out of the local minimum or frontal obstacle range. After that, the robot re-planned the route. If the robot falls in to the above situation again, the algorithm sets the second intermediate target point. In the end, the robot reached its destination smoothly. As shown in Fig. 4, in the figure, G is the destination, g_1 is the middle set point, NAO is the position of NAO robot, and the arrow is the direction of NAO robot's movement.

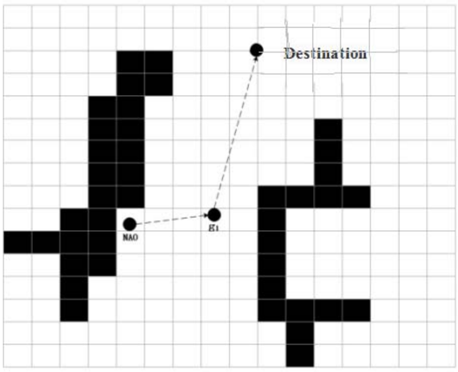


Fig. 4. Setting of middle target point with local minimum.

In the following we explore the feasibility of setting intermediate targets by solving the local minimum problem. When the robot falls into a local minimum state, we set an intermediate target point in the path, which aims to generate new traction for the robot and hence the robot Escape from the local minimum problem. For ease of analysis and understanding, Fig. 5 shows the robot's force in the motion space, including the repulsion of each obstacle to the robot and the gravitational pull of the robot to the destination.

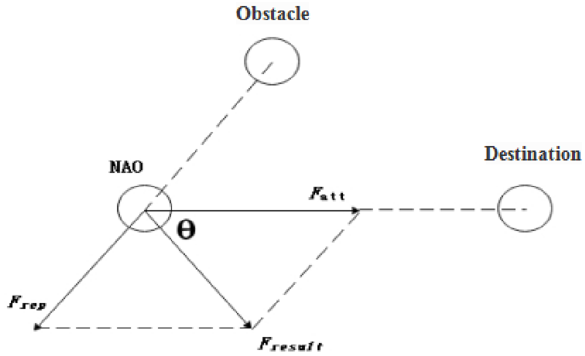


Fig. 5. robot force diagram.

Analysis of the robot's force situation shows that the potential field angle θ and the force F_{result} are in the same direction, the robot moves along the direction of potential angle.

Here is the repulsion of the i-th obstacle that the robot is subjected to, k----the total number of obstacles.

When the robot satisfies the following two conditions, it is in the local minimum phenomenon.

$$\begin{cases} \dfrac{F_{att}(w)-F_r}{F_{att}(w)} < \beta & (|\beta| \to 0) \\ \cos(\angle F_{att}(w)-F_r) = \eta & (\eta \in [-1,0]) \end{cases} \quad (1)$$

$$F_r = \sum_{i=1}^{k} F_{repi}(w) \quad (2)$$

At this point, we set the intermediate target point, which gives the robot a new tractive force (as in the formula) that hits the robot away from the local minima.

$$F_{pull} = \frac{a}{(w-w_o)_{\min}^{\lambda_1} + l_0^{\lambda_2}} \left|\cos(\angle F_{att}(w)-F_r)\right| \quad (3)$$

F_{pull} is the new target of the middle of the robot's traction, a, λ_1, λ_2 are proportional parameters, $(w-w_o)_{\min}$ means that the minimum distance between the robot and the obstacle, l_0 is the length of the obstacle affected range.

C. Path Optimization

When the robot reaches a certain position, the artificial potential field algorithm will calculate the next path point according to the preset robot step length and locate the path point at the next-level target point. In this process, the artificial potential field algorithm to develop a smooth curve of the route, which led to the robot constantly adjusted forward, wasting time and power consumption. This paper uses a "take a straight line" approach to optimize the path, the design idea from the "two points between the shortest line," this theorem. In the path optimization method, the optimal path is composed of a straight line.

The method of "take straight line" is as follows: In this process of moving the robot from the current position to the destination, using the position of the robot as a starting point and connecting the closest path point to make it a straight line. If the straight line does not cross the obstacle, the starting point reconnects to the next path point to form a new straight line until the line crosses the obstacle or the line reaches the obstacle less than or equal to the distance M_0. This line is the local optimal path we need. Then we use the end point of this line as the starting point of the next line and then create a new local optimal path as described above until the robot reaches its destination.

Use Fig. 6 to illustrate the "taking straight line" optimization method. The hypothesis $T_i \in \{T_1, T_2, T_3, \cdots, T_i, T_{i+1}, \cdots, T_n\}$ is a set of path points formulated by the artificial potential field algorithm. First of all, T_1 is the robot's current position. Use this point as an initial point and connect the next path point T_2 to form a straight line L_{1-2}. Then, it is determined whether the straight line passes through the obstacle or whether the distance Dis between the straight line and the obstacle is not smaller than the distance Dis_0. If there is no obstacle or if Dis is greater than Dis_0, then connect the next path point T_3 to form a new straight line L_{1-3}, and continue the above operation until the obstacle is crossed or Dis is less than or equal to Dis_0, then the straight line formed is the local optimal path. Then the point T_i as the initial point, followed by the path to connect the back point, repeat the above operation. In the figure, the final optimal path is composed by L_{1-i} and . L_{i-n}

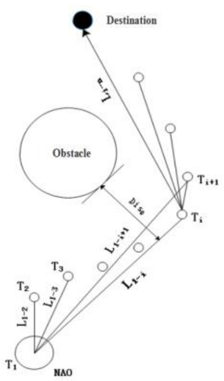


Fig. 6. Path optimization diagram.

III. SIMULATION AND RESULTS

A. Matlab Simulation Environment Settings

In the Matlab environment, this paper verifies the feasibility of improved artificial potential field algorithm in path planning. In this paper, a square with a side length of 25m is set as the robot's motion space, and randomly arranged in the space of eight points, which represents the home environment of the obstacle that k = 8, the obstacle distribution shown in Fig. 7. Starting from (0,0), the robot eventually needs to reach its destination (25,25).

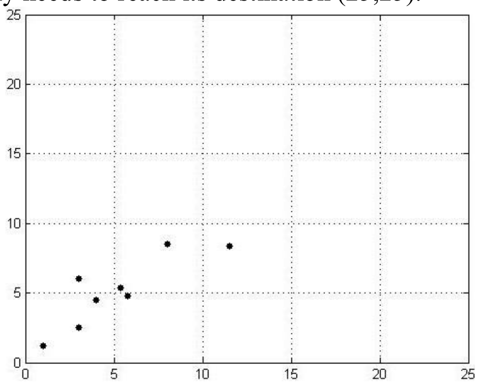


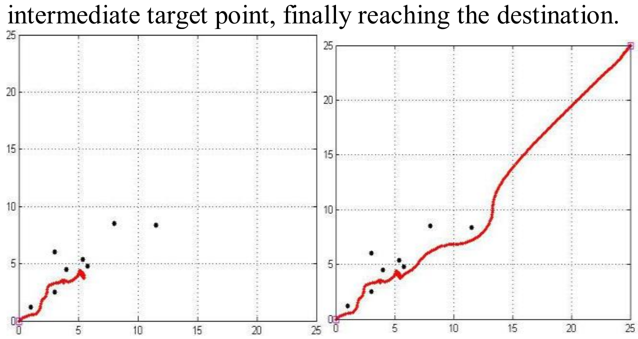
Fig. 7. The obstacle distribution.

Before starting the simulation, we need to set various parameters in the algorithm. Set the gravitational potential factor equal to $k_{att} = 1$, repulsive potential field factor equal to $k_{rep} = 1$, obstacle impact on robot length range equal to $l_0 = 0.5m$, a = 2, $\lambda_1 = 0.5$, $\lambda_2 = 0.5$ $\beta = 0.1$ In order to obtain the optimal path, set $Dis_0 = 0.2m$.

B. Simulation Results and Analysis

This section takes the experiment to solve the problem of local minima as an example to verify the feasibility of the modified artificial potential field algorithm through simulation experiments.

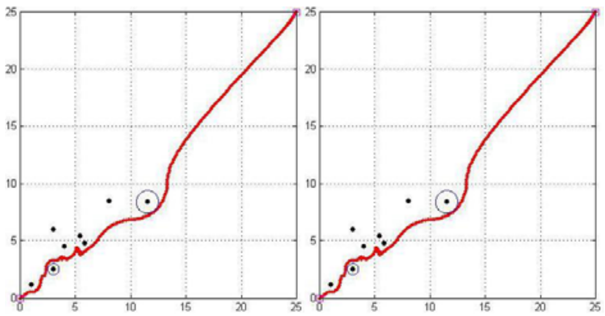
First, we use the traditional artificial potential field algorithm to simulate the environment set in the previous section. The simulation results are shown in Fig. 8(a). From the figure we can see that the robot is in a local minimum during operation , Resulting in the robot has been hovering in this position, can not reach the destination. Fig. 8(b) shows the robot getting rid of the local minimum after setting the intermediate target point, finally reaching the destination.



(a) (b)

Fig. 8. Simulation path planning.

Home service robots work in real homes where there are different shapes of obstacles, and robots need to consider the volume of these obstacles so as not to collide. Fig. 9(a) shows the path without considering the obstacle volume, and Fig. 9(b) shows the path map taking into account the obstacle volume, so that the robot is more adaptable in the home environment,



(a) (b)

Fig. 9. Simulation path planning.

The traditional artificial potential field algorithm to develop a smooth curve of the route, which led to the robot constantly adjusted forward, wasting time and power consumption. In this paper, a "straight line" method is used to optimize the original path and finally the optimal path is obtained, as shown in Fig. 10.

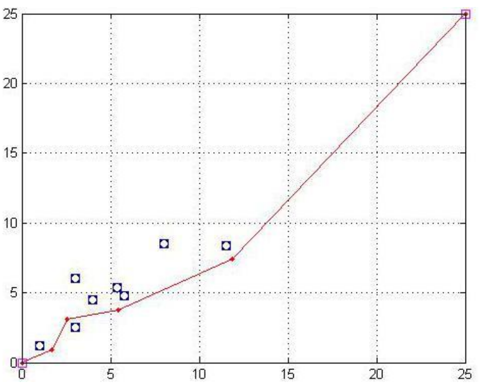


Fig. 10. Path optimization diagram.

In order to verify whether the "straight line" method really shorten the distance, we set up a number of departure points and destinations, respectively, using the traditional artificial potential field algorithm and improved artificial potential field algorithm, respectively, the results shown in Fig. 11. From the figure we can see that in the case of the same starting point, destination and obstacle environment, we find that the path after optimization is shorter, which verifies the superiority of the "straight line" method.

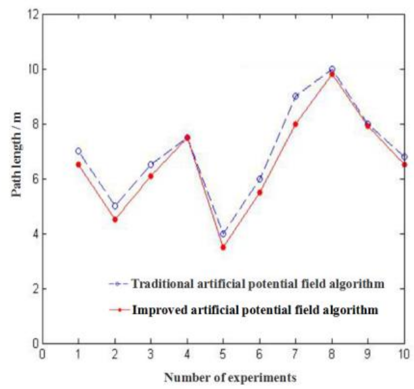


Fig. 9. Comparison of two algorithm paths.

IV. CONCLUSIONS

In this paper, aiming at the shortcomings of the traditional artificial potential field algorithm, a corresponding solution is proposed. In addition, the algorithm designed in this paper also deal with obstacles in the home environment, making the algorithm more practical. Then the path is taken "straight line" method to optimize, shorten the robot's power consumption and time-consuming. Then, the feasibility of the improved artificial potential field algorithm designed in this paper is verified in MATLAB simulation environment.

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