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Nursing Robot Safety Path Planning Based on Improved A Star Algorithm

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Abstract. The nursing robot independently developed by our research group is large in size and complex in structure, so it needs suitable path planning algorithm when it works in indoor environment. I If the path planning based on the traditional A* algorithm is adopted, the problem of collision with obstacles may occur. This paper proposes an A* algorithm for virtual obstacle points combined with segmented navigation. Improve the cost estimation function and segment the planning and increase the virtual obstacle points, so that the overall path is centered away from obstacles, avoiding the head and foot collision obstacles. Experimental results show that the proposed algorithm is compared to the traditional A* algorithm: the navigation path is centered, the operation time is increased by 35%-47%, the turning point and the cumulative turning angle are reduced by 50%-80%, and the path length is basically unchanged. The proposed algorithm can meet the safety requirements of nursing and lifting robots, and at the same time improve the computing efficiency to some extent.

Keywords: A* algorithm, cost estimation function, nursing robot, path planning, safe path, virtual barrier

1 Introduction

Path planning is one of the key technologies for mobile robots to complete navigation. The problem of path planning is that, in the environment map with obstacles, a path is planned to reach the end point without collision with obstacles. Usually, a set of evaluation system, such as path distance, time consumption and number of turns, is developed to evaluate the merits of the algorithm [1]. The core of path planning problem is path planning algorithm, common path planning algorithms include: fuzzy logic algorithm, artificial potential field method and raster method, etc. [2]. In recent years, with the rapid development of artificial intelligence technology, some artificial intelligence-like algorithms have been applied in path planning, including genetic algorithm, ant colony algorithm and neural network [3-4]. In the path planning problem, the first thing to be solved is the environment modeling problem. The raster method is simple to model and easy to program.

The common path planning algorithms based on raster method and mainly applied in static scenes are In this paper, the raster method is selected to build the environment map and then optimize the path planning algorithm. Dijkstra algorithm [5] and A* algorithm [6]. Among them, A* algorithm can usually calculate the optimal path faster and more efficiently [7].

The nursing robot independently developed and designed by our research group is tall and complex with a height of 170cm and a width of 90cm. The daily working environment of the nursing robot is indoor environment. The indoor environment is intricate and there are usually different obstacles at different heights. After perceiving the environmental information of the height of each layer, the corresponding algorithm is required for path planning before the robot can move and work. The purpose

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of this paper is to study the path planning algorithm for nursing robot. Fig. 1 is the nursing robot independently developed by our research group.

Fig. 1. Robot examples

Because the research of nursing robot at the present stage mainly focuses on the path planning of indoor static environment and selects grid method for environment modeling, A* algorithm is the fastest and most efficient algorithm under this constraint. However, there are many defects in the traditional A* algorithm, such as multiple steering, large cumulative turning Angle, close to obstacles, etc. These problems not only affect the efficiency, but also affect the safety of the nursing robot. In view of such defects, this paper proposes A method combining virtual obstacle points with segmented navigation, which optimizes and improves the cost estimation function of the traditional A* algorithm, and changes the traditional one-time planning into segmented planning, making the planning method and the path planned by the new algorithm more suitable for indoor navigation of nursing robots.

2 Traditional A* Algorithm

A* algorithm is A typical heuristic search algorithm. A* algorithm starts from the starting point and continuously searches for the node with the minimum value of the overall calculation generation, and takes this node as the starting point of the next search until the path extends to the target point [8]. In this way, the generation value of each calculation can be minimized, and the final generation value can be guaranteed to be minimized [9]. Specific process: the distance from the current point to the end point is calculated through the prediction function f(n), and the direction of n+1 search is determined. If the search fails, look for another path. Therefore, the success of A* algorithm mainly depends on the calculation effect of the evaluation function f(n) [10]. The expression of the evaluation function is:

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

Here, f(n) is the sum of the estimated cost from the initial point to the end point, and g(n) is the actual value of the substitution from the current position point to the eight surrounding points in the grid environment. H (n) is calculated from the path of 8 points around the state n to the target point. The calculation method of h(n) directly determines the search efficiency of A* algorithm. From a numerical point of view, when the sum of g(n) and h(n) reaches the minimum value, the algorithm is the optimal solution. The common functional forms of h(n) are Manhattan distance, Euclidean distance and Chebyshev distance [11]. Generally, A* algorithm USES the Euclidean distance algorithm, which is also the algorithm in contrast with the algorithm in this paper. Euclidean distance:

$$D = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \tag{2}$$

According to the principle of A* algorithm, the algorithm is simulated. The simulation figure is shown in Fig. 2, “+” on behalf of the starting point, “*” represents the target endpoint. The red circles in the squares represent obstacles, and each grid unit in the figure is 1. Through the simulation, it is found that there are many problems such as multiple steering times and close to obstacles.

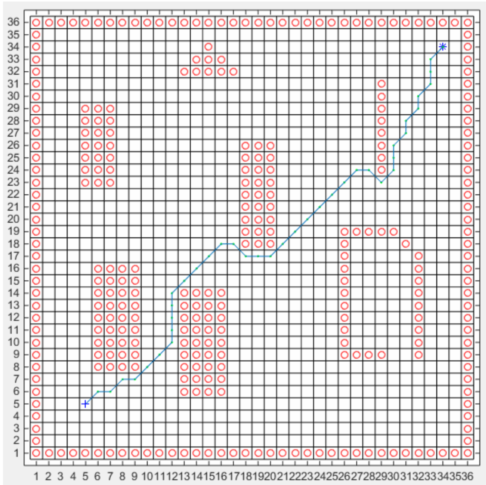

Fig. 2. Path planning based on traditional A* algorithm

3 Algorithm to Improve

Through the theoretical research and simulation implementation of the traditional A* algorithm, it is found that the algorithm has many turning times and is close to obstacles. The fundamental reason lies in the estimated cost function of the algorithm. Since f (n) is composed of the actual cost and the estimated cost, where the actual generation value is the actual distance value of 8 points around the point, and the estimated cost is the calculated value of the distance from 8 points around to the end point.

Since most of the previous A* algorithms used Euclidean distance as the estimated cost function to calculate, and the calculated value of Euclidean distance was the straight-line distance between two points, this led to some problems in the actual environment of the algorithm:

(1) When the Euclidean distance is the estimated cost, the estimated cost usually accounts for a higher proportion of the overall generation value, which leads to the algorithm's pursuit of the shortest straight-line distance between two points to a large extent, leading to the path close to the obstacle in some directions.

(2) A* algorithm has more turning points and turns frequently.

(3) Due to the algorithm itself, the local change changes the overall circuit of the algorithm greatly.

According to the practical environment and application of nursing robot, the following standards for algorithm security are proposed:

(1) The indoor path planning of nursing robot should be centered as far as possible to reduce the risk of head-foot collision with obstacles.

(2) Reduce steering times and improve efficiency.

(3) Local changes have little influence on the overall route planning.

Therefore, this paper proposes A virtual obstacle point combined with segmented navigation algorithm to innovate and optimize the traditional A* algorithm. This algorithm is divided into three parts: Firstly, a new cost evaluation function is selected, and then the algorithm is optimized by combining piecewise programming and adding virtual obstacle points.

The new cost evaluation function selected in this paper is:

$$h(n) = k \times \min(|x_n - x_{goal}|, |y_n - y_{goal}|) \quad (3)$$

Where K is the length of each grid in the grid environment where the chassis is located, x_n and y_n are used to represent the position of mobile robot chassis x_{goal} and y_{goal} are used to represent the position of the target end point. x_n, y_n, x_{goal}, y_{goal} are all coordinate values.

Fig. 3 and Fig. 4 respectively show the pathfinding method of the cost evaluation function of the traditional A* algorithm and the pathfinding method of the cost evaluation function selected in this paper. In the figure, S is the starting point, E is the end point, the yellow square around point S is the actual distance function g (n), and the dotted lines in the figure are the pathfinding methods of two estimation functions. Fig. 3 shows the path finding method of the traditional European algorithm, that is, the straight-line distance between two points. Fig. 4 is the pathfinding method of the algorithm selected in this paper, and the minimum value of the horizontal and vertical wheelbase distance is selected. The advantage of the evaluation function selected in this paper lies in the selection of the shortest x value and y value between the target point. When a certain value of the function on the X-axis and Y-axis reaches the minimum, the overall route planning can be more close to the horizontal or vertical direction, rather than the calculated value between two points using the Euclidean algorithm, so as to realize the control and centralization of the route.

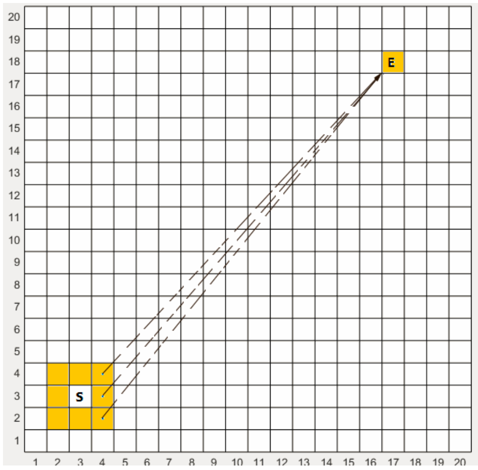

Fig. 3. European distance pathfinding

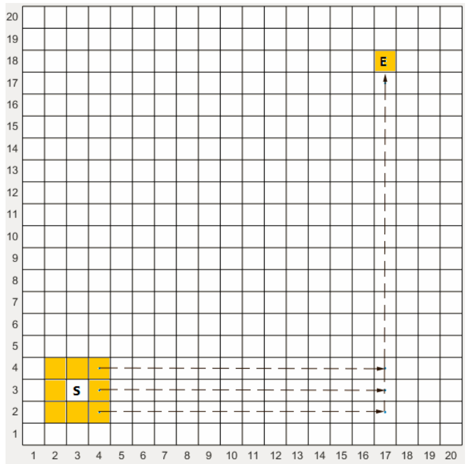

Fig. 4. The pathfinding method of the cost evaluation function selected in this paper

If the target point of the evaluation function is set as the terminal point, the change rules of the route trajectory are all based on the target terminal point, so the planning of each path cannot be controlled accurately. By piecewise planning, the evaluation function can control each safety path with the safety points in the middle as the reference. Since the turning point of the path, the algorithm will select the point with the lowest overall cost, and virtual obstacle points need to be added to realize the safe path at the turning point.

The path that conforms to the safety criteria of pension care robot is the median path, as shown by the black dotted line in Fig. 5. Set the coordinate (11, 15) as the intermediate point for path planning. But the route is still close to the obstacles at the corner, adding virtual obstacle points. The yellow point is the virtual obstacle point set, as shown in Fig. 6, which conforms to the safety criteria of the nursing robot. The second planning of the remaining path was carried out from the starting point of coordinate point (11, 15). The planning path was shown in Fig. 7, which met the safety standard of nursing lifting robot.

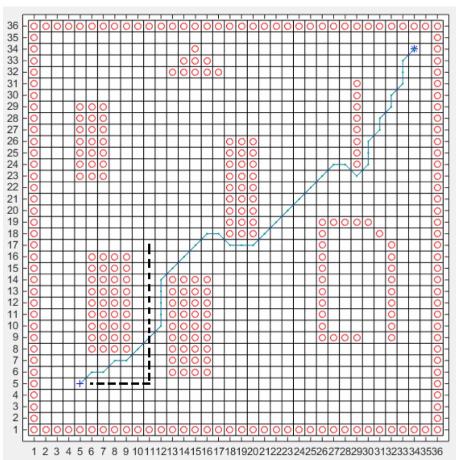

Fig. 5. The black dotted line is the standard safe route

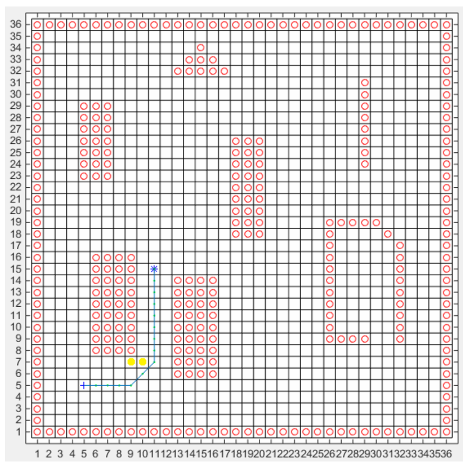

Fig. 6. The optimization algorithm path of intermediate point is added

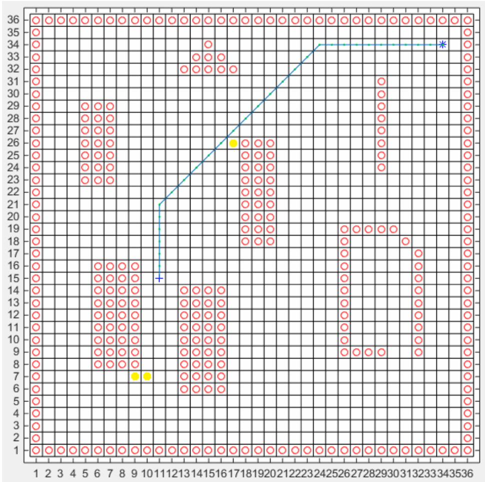

Fig. 7. Optimize the algorithm of quadratic programming path

4 Application Example and Simulation

Carry out algorithm simulation on Matlab 2014b, set up a map and fixed obstacles, set up three groups of different starting points and target points, and improve and realize the algorithm. The size of the grid is 35 * 35, which represents the size of the path planning area of the mobile robot, the red circle in the grid represents the position of the obstacle, and the yellow solid circle is the virtual obstacle.

In order to better verify the superiority of this algorithm, this paper carried out three groups of experiments. The algorithm was tested with the path neutral, path distance, steering times, operation time and cumulative turning Angle, among which the path neutral was an important index.

Fig. 8, Fig. 10 and Fig. 12 are all planning results of traditional A* algorithm. Fig. 9, Fig. 11 and Fig. 13 are all A* algorithms combining virtual obstacle points with segmentation. Fig. 8 and Fig. 9 are comparison groups, Fig. 10 and Fig. 11 are comparison groups, and Fig. 12 and Fig. 13 are comparison groups.

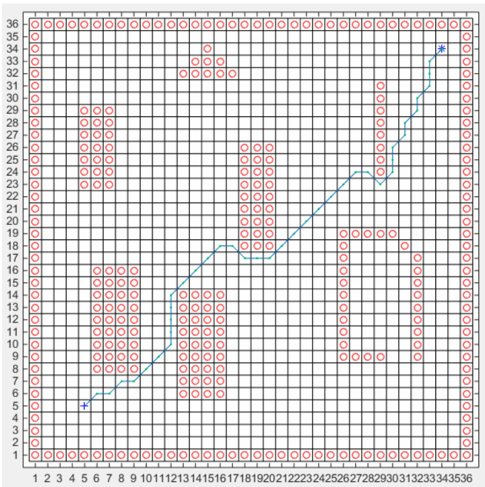

Fig. 8. Path planning based on traditional A* algorithm

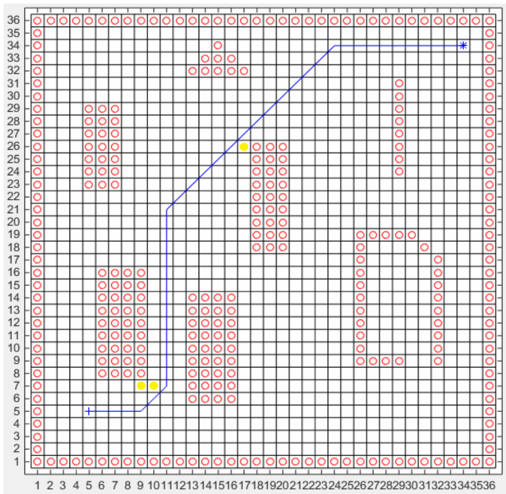

Fig. 9. The path planning diagram of the optimization algorithm

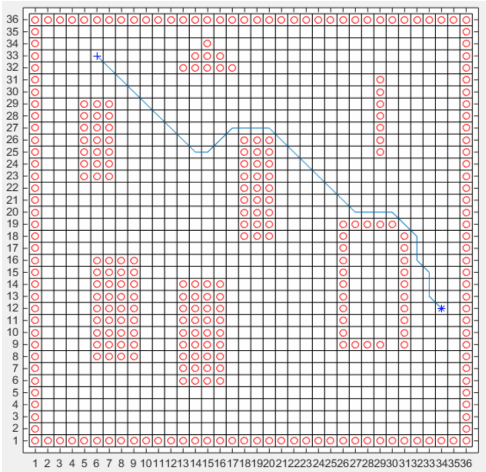

Fig. 10. Path planning based on traditional A* algorithm

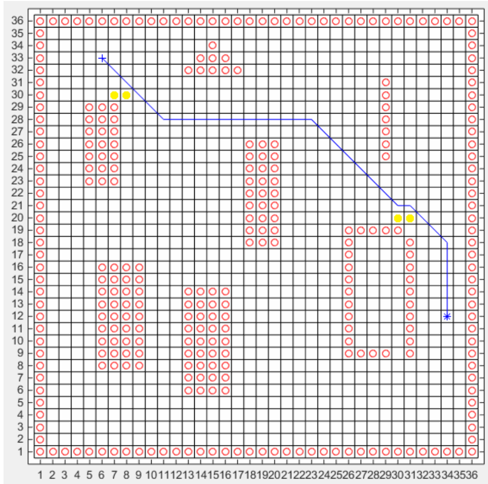

Fig. 11. The path planning diagram of the optimization algorithm

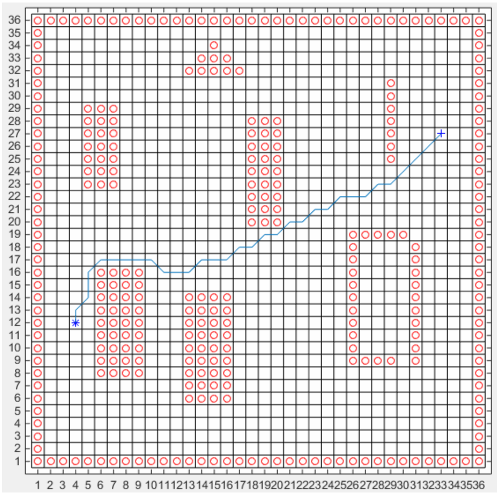

Fig. 12. Path planning based on traditional A* algorithm

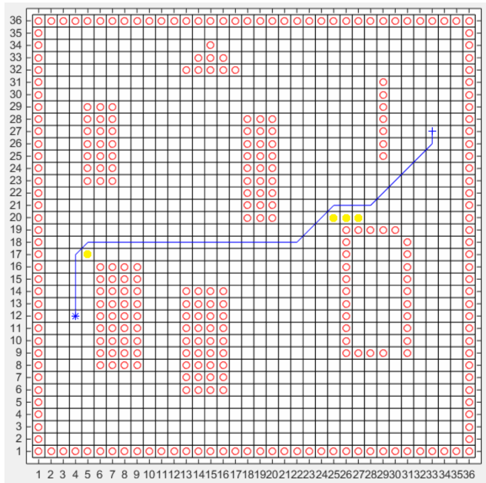

Fig. 13. The path planning diagram of the optimization algorithm

The comparison of performance parameters before and after the algorithm improvement in Table 1 shows that the improved virtual obstacle point combined with segmented A* algorithm consumes more time in terms of running time than the original A* algorithm. The extra time consumed is 47%, 31% and 46% respectively, but it is much better than the traditional A* algorithm in terms of route and turning times. On the data of turning points, the number of turning points in Fig. 9 is 17 less than that in Fig. 8, which is 80% less. The number of turning points in Fig. 11 is 5 less than that in Fig. 10, and the percentage is reduced by 50%. Fig. 13 shows a reduction of 15 transition points over Fig. 12, with a percentage reduction of 71%. It can be seen from the data in Fig 9, Fig. 11 and Fig. 13 that the optimized algorithm is significantly better than the traditional A* algorithm to the extent that the line is centered. The optimized total turning angles were reduced by 80%, 50% and 71%, respectively. The distance between the improved path and the traditional A* algorithm does not change much. According to the comprehensive analysis, the path is moderate enough to meet the safety requirements of the nursing lifting robot. Although a part of time is sacrificed, there is a great improvement in the number of turning points and the Angle of turning points. Under the premise of safe path of nursing lifting robot, the overall efficiency is improved. At the same time, in the process of path planning, the change of local obstacle points does not affect the overall path trend, and the algorithm is easy to realize.

Table 1. A* comparison of performance parameters before and after algorithm improvement

algorithm	distance	time	Break point	safety	Angle
Fig. 8	48.52	2.891	21	worse	2790
Fig. 9	49.21	5.511	4	well	540
Fig. 10	40.69	3.694	10	worse	1350
Fig. 11	40.21	5.409	5	well	675
Fig. 12	37.79	2.836	21	worse	2790
Fig. 13	38.72	5.256	6	well	810

5 Conclusion

A* algorithm is an important algorithm in the intelligent control algorithm, but it also has the problem of low search efficiency and multiple fold points, and at the same time cannot meet the security needs of the nursing robot. In order to realize the optimal algorithm of safety, stability, high efficiency and fewer fold points, the virtual obstacle point combined with piecewise improvement method achieves the optimization by optimizing and improving the cost evaluation function of the traditional A* algorithm itself. Experimental simulation comparison and comparison of various performance parameters show that virtual obstacle points combined with segmentation A* algorithm not only avoid the danger of getting close to obstacles in practice. At the same time, it also solves the problems of multiple fold points and the change of algorithm line Louis, improves the efficiency, and makes the algorithm more suitable for the application of pension care robot on the whole.

As the overall navigation equipment of the nursing robot platform is under construction, this topic is currently in the stage of algorithm optimization and improvement, and the algorithm effectiveness will be verified in the next stage. Although the algorithm proposed in this paper can effectively solve the problem of close to obstacles and multiple transitions, the time consumed by piecewise planning is greater than that of one-time planning. In the next stage, a one-time planning study will be carried out. While the planning effect remains unchanged, it will be convenient for optimization and improvement in time consumption.

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