Improved A-star algorithm for robot path planning in static environment

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abstract: A-star algorithm is a kind of simple path planning algorithm without solving the calculus, which has a high application. However, compared with other path planning algorithms, it occupies a large memory space. To solve this problem, this paper proposes three new concepts such as the bidirectional search, a guide line and a list of key points. A-star algorithm is optimized and rasterize on indoor environment modeling method, finally through the MATLAB simulation experiments prove that the optimized algorithm feasible experimental results show that the improved algorithm in target different under the two kinds of experiment are able to reduce memory footprint by more than 60%.

1. Introduction

Robot path planning has always been a hot research topic in the field of artificial intelligence [1,2,3,4]. Traditional algorithms mainly include genetic algorithm (Ga), artificial potential field algorithm, and free space method [5]. Intelligent algorithm mainly has a fuzzy logic algorithm of artificial neural network algorithm A-star algorithm [6], even though the solution of the problem and many, but the algorithm has disadvantages to improve [7] no matter what kind of algorithm, its core idea is to make the robot through a minimum cost, finding the shortest path in the specific environment for the guidelines, planning out a continuous and collision free path as a result, planning path before the need to model construction of environment, the main building and map model are raster map method [8] can attempt to method [9] structure space method [10], etc. Generally speaking, path planning methods are classified according to planning ideas and can be divided into global path planning and local path planning [11]. Global path planning can usually plan an optimal path for the robot, but it requires prior information of the environment and requires a large amount of calculation. Sensors local path planning is access to environmental information, and can make real-time adjustment along with the change of environment, by contrast, if the actual situation is not very strict to the optimal path, local path planning is more practical and real-time performance for A-star algorithm [12] is a local path planning algorithm of heuristic search, its calculation is simple, without solving calculus and applicability widely etc., as the main algorithm for research because of its unique way of computing cost of search and take up a direct link between the storage space, inspired by the literature [13]. In this paper, the cost function is improved by introducing the concept of wire to reduce the unnecessary
search area in the two-dimensional static environment, so as to reduce the search cost, and improve the search efficiency in the use of MATLAB carries on the simulation experiment.

2. Environment modeling
Taking indoor environment as an example, two-dimensional plane simulation was carried out (grid method was used for Map modeling, and the advantage was that the search area was displayed with A-star algorithm, which was easy to calculate). The white grid represented barrier-free and accessible area raster $M_{ij}$. 

$$\text{Map} = \{M_{ij} | M_{ij} = 0, 1\}$$

(1)

In the grid diagram, "0" is the white grid (barrier-free accessible area), and "1" is the black grid (area with obstacle impassable area). Establish a 40×40 grid map as shown in Figure 1:

![Fig 1. Test map](image)

3. Algorithm design

3.1. Illustration of algorithm

3.1.1. A-star algorithm
The traditional A-star algorithm comprehensively evaluates each node (i.e. search area) around the current position in the grid by setting the evaluation function. Each node is the position that the robot can reach. After intelligent assessment of each position point, the optimal position point can be found, and the position can be replaced until the target position is found. Its evaluation function is as follows:

$$F(n) = G(n) + H(n)$$

(2)

$G(n)$ represents the actual cost of the current node to the next node; $H(n)$ Represents the estimated cost of predicting the destination of the current node. The formula of Manhattan estimation method is as follows:

$$H(n) = D^* (ab(n.x - goal.x) + ab(n.y - goal.y))$$

(3)
3.1.2 Improved algorithm

Based on the A-star algorithm, the constraint function \( C(n) \) is introduced, which is similar to the estimated cost \( H(n) \). The evaluation function formula of the improved algorithm is as follows:

\[
F(n) = G(n) + H(n) + C(n)
\]  

(4)

\( C(n) \) is the vertical distance between the node and the "boot line", as shown in Figure 2, a straight line is drawn to connect the starting point and the target point, which is called the "guide line". Solid blue lines 1 and 2 in the figure are \( C(1) \) and \( C(2) \). The gray square is the search area; The blue dotted line is the reference line perpendicular to the "guide line" and parallel to lines 1 and 2.

![Fig 2. Illustration of C(n)](image)

By introducing the concept of \( C(n) \), can restrain algorithm search area always around to "guide line", the advantage is that regardless of the obstacles, "guide lines" as the starting point for the shortest distance to the target point, always revolve around the surrounding can follow the principle of the shortest path search, at the same time reduces the search area. (Eight-neighborhood search is adopted, that is, eight surrounding nodes are searched each time, as shown in Figure 3.)

![Fig 3. Eight-neighborhood search pattern graph](image)

In this way, the search points for the next two steps in Figure 2 are shown in Figure 4 and Figure 5, where the red square is the optimal node, that is, the node where the next step replaces the starting point.
3.2. The simulation results

3.2.1. Explanation of experiment
In this paper, Intel(R) Core(TM) i7-8750h CPU @2.20ghz 2.21ghz, RAM 8.00GB, 64 operating system, Windows 10 home Chinese version computer and MATLAB 2018B were used for experimental simulation.

3.2.2. A-star algorithm simulation experiment

as shown in FIG. 6 and FIG. 7, before the simulation experiment of the improved algorithm, the A-star algorithm simulation experiment to be compared was carried out first.

3.2.3. Improved algorithm simulation experiment
The improved algorithm is used to change the position of the target point when other conditions are unchanged. as shown in FIG. 8 and FIG. 9, respectively correspond to FIG. 6 and FIG. 7 for simulation experiments.
according to the comparison of simulation results, in the experimental figure (1) of the two algorithms, the step length of A-star algorithm is 51.4 (definition: each cell length is unit step value 1), and the search area reaches 382 (definition: each cell is unit search area 1), while the step length of the improved algorithm is 50.6, and the search area is only 145. The improved algorithm increased the step size by 1.56% and reduced the storage space by 62.04%. However, by comparing the experimental figure (2) of the two algorithms, it is found that the improved algorithm changes the position of the target point, and falls into the misunderstanding of not being able to find the target point after increasing the difficulty of searching. Therefore, we have carried out the second improvement, and the idea is as follows:

Step 1: analyze the path to find the transition nodes that have fallen into a misunderstanding. According to the nodes surrounded by the solid blue line in Figure 10, the simulated robot made a wrong judgment when searching for the point and turned on the wrong road, so it got into a misunderstanding.

Step 2: after finding the turning point according to step 1, we introduce a new concept, which is as follows: When the A-star algorithm is executed, it will create two lists, one is an open list, which is used to store the surrounding 8 unextended nodes; Is a closed list, to hold the extension of the end of the node through the order of the open list node values of $F(n)$, choosing a node for the next step after the minimum value in the closed list due to A-star algorithm to search path in this way, so it takes
up storage space but is directly related to establish a list of improved algorithm through the guide line of constraints to reduce nodes at the same time also makes the search appear unstable situation of misunderstanding, so we put forward a new list, The key point list is used to store the key points. When the robot search falls into a misunderstanding, it can jump out of the open list to the key point list, after looking for the most recent key point in the key point list, it can be taken as the best point to choose another road for searching, so as to avoid the misunderstanding situation when the path search occurs.

Key point setting method is as follows: as shown in figure 11, figure 12, the search to the node to establish a coordinate system, the connection of the node and the target point (blue dotted line), to determine the nodes around (blue ring dashed lines), if a target point with the obstacles in the blue dashed line of quadrant, and no obstacles other quadrants, referred to as the "key", the node will be in the "key points list".

Step 3: Carry out preliminary simulation of the improved algorithm on the experimental figure (2) of the improved algorithm, as shown in Figure 13.

Through the experimental results, after secondary to improve simulation robot can solve misunderstanding, find the target point, and the search area less than a star algorithm, a star algorithm search area for 483, the second time improved algorithm search area for 162, considering the occupy storage space and the open list, closed list and related key points list, so the actual storage space decreased by 65.83% However, the experimental results show that the step length value of the quadratic improved algorithm is 54, which is 1.6 more than that of the A-star algorithm and there are unnecessary turning points on the path, so we continue to improve it.
Step 4: Through the previous experiment, we found that in the improved algorithm,
\[
F(n) = G(n) + H(n) + C(n)
\]  
(5)

There may be two nodes have the same value, the algorithm under the condition of default based on the probability of 1/2 randomly select a node as the situation continue to search optimal, combined with the introduction of the concept of "critical point" at the same time, we decided to let algorithm in both cases a bidirectional search, when a direction search to the target point, the other party to stop, because the first search to the direction of the target must be the fastest shortest path. Finally, MATLAB simulation experiment was carried out, and the results were shown in Figure 14.

Fig 14. The final experimental diagram of the improved algorithm

The experimental results show that the step size of the final improved algorithm is 46.6, which reduces the step size by 11.06% and the search area by 169 compared with the A-star algorithm. also considering the influence of "key point list", the final storage space is reduced by 64.38%.

3.2.4. Data processing

| Number of experiment   | A-star algorithm | Improved algorithm | second improved algorithm |
|------------------------|------------------|--------------------|----------------------------|
| Experiment 1 | Experiment 2 | Experiment 1 | Experiment 2 | Experiment 1 | Experiment 2 |
| Path value | 51.4 | 52.6 | 50.6 | — | 50.6 | 46.6 |
| Search area | 382 | 483 | 162 | — | 162 | 169 |
| Time | 2.71 s | 4.41 s | 1.03 s | — | 1.07 s | 1.13 s |

As shown in Table 1, through comparison of experimental data, the final improved algorithm is superior to A-star algorithm in terms of step size, search area and search time.

4. Conclusion

against A-star algorithm on occupy storage space problem, in this paper, by introducing a "guide line", "key points list", "two-way search" three new ways, such as the A-star algorithm is optimized, finally through MATLAB to indoor environment simulation, the simulation experiment, the two target different situations, take up the storage space by 62.04% and 64.38%, step length value and the search time are better than A-star algorithm, proving the feasibility of improvement.
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