Path Planning Using an Improved A-star Algorithm

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***Abstract*—There has been a heated issue in the field of robotics about how to plan the shortest path of a map with obstacles. This papers mainly analysis the issues about the path planned are not the shortest path by the A-star algorithm under certain conditions. An effective method is proposed which is called an improved A-star algorithm. The improved A-star algorithm is proposed to solve path planning under certain conditions, which can find a shorter path in contrast of other related methods. The simulation results show that the proposed algorithms are effective to settle above the issue, in which the path generated by the improved A-star algorithm has a shorter path than the path of other improved A-star algorithms.**

Keywords*—*improved A-star algorithm, path planning, a shorter path

I. Introduction

The path planning problem has a wide range of applications for many fields, such as autonomous navigation of mobile robots and underwater autonomous vehicles. Path planning is divided into global path planning and local path planning, global path planning is called static path planning which can generate an optimal path on a static map, while local path planning is called dynamic path planning whose obstacles on the map change dynamically. At present, mature path planning methods included A-star algorithm [1, 5], rapid random tree (RRT) [2], artificial potential field method [3], and artificial moment method [4].For the path generated by the traditional A-star algorithm should be more effective in global path planning, however, in some situations, the path is not the shortest path. In this paper, inspired by the shortest line segment between two points, an improved A-star path planning algorithm is proposed.

II. Related Works

In recent years, the problem that the path generated by the traditional A-star algorithm is not optimal has attracted the attention to many scholars. For the problem that the path generated by the traditional A-star algorithm is not optimal. Based on the A-star algorithm, combined with the jump point search algorithm, an improved A-star algorithm is proposed [1], The path-finding speed of the improved A-star algorithm is 200% higher than the traditional A-star algorithm. A new heuristic energy consumption estimation cost is designed to improve the A-star algorithm [5]. The A-star algorithm is improved by considering the three aspects of channel constraints, optimization cost function and valuation function [6]. [7] proposed improved heuristic search strategy and bidirectional 24 neighborhood A-star algorithm. [8, 9] also proposed two methods of improving heuristic functions. Therefore, a new and improved A-star algorithm are proposed to get a shorter path than above.

III. Improved A-Star Algorithm

The traditional A-star algorithm is a typical heuristic algorithm. The cost function of the A-star algorithm is defined as followings:

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

among them n is the current inspection point; $f(n)$ is the sum of the valuation function; $g(n)$ is the actual path substitution value from the starting point to the inspection point; $h(n)$ is the estimated substitution value from the inspection point to the end point.

$h(n)$ is calculated using the Euclidean distance between the inspection point and the end point:

$$h(n) = \sqrt{\left(x_n - x_{goal}\right)^2 + \left(y_n - y_{goal}\right)^2} \tag{2}$$

The specific implementation steps of the traditional A-star algorithm are given below.

Algorithm 1 A-star algorithm
1 **algorithm** $A\_star(start, map, goal)$
2 $close \leftarrow NULL$
3 $open \leftarrow start$
4 $G[start] \leftarrow g[start] = 0, H[start] \leftarrow h[start]$
5 $F[start] \leftarrow H[start]$
6 **while** $open \neq \varnothing$ **do**

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```
    current_Node ← Node with the minimum F value in open
    open ← open \ {current_Node}
    close ← close ∪ {current_Node}
    if current_Node = goal then
        return best_path
    end
    neighbor_Nodes ← All neighbor Nodes of current_Node
    for N ∈ neighbor_Nodes do
        if N ∈ close then
            do nothing
        else if N ∈ open then
            G[N_new_calculated], H, F ← calculated N's G,H,F
            if G[N ∈ open] > G[N_new_calculated] then
                N's parent ← current_Node
            end
        else
            N's parent ← current_Node
        end
    end
end
```

Here we will discuss our improved A-star algorithm, first consider a simple case, using a straight line segment to connect the starting point and the ending point, assuming that obstacles that only pass one, as shown in Fig.1. Taking point C as the center and make a circle with radius r. Points D and E are the intersection points of this circle and the line segment $\overline{AB}$. First solve the equation of the straight line segment $\overline{AB}$:

$$\left(y-y_{start}\right)\left(x_{goal}-x_{start}\right)=\left(x-x_{start}\right)\left(y_{goal}-y_{start}\right) \tag{3}$$

Then solve the circle equation with the obstacle C whose coordinates are $(x_{obstacles}, y_{obstacles})$ passing through it as the center and radius r:

$$\left(x-x_{obstacles}\right)^2+\left(y-y_{obstacles}\right)^2=r^2 \tag{4}$$

Through (3) and (4), the coordinates of points D and E can be found, respectively $D(x_D, y_D)$ and $E(x_E, y_E)$.

D and E will be used as the starting point and ending point, so it is necessary to determine which is the starting point and ending point, and make the following judgments:

$$x_E-x_D=L \tag{5}$$

If the value of L is greater than 0, then choose D as the starting point and E as the ending point. Otherwise choose E as the starting point and D as the ending point.

According to Fig.1, it is obvious that D is the starting point and E is the end point, and then taking the local starting point D and the local end point E as the known conditions, substituting into the traditional A-star algorithm in the previous section, a line will be generated with D as the starting point, E is the optimal path of the end point, that is, the black arc $\overset{\frown}{DGE}$.

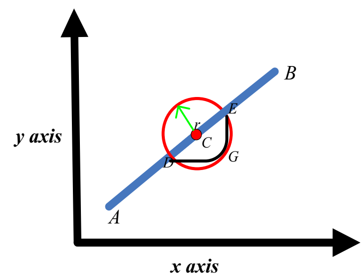


Figure 1. Improved A-star algorithm simulation diagram

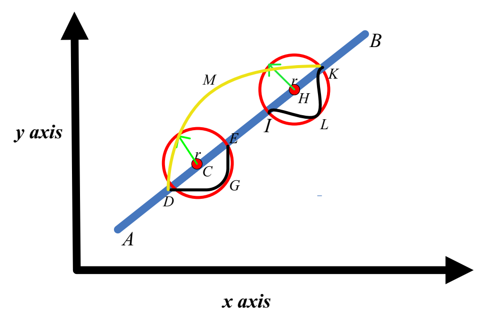


Figure 2. Improved A-star algorithm simulation diagram

Then the path point after fusing this path with the previously generated path is $[A, D, G, E, B]$, an approximately straight global planning path is generated.

In most cases, there is more than one obstacle on the straight line $\overline{AB}$. So here is an optimized method to merge adjacent small segments. Consider the situation where there are two obstacles and they are very close to each other, as shown in Fig.2, where H is the obstacle passed by the straight line $\overline{AB}$. Take point H as the center and make a circle of radius r. Points I and K are the intersection points of this circle and line segment $\overline{AB}$. According to the above method, the path of A to B should be $[A, D, G, E, I, L, K, B]$. However, If the following (6) is satisfied:

$$\left(x_E-x_I\right)^2+\left(y_E-y_I\right)^2 \le \varepsilon^2 \tag{6}$$

where ε is the set threshold. Then combine $[x_D, x_E]$ and $[x_I, x_K]$ into $[x_D, x_K]$, that is, use x_D and x_K as the starting point and ending point, respectively, to call the A-star algorithm to generate a local path. Then the path from A to B at this time is $[A, D, M, K, B]$.

The principle is the same as the case described above, the specific improved A-star algorithm will be given below.

Algorithm 2 Improved A-star algorithm

algorithm *improved_Astar(start,goal,map,obstacle)*
Line $\leftarrow$ *a line connecting the start and end goals*
$circle\_sum, center, local\_coordinate \leftarrow \varnothing$
for each $obs \in obstacle$ **do**
    $center \leftarrow center \cup ispass\_line(obs, Line)$
end
for each $c \in center$ **do**
    $local\_coordinate \leftarrow local\_coordinate \cup solve\_line\_circle(c, r, Line)$
end
for $(local\_start, local\_goal) \in (local\_coordinate)$ **do**
    if $\|local\_goal(i) - local\_start(i+1)\| \le \varepsilon$ **do**
        $[local\_start(i), local\_goal(i+1)] \leftarrow [local\_start(i+1), local\_goal(i+1)]$
    end
end
for $(local\_start, local\_goal) \in (local\_coordinate)$ **do**
    $path \leftarrow path \cup A\_star(start, map, goal)$
end
$Line \leftarrow Line \setminus \{circle\_sum\}$
$path\_final \leftarrow Line \cup path$
function $ispass\_line(obs, Line)$
    if $obs \in Line$ **do**
        return *obs*
    end
end
function $solve\_line\_circle(c, r, Line)$
    $circle \leftarrow$ *a circle with c as the center and r as the radius*
    $circle\_sum \leftarrow circle\_sum \cup circle$
    $D, E \in (Line \cap circle)$
    return *D,E*
end

IV. Simulation And Analysis

We will evaluate the feasibility and validation of our proposed path planning method. We first setup the experiment environment. Then we conduct experiments to evaluate the performance of the proposed methods.

A. Mapping and Parameters setting

We drew a map with a length and width of 40 meters. For the reference method to be compared with the method proposed in this article, the start and end coordinates are as follows: [(1,1) (20, 20)]. The radius r is 0.5 meters and 100 obstacles are randomly added to the map. The improved A-star algorithm and the other reference methods will be carried on for simulation.

B. Evaluation Metric

In order to evaluate the performance of the improved algorithm, we define two evaluation standards as follows:

$$R_{length} = \frac{length_{improved} - length_{reference}}{length_{reference}} \tag{7}$$

$$R_{time} = \frac{time_{improved} - time_{reference}}{time_{reference}} \tag{8}$$

where R_{length} represents the index of the improvement on the improved A-star algorithm proposed in this paper and the reference method in terms of the path length. $length_{reference}$ is the path length generated by the reference method, and $time_{reference}$ is the calculation time required for the path generated based on the reference method.

C. Reference methods

We use traditional A-star method and an improved A-star algorithms [8] as reference methods. The heuristic function $H(n)$ represents are as follows:

$$H(n) = \sqrt{2} \times H\_diagonal + (H\_straight - 2 \times H\_diagonal) \tag{9}$$

$$H\_diagonal = \min\{|x(n) - x(g), y(n) - y(g)|\} \tag{10}$$

$$H\_straight = |x(n) - x(g)| + |y(n) - y(g)| \tag{11}$$

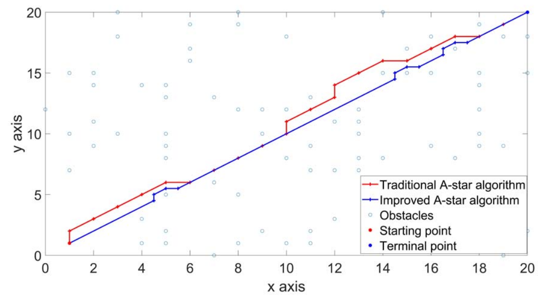
among them, $H\_diagonal$ represents the minimum distance between the current node and the target node in the horizontal and vertical directions; $H\_straight$ represents the sum of the horizontal and vertical distances between the current node and the target node.

To compare their's planning performance fairly, we do implement the reference methods completely.

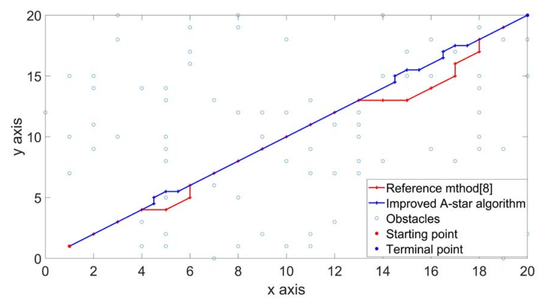
D. The planning performance evaluation

We utilize the method of reference [8] and the traditional A-star algorithm to make path planning with the following start point and end points: [(1, 1), (20, 20)]. First we calculate the length and calculation time of the path generated by each path planning algorithm. Then we will compare the path length they generated and the time required for path planning. And we give the path generated by the above algorithms in Fig.3. We first give the original data of the experiment in Table I. And then show the results of the comparison in Table II.

From Fig.3 and Table II, we can see that our proposed improved A-star algorithm has a shorter path length than that of other methods. More specifically, relative to traditional A-star algorithm-based, reference method [8]-based, our proposed method can be reduced at the scale of 3.07%, 3.07%. Besides, we can see that the processing time of our proposed method is higher than that of the other methods. The amount of calculation of our proposed improved A-star algorithm depends on the sett of the number of obstacles passing through the start and end points. The method we propose can be used in occasions with low real-time requirements but high path length requirements.



(a) Path planning based on Traditional A-star algorithm



(b) Path planning based on reference method [8]

Figure 3. The path generated by the method in this paper is compared with other reference methods

TABLE I. THE ORGINAL DATA OF PLANNING LENGTH AND CALCULATION TIME BASED ON DIFFERENT METHODS

	Traditional A-Star	Reference method [8]	Improved A-star
Path length	28.63(*m*)	28.63(*m*)	27.75(*m*)
Calculation time	10.72(*s*)	9.06(*s*)	41.28(*s*)

TABLE II. THE RESULTS OF COMPARISON IN TERMS OF CALCULATING TIME AND PLANNING LENGTH

	Traditional A-Star	Reference method [8]
R_{length}	-3.07%	-3.07%
R_{time}	285.07%	355.63%

V. CONCLUSION

In order to solve the problem that the path generated by the traditional A-star algorithm is not the shortest under certain conditions, we propose an algorithm namely the improved A-star algorithm. Compared with the traditional A-star algorithm and two other reference methods, the path generated by the improved A-star algorithm will be shorter. Because it uses the shortest line segment between two points as the inspiration for path planning. We perform simulation to evaluate the validation and feasibility of our proposed method. And the simulation results illustrate that the algorithm proposed is effective and feasible.

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