Jump Point Search Plus Algorithm Based on Radar Simulation Target Path Planning

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***Abstract*—This paper studies the target's path control strategy in radar simulation system. Aiming at the complexity of the radar path planning, the JPS+ (jump point search plus) algorithm is introduced into the radar path planning. The grid environment is preprocessed by the grid signage method, and the optimal path is selected by the valuation function. The standard JPS+ algorithm for path planning consumes a lot of time in an open list and it costs a great price according to the actual characteristics of the ship. In view of these shortcomings, the JPS+ algorithm is improved in two aspects. One is to optimize the open list with the least binary tree to improve the path efficiency, and the other is to select the appropriate valuation function and increase the valuation function weight coefficient. Finally, the algorithm is applied to the radar simulation system, which has great engineering application value.**

Keywords—Radar simulation system, JPS+ algorithm, path planning

I. INTRODUCTION

Haiphong radar plays an important role in national defense and security. The routine training of radar soldiers will affect the life span of radar, so the radar simulation system has emerged. Radar simulation system by simulating real sea vessels sailing scene for the coastal armies of radar soldiers used coastal defense observation training, the main completion of the reconnaissance training mission. The quality of the ship track planning determines the authenticity of the simulation system and thus the quality of the radar training. Therefore, it is of great significance to study the trajectory planning of the target in the radar simulation system.

Radar Simulation System Path planning refers to finding a collision-free path from the initial state to the target state according to certain evaluation criteria in an environment with obstacles. At present, many achievements have been made in the research of path planning algorithms. Path finding is the main content involved in various fields such as games and mobile robots. The commonly used heuristic search algorithm to find the optimal path is A * algorithm [1], but A * algorithm finds the optimal one by cropping higher cost neighbors Path, the search path is less efficient when the environment is complex. JPS (jump point search) algorithm [2] is a new pathfinding algorithm, based on the A-Star algorithm, only looking for the so-called "jump point" as the search node can be trimmed within the rectangular area. A large number of nodes makes the number of nodes in the open list relatively small. Skip a lot of useless nodes, keep the key master node. However, when the map environment is large, JPS path finding is mainly time-consuming in searching for jump points. In order to solve this problem, Steve Rabin proposed an improved JPS algorithm [3-4]. The JPS+ algorithm completely eliminates the recursive step of search for jump points. JPS+ algorithm consists of environment preprocessing and selection path. Environment preprocessing includes path searching, which makes running search simpler and faster than traditional searches.

Based on the previous research, this paper applies JPS+ algorithm to the simulation system of sea defense radar. According to the actual sailed target, this paper selects the appropriate valuation function and cost weighting coefficient, and optimizes the open list to improve the path efficiency.

II. ESTABLISH AN ENVIROMENT MODEL

The radar simulation system simulates the sea scene and needs to establish a two-dimensional space model of the sea environment [5], assuming that the island is stationary obstacles. Record the movement of the vessel and the obstacle information on a grid, defining the properties of the grid. According to grid method divides the work environment, the size of the boat depends on the size of the grid, barrier-free grid is a feasible grid, grid with obstacles is not feasible grid, and obstacles should be properly puffed to avoid getting the boat too close to the island.

The direction information on each grid specifies the movement of the vessel on this grid. Taking into account the complexity of the modeling, generally only 8 directions are defined in practical application. As shown in Figure 1, they are: east, south, west, north, northeast, northwest, southeast and southwest.

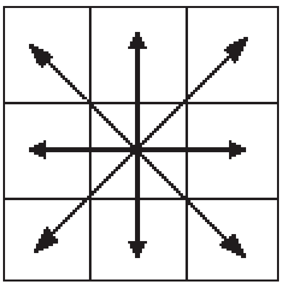

Fig. 1. Grid map and 8 possible directions of movement

III. JPS+ ALGORITHM

A. JPS+ Algorithm Basic Principle

1) Jump Points.

Jump points are that JPS + algorithm environment pretreatment and find the optimal path of the important factors. JPS + algorithm has three jump points: primary jump points, straight jump points, diagonal jump points.

The primary jump point is an intermediate node that may pass through the path. A jump to another jump point to avoid A * algorithm open list of many unnecessary operations. The following Figure 2 eight cases of the primary jump point, N is the primary jump point, the arrow indicates the source of the primary jump point P direction.

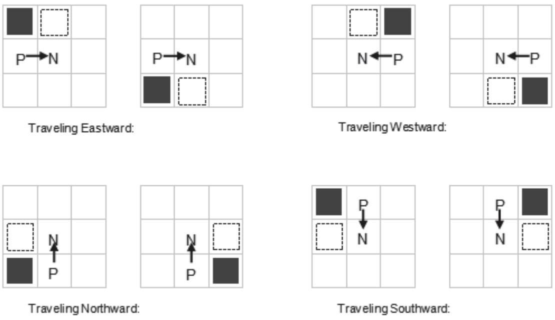

Fig. 2. Primary jump point

After determining all the primary jump points, you can find the straight jump points. Straight jump point is to find along the four directions (south, east, north, west), and eventually will be the primary jump point in the direction of the trip. The straight jump point distance is the maximum distance traveled until an obstacle is encountered in that direction (the distance value is not the distance to any primary jump point but only the primary jump point in the direction of travel). For example, the bottom-left node has a value of 3 in the upward direction. It should look like it's 1, but the primary jump point in the node above it is not the primary jump point in that direction (check carefully on Figure 3). The actual primary jump point of the uplink is 3 nodes.

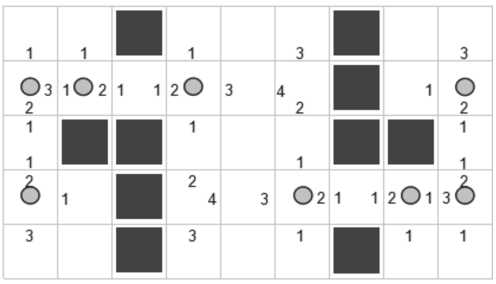

Fig. 3. Straight jump point

After determining the Straight jump points and their distance from the primary jump point, we need to determine the diagonal jump point. The diagonal jump point is any node on the diagonal direction of travel that will reach the primary jump point or a straight jump point (before hitting the wall) traveling in a direction related to the diagonal direction. As we did with straight jump points, we need to fill diagonal jump points with distances to the other jump points. Figure 4 shows our map with the diagonal jump points filled in.

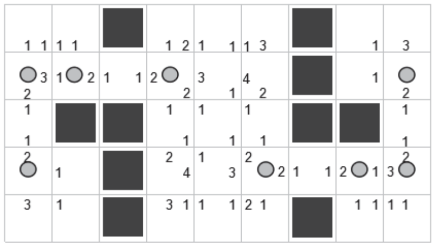

Fig. 4. Diagonal jump point

2) JPS+ algorithm process

JPS+ algorithm can be divided into two parts, one is environmental preprocessing, and the other is to find the optimal path [6]. The first part preprocesses the environment according to the signage method. Each pre-processed grid has eight directions. A positive number represents the number of steps a node can jump to a jump point in that grid. The negative value represents the maximum number of steps from the current grid to the obstacle, as shown in Figure 5, which results from the environmental preconditioning. The second part is to find the optimal jump point with the lowest cost until the end point is found. Figure 6 shows the result of node path finding, blue node is the starting point, red node is the end.

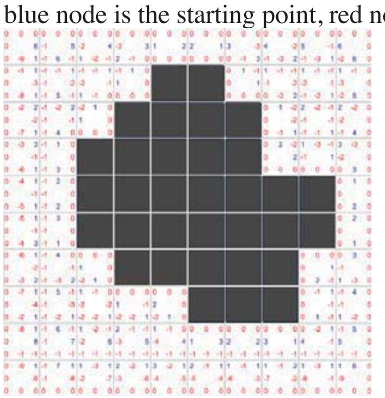

Fig. 5. JPS + algorithm environment pretreatment

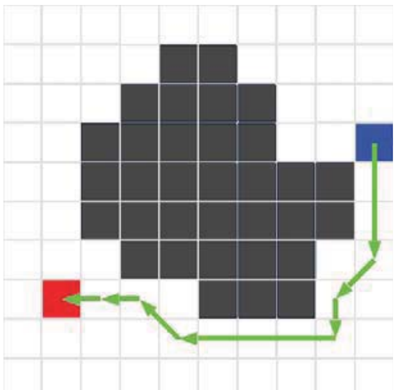

Fig. 6. JPS+ algorithm find path process

The core steps of the standard JPS + algorithm can be summarized in the following five steps [7].

Step 1: According to certain rules to find the primary point in the map, straight jump point, diagonal jump point.

Step 2: Calculate the indicated value of straight jump point and diagonal jump point.

Step 3: Find the optimal node by heuristic search based on the starting and ending positions. Write the expanded new node to the open list.

Step 4: Sort the open list in ascending order according to the value of the valuation. Set the node with the smallest cost to be the current node from the open list.

Step 5: If the current node is the end point, or in a certain direction of the end point, and the direction indicator value is greater than the current node point from the end point indication value, the path finding succeeds. Otherwise continue to find new extension points, continue to step 4.

The evaluation function of the standard JPS+ algorithm is expressed as: f (n) = g (n) + h (n). Where f (n) is the evaluation function of node n; g (n) is the actual cost from the initial node to node n in state space; h (n) is the estimated cost of the best path from node n to destination. The valuation function is closely related to the actual situation. Whether the valuation function is correctly selected will directly affect the success of the algorithm.

B. Disadvantages of Standard JPS+ Algorithm

The JPS+ path planning algorithm applied to the radar simulation system, the following two deficiencies: affiliations.

1) The maintenance of the open list.

The data stored in the open list need to take up memory space. If the path is long, the amount of temporary data generated by it will be very large and too much memory space is occupied, resulting in a decrease in the operating efficiency of the JPS+ algorithm. That is, the longer the search path, the lower the operation efficiency of the algorithm. Therefore, how to quickly sort the data in the open list is the core of JPS+ algorithm running efficiency.

2) The selection of valuation function.

The total value of valuation is composed of the value of the starting point to the extension point and the total value of the extension point to the target node. The cost of nodes should be related to the specific objectives and environmental information. For example, when a ship sails on the sea, as the boat needs to consume energy when turning, the valuation function needs to reasonably add other intelligent cost functions. Heuristic function h (n) also need to be based on the actual environmental information to make a reasonable choice. If the result of heuristic function h (n) is less than the actual value of the current node reaching the target vertex, JPS+ algorithm must be able to search out the optimal path. The smaller h (n) is, the more nodes will be expanded during operation. But this will lead to the algorithm to run less efficiently. On the contrary, if the heuristic function h (n) is greater than the actual value of the current node to reach the target vertex, it may not be able to search the optimal path, but the algorithm will run more efficiently. Therefore, adding appropriate cost factors to the heuristic function as needed can improve the pathfinding efficiency.

The selection and optimization of the valuation function not only determine the quality of the algorithm running process and path results, but also affect the operation efficiency of the algorithm to a certain extent. A good valuation function makes the target path close to the actual navigation scenario, effectively reduces the number of nodes extended and improves the operation efficiency of the algorithm.

C. Improvement of JPS+ Algorithm

According to the deficiency of JPS+ algorithm in radar simulation system, two improvements are proposed:

1) Optimize the open list.

JPS+ algorithm in the process of running, you need to repeatedly search the node with the lowest total cost in the open list. If the minimum binary heap save the open list storage, the top of the binary heap is that we search for the node. Binary heap storage to achieve the open list insert and delete operations, then the use of sorting the order of fast storage, especially when the number of vertices more, the effect is even more obvious. If you use a binary heap for insertion, you can insert the value as long as you do a few times. As for the delete operation, remove the heap vertex, and then move the vertices several times, as long as the new binary heap to ensure that the smallest binary heap can be. In summary, using binary heap storage to process open list data in large maps is faster and easier than any other sequential storage methods.

2) Improving the valuation function.

The valuation function is the core of the JPS+ algorithm's path cost. A good valuation function can be more intelligent and close to the actual situation to find a way. It can also reduce the amount of data in the open list to improve the algorithm's path efficiency, on this basis, search for a better path.

Currently used heuristic function Manhattan distance, diagonal distance, Euclidean distance. Manhattan has the high efficiency of path-finding, but the quality of the path-finding is low. The Euclidean distance-finding quality is high, but the path-finding efficiency is low. Path-finding efficiency and path-finding quality are the two factors that need to be balanced. According to the actual application of radar simulation, we choose the diagonal distance between the path-finding efficiency and the path-finding quality as the heuristic function, and add a certain factor to the heuristic function to increase Pathfinding efficiency.

The simulation environment of the radar, that is, the actual ship navigation, adds the turning cost function to the valuation function, and the turning cost function R (n) represents the turning cost of the current node n in terms of time and energy consumption.

$$R(n) \approx k \frac{V * L}{1 - \sin \theta} \tag{1}$$

L is the length of the ship, V is the speed and is the turning angle, and k is the coefficient.

In summary, the path planning evaluation function can be expressed as:

$$F(n) = \alpha * G(n) + \beta * H(n) + \delta * R(n) \tag{2}$$

G (n), H (n) and R (n) are respectively the path cost from the starting point to the current point, the path cost from the current point to the end point, the turning cost,〈,®,™is the corresponding coefficient.

IV. Do Simulation Experiment

This article uses the Microsoft Visual Studio 2010 development environment, C # language to complete the algorithm and system implementation. Set the obstacle distribution in a known global static 50 * 50 grid matrix, the obstacle is a gray-filled cell, the starting point coordinates (5,21), the end point coordinates (46,23), set 〈= 1, ®= 1. 4,™ = 1.2. Figure 7 and Figure 8 show the path search of the basic JPS+ algorithm and the improved JPS+ algorithm. As can be seen from Figure 8, the improved JPS+ algorithm avoids more turning costs and achieves a lower cost of turning from start to finish. At the same time improve the algorithm also shortens the running time, the effect will be more obvious in the big map.

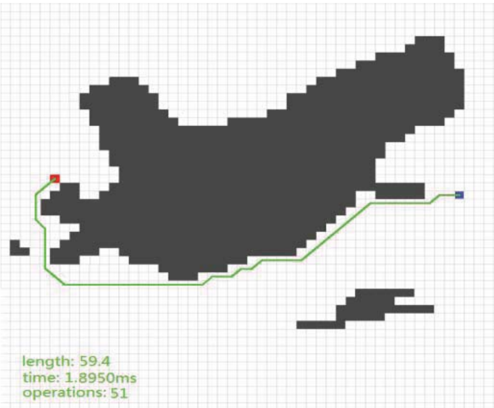

Fig. 7. Basic JPS+ algorithm path planning

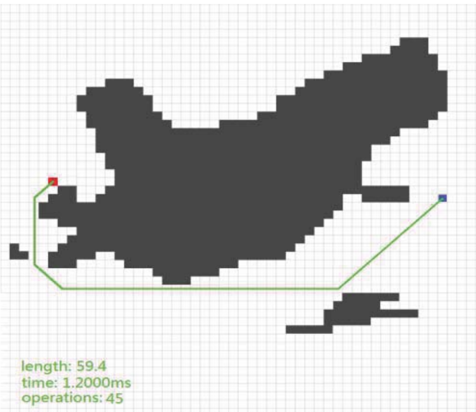

Fig. 8. Improving JPS+ Algorithm Path Planning

The radar simulation system has three layers of data clutter, and the last layer of clutter (6000 * 1000) is modeled by the grid method according to the size of the setting ship (50 * 50). The improved JPS+ algorithm is applied to the radar simulation system target path Planning. Figure 9 shows the running environment of the radar simulation system (1000 * 1000). The interface shows a path from appearance to stop. The target quantity can be set according to training needs. Note: When two targets are in the same place at the same time, one of the targets waiting. Finally, the operational efficiency and quality of JPS+ algorithm path planning satisfy system and training standards.

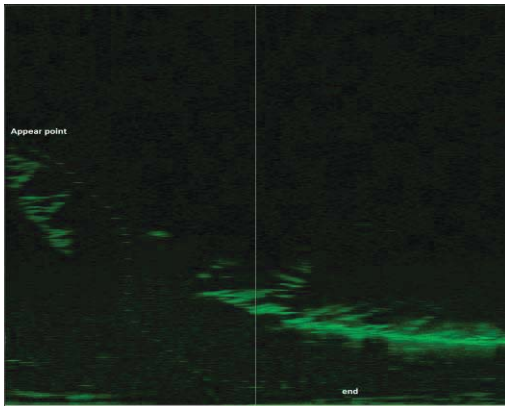

Fig. 9. Target path in radar simulation system

V. Conclusion

Path planning is one of the key problems that the radar simulation system faces. The system simulates the ship's sailing by finding a fast and efficient path. This paper improves the basic JPS+ algorithm by optimizing the evaluation function and introducing the binary heap. On the one hand, the improved algorithm can find the path of least cost according to the actual cost, on the other hand, it can reduce the number of extension points and the time of path. Finally, through the computer simulation, the algorithm in this paper can be successfully applied in the radar simulation system to find an efficient and high-quality path.

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