# A Path Planning Algorithm of Raster Maps Based on Artificial Potential Field


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***Abstract*—Based on the analysis of traditional artificial potential field method in path planning and the lack of intelligent tracking control, a path planning algorithm which combine artificial potential field and grid map is put forward in this paper. The method reduces the amount of calculation and also avoids the a serious problem of artificial potential field- the local minimum problem "deadlock". Compared with the exhaustive traversal of traditional grid method and recursion, testing, backtracking algorithm, the method is greater optimization on reliability, safety and efficiency.**



***Keywords— mobile robot ; path planning ; artificial potential field, ; grid map ; path tracking***


## I. INTRODUCTION

Intelligent mobile robot is a kind of robot systems which is capable of sensing the environment through sensors and their own states, to achieve self-movement during obstacles environments [1]. Robot path planning is a key technology of intelligent robot. Typically, the model of artificial field describes simply and successful. The path planning by the method is more safe[2-4]. But on the other hand artificial potential field method is easy to fall into local minima, so that the robot cannot reach the target position[5-7]. A fundamental part of the traditional method of raster map is a minimum grid scale. Then the map will be divided into grid. Grid map method can be more convenient to use a recursive algorithm to obtain collision-free path between any two prevailing grid, but it requires greater resources and time, and the path is not ideal degree of optimization.

In order to make the best use of the artificial potential field method's advantages and make it suitable for global map path planning, a simple and stable path planning algorithm – grid map of artificial potential field is proposed in this paper.

## II. TRADITIONAL METHODS OF GRID MAP AND ARTIFICIAL POTENCIAL FIELD

### A. Grid Map Method

A small grid is the basic component of the grip map.Blank grid is the space that robot can freely through, and shadow grid represents the obstacles. The algorithm will traverse from the starting point to the end of all possible paths, and the number of times that each grid is traversed will be counted. Then the prevailing factors (1 or 0) will be summed to strike path. When the grid map is initialized, barriers grid will be assigned 1and blank grid will be assigned 0. When all waypoints have been assigned, the computer will finish the path planning. Fig.1 is a schematic diagram of the conventional raster division.

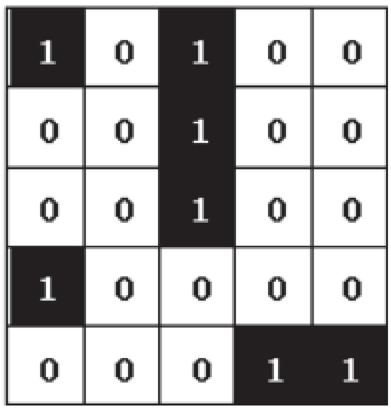


Fig.1. Schematic diagram of the traditional grid method

The recursive algorithm can be used easily to obtain any two traffic collision-free path , but it requires more resources and time. And the path is not ideal degree of optimization.

### B. Artificial Potencial Field Method

Attractive field is defined as:

$$U_{att}(X) = \frac{1}{2} k_1 \rho^2(X, X_g) \quad (1)$$

Repulsive field is defined as:

$$U_{rep}(X) = \begin{cases} \frac{1}{2} k_2 \left(\frac{1}{\rho(X, X_0)} - \frac{1}{\rho_0}\right)^2, & \rho(X, X_0) \leq \rho_0 \\ 0 & \rho(X, X_0) > \rho_0 \end{cases} \quad (2)$$

In which $k_1$ is the attractive field gain coefficient , $k_2$ is repulsive gain factor, $X_g$ is the target position, $X_0$ is the obstacle position, $\rho(X, X_g)$ is the distance between the robot and the target. $\rho(X, X_0)$ is the distance between the robot and the obstacle.

Attractive force $F_{att}$ is defined as the negative gradient of attractive field $U_{att}(X)$.

$$F_{att}(X) = k_1 \rho(X, X_g) \quad (3)$$

Repulsive force $F_{rep}$ is defined as the negative gradient of repulsive field $U_{rep}(X)$.

$$F_{rep} = \begin{cases} k_2 \left(\frac{1}{\rho(X, X_0)} - \frac{1}{\rho_0}\right) \frac{1}{\rho^2(X, X_0)}, & \rho(X, X_0) \leq \rho_0 \\ 0 & \rho(X, X_0) > \rho_0 \end{cases} \quad (4)$$

So the total force of the robot received:

$$\vec{F} = \vec{F_{att}} + \vec{F_{rep}} \quad (5)$$

Traditional artificial potential field method is simple to use but limited. In practical engineering applications, obstacle is often in the vicinity of the target position. When the mobile robot approaches the target, the attractive force increases and repulsive force decreases . Then the robot will be hovering near the target occurs. When the target is in the same line with an obstacle and the robot, the force of the robot is zero. But the position of the robot is not the minimum point of the whole situation in the field, so the robot will not reach the target point.

## III. THE METHOD BASED ON GRID MAP OF ARTIFICIAL POTENCIAL FIELD

### A. *Model Establishment*

The grid map of artificial potential field changes the grid from simple 0,1 into matrix grid so that each minimum grid could be assigned. When the obstacle region is detected , repulsive will be assigned through artificial potential field. And the repulsive will be expanded to the grid map, ranging focus of equipotential surfaces and raster center.

The model of grid map of artificial potential field is shown in Fig.2

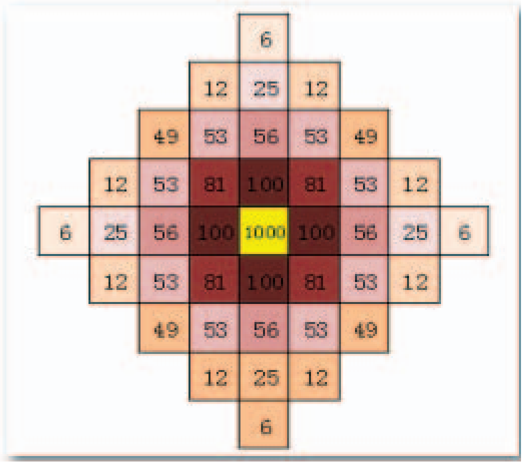


Fig.2. Grid map of artificial potencial field

According to (4), the detected obstacle region is the center of repulsive field. Repulsive field is built. If the repulsive field is interacted, superimpose them.

Previously mentioned traditional artificial potential field may cause the "deadlock"of local optimal point because of the superposition of attractive field and repulsive field.

The grid map of artificial potential field that constructed this paper, will no longer calculate attractive field after the calculations of repulsive field. In each grid by grid map of the potential field force has been superimposed completed values and by searching algorithm to meet the trend to guide the way to control the direction toward the end of the set. Since the path planning does not involve force field vector calculation, fundamentally to avoid the traditional artificial potential field method local minimum point "dead lock" problem .

### B. *The Algorithm Based on Grid Map of Artificial Potential Field Introduced*

The algorithm is based on grid map of artificial potential field thought nonergodic search algorithm to search grid whose radius is n . Fig.3 is to search a radius of 3 raster map illustrates.

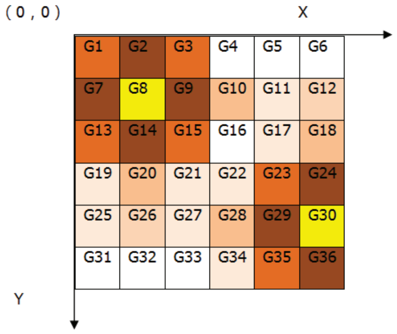


Fig.3. Grid map initialization

Assume that the obstacle is located in G8 and G30. Repulsive field is built with center of G8 G30, and according to the environmental information to initialize a grid map. As shown in Fig.3

In Fig.3, assuming that the mobile robot is currently in point G26, at first, it will search directly adjacent G 27, G32, G 25, G20 .

According to the coordinates of starting point ( $X_s$ , $Y_s$ ) and the end point ( $X_f, Y_f$ ) to generate detection direction priority, different weights will be given .

$W_{directiong}[i]; i = E, S, W, N$ as the priority weight coefficient. Eight search orders sumed up as follows:

1) if: $X_s > X_f, Y_s > Y_f, |X_s - X_f| > |Y_S - Y_f|$

then：the search order is:W→N→E→S

$W_{directiong}[W] > W_{directiong}[N] >$

$W_{directiong}[E] > W_{directiong}[S]$

2) if： $X_s > X_f, Y_s > Y_f, |X_s - X_f| < |Y_S - Y_f|$

then ：the search order is:N→W→S→E

$W_{directiong}[N] > W_{directiong}[W] >$

$W_{directiong}[S] > W_{directiong}[E]$

3) if： $X_s < X_f, Y_s > Y_f, |X_s - X_f| > |Y_S - Y_f|$

then：the search order is:E→N→W→S

$W_{directiong}[E] > W_{directiong}[N] >$

$W_{directiong}[W] > W_{directiong}[S]$

4) if： $X_s < X_f, Y_s > Y_f, |X_s - X_f| < |Y_S - Y_f|$

then：the search order is: N→E→S→W

$W_{directiong}[N] > W_{directiong}[E] >$

$W_{directiong}[S] > W_{directiong}[W]$

5) if： $X_s < X_f, Y_s < Y_f, |X_s - X_f| > |Y_S - Y_f|$

then：the search order is:E→S→W→N

$W_{directiong}[E] > W_{directiong}[S] >$

$W_{directiong}[W] > W_{directiong}[N]$

6) if： $X_s < X_f, Y_s < Y_f, |X_s - X_f| < |Y_S - Y_f|$

then：the search order is:S→E→N→W

$W_{directiong}[S] > W_{directiong}[E] >$

$W_{directiong}[N] > W_{directiong}[W]$

7) if： $X_s > X_f, Y_s < Y_f, |X_s - X_f| > |Y_S - Y_f|$

then：the search order is:W→S→E→N

$W_{directiong}[W] > W_{directiong}[S] >$

$W_{directiong}[E] > W_{directiong}[N]$

8) if： $X_s > X_f, Y_s < Y_f, |X_s - X_f| < |Y_S - Y_f|$

then：the search order is:S→W→N→E

$W_{directiong}[S] > W_{directiong}[W] >$

$W_{directiong}[N] > W_{directiong}[E]$

(6)

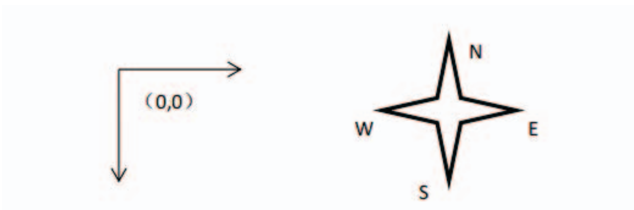


Fig.4. The global coordinate system and the direction of marking sketch

Assume that the end point is G17, as shown in Fig.3 The search order will be 3). The planning algorithm will be in accordance with the order from G27, G20, G25,G32 search. The first search point is G27.The repulsive field with the center of G27 in seven directions (besides G26)will be summed as $W_{directiong}[0]$ and multiplied by the weighting factor priority direction $W_{directiong}[0]$.

The guiding factor of G27:

$$G_{Guiding\ factor\ Po\mathrm{int}\,26-27} = Sum_{po\mathrm{int}\,26-27} * W_{directionorg}[E] \tag{7}$$

Similarly :the guiding factor of G20 is:

$$G_{Guiding\ factor\ Po\mathrm{int}\,26-20} = Sum_{po\mathrm{int}\,26-20} * W_{directionorg}[N] \tag{8}$$

The guiding factor of G25 is :

$$G_{Guiding\ factor\ Po\mathrm{int}\,26-25} = Sum_{po\mathrm{int}\,26-25} * W_{directionorg}[W] \tag{9}$$

The guiding factor of G32 is:

$$G_{Guiding\ factor\ Po\mathrm{int}\,26-32} = Sum_{po\mathrm{int}\,26-32} * W_{directionorg}[S] \tag{10}$$

Choose the minimum guiding factor of the four points as the next point.

As is shown in Fig.5

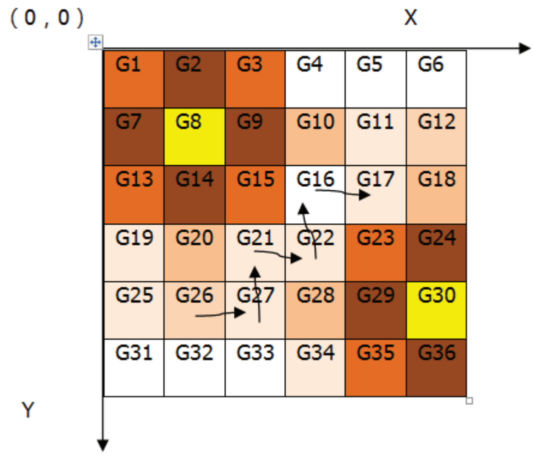


Fig.5. Example of the path planning algorithm

G27 for the center continue to be calculated around three points, G28, G21, G33 guiding factors. And the data is stored for retrospective reference list. Its minimum is retrieved to set point for the path point of the first layer. The point is treated as the new center. Repeat the above algorithm until find the target point. If the values are equal situation appears, choose the smallest motion platform postural changes point the way for the next waypoint.

### C. *Gestalt Processing Special Obstacle Area*

When appear as shown in Fig.6 , due to the search of mobile robot in a red box body, the sensor feedback surroundings get obstacle area. When trying to red frame covered area is smaller than the set threshold $SP_{rect}$ barrier region merging. This should be the kind of obstacle region finished type combined with operation.

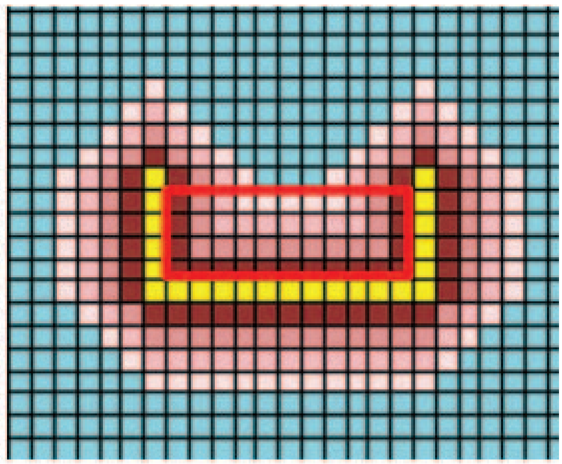

Fig.6. Special obstacle region over type processing

### D. *Path Queue Optimization*

Because the search is W, E, N, S four directions. The resulting diagonal path for ladder type are not friendly to the mobile robot, and therefore the establishment algorithm will step type transformation. The path information is transmitted to the tracking controller optimally. As shown in Fig.7 all purple points sent to the path planning point tracking controller.

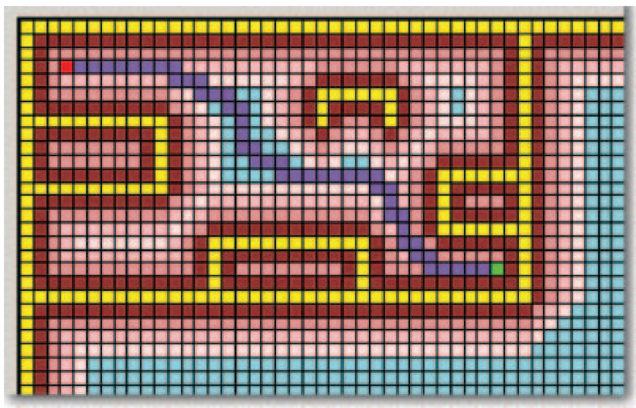

Fig.7. Path planning is not optimized

### E. *The Real Turning Point Grid Path Optimization*

Because the basic path planning for grid map, in the core algorithm of path planning under the premise for the artificial potential field path planning of arc, but became constant angle, disguised by the path makes hardware cumulative error increases. For the optimization of this kind of problem, optimization algorithm will be three, four, five paths to fold is constituted by a set of horn shape template (four total) orderly queue traversal search path stored in the whole key path points generated in front of the queue, the angular shape template into the bends of the straightening template. But the direct template connected diagonal point may cause the mobile robot in the critical marched, there is an obstacle to its volume, so it needs to check.

The validation process for the critical path through the queue the last optimization, the robot vertical projection area of X projection to the path, that is generating the full path to a safe range, as shown in Fig.8 (note that in the example below for convenience of description, set the X size is a grid, then purple grid coverage area for the full path to the safety range), found the reality path optimization effect of grid key turning points, keep line part if the full path safety range according to a template connected diagonal point the connection not covered in purple grid, so keep angle.

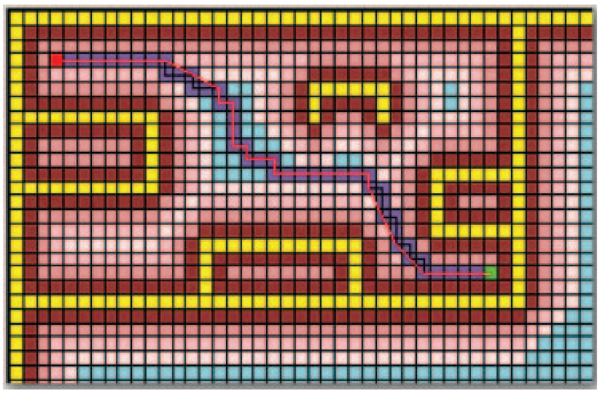

Fig.8. The effect of grid reality optimization path key turning point

### F. *The Path Planning Process Flow Chart*

The workflow of the algorithm based on grid map of artificial potencial field is shown in Fig.9

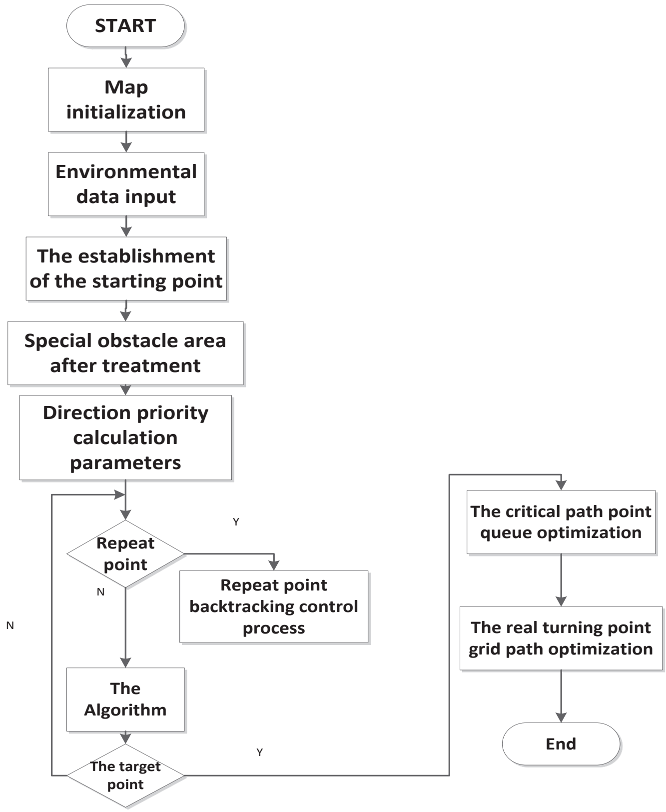


Fig.9. The path planning process flow chart

## IV. The Results of The Experiments

In order to verify the feasibility of the algorithm based on grid map of artificial potential field, a mobile robot is designed. And the development of Visual Basic based on the PC support a variety of communication protocols, with map data storage and playback functions path planning. Visual interface development as shown in Fig.10, the upper computer practical planning two examples as shown in Fig.11

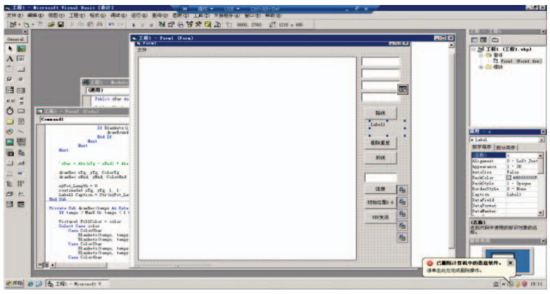

Fig.10. Visual Basic visual interface development

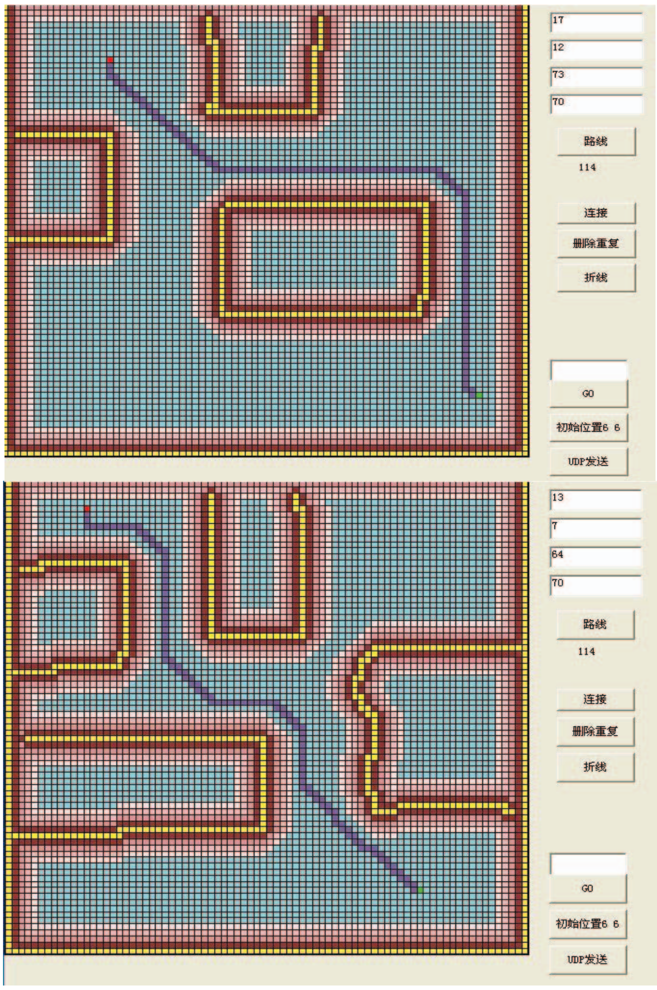


Fig.11. Path planning PC actual planning of two cases

## V. CONCLUSIONS

Experiments show that the paths generated by grid map of artificial potential field method have advantages on accessibility and reliability, than simply using the grid map method. The application of grid method is as the foundation, compared with the traditional artificial potential field method which need to calculate the full path full situation in the field. The calculation amount is greatly reduced, guided by global trends and the combination of real-time trends to guide and optimize the interaction between the obstacles and set the end point, the use of variable radius search algorithm applied to different grid size corresponds to the complexity of the obstacles to a different base map. The grid map of artificial potential field that constructed this paper, will no longer calculate attractive field after the calculations of repulsive field, in each grid by grid map of the potential field force has been superimposed completed values and by searching algorithm to meet the trend to guide the way to control the direction toward the end of the set. Since the path planning does not involve force field vector calculation, thus fundamentally to avoid the traditional artificial potential field method local minimum point "dead lock" problem. When constructed according to the site map, even use of larger scale grid, due to the core path planning algorithm for artificial potential field, the path still has high reliability.

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