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Path Planning Research for Mobile Robot Based on Immune Genetic Algorithm

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ABSTRACT: Mobile robots have played an important role in many fields, its related technologies research naturally attracted people's attention. As one of the key technologies of the robot, path planning has been a hot topic for scholars. Therefore, the study of path planning is of great practical significance. Based on this, the immune genetic algorithm and its application in robot path planning are studied in this study. Immune genetic algorithm can be seen as an improved genetic algorithm with immune function. It has been widely used in mechanical optimization design, controllers' optimization, channel optimization and other fields. For practical problem of mobile robot path planning, an improved immune genetic algorithm - adaptive immune genetic algorithm (AIGA) is proposed in this paper, and is applied in mobile robot dynamic path planning. Besides, the simulation results are analyzed and studied, which show that AIGA is fully capable of performing optimization work of the robot in dynamic environment, and the real-time is strong.

KEYWORDS: Mobile robot; Path planning; Immune genetic algorithm; Dynamic path planning.

INTRODUCTION

Today, robots have played an important role in many fields, and they will be gradually penetrated into personal lives like computer in the future. If the robot wants to work properly, navigation technology is one of the key technologies. Path planning technology as a key issue of navigation technology, its research naturally attracted widespread attention [1,2].

Currently, a variety of intelligent algorithms (such as: ant colony algorithm, particle swarm optimization, immune algorithm, etc.) have been successfully applied in solving path planning. As a class of smart search algorithm with robust that is applied to complex system optimization, genetic algorithm has been applied in the study of path planning early. But it also has many disadvantages in evaluating programs that is the required storage space and computing time are large, operation speed is slow, and it has five inherent problems [6]. Then a series of improved genetic algorithms have been proposed, such as particle swarm genetic algorithm [7], multi-agent genetic algorithm, immune genetic algorithm [8], etc. Among which the immune genetic algorithm as one of the best, has been successfully applied in mechanical optimization design, controllers' optimization, channel optimization and other fields, and have achieved good effects.

In path planning, the current work environment modeling methods include grid method, geometric method and topological method. These methods have advantages and disadvantages, and have their own acclimatization. How to select the appropriate modeling approach aiming at specific environment is the key [9-10]. As mentioned above, the path planning problem has been concerned widespread and studied in-depth, which is also the subject of this paper. Path planning includes static path planning and dynamic path planning these two contents. This paper mainly studies dynamic path planning which is not thorough enough at present, and this study is required to ensure that the robot can work properly under dynamic environment. This paper proposes immune genetic operator applied in path planning, making the robot can complete a complex path planning in static environment. The simulation results are analyzed and studied, proving the superiority of the algorithm mentioned herein.

IMMUNE GENETIC OPERATOR APPLIED IN PATH PLANNING

Common crossover and mutation operators obviously can not be applied in robot path planning, they need to make certain changes to adapt the path planning in set environment. However, only relying on modified crossover and mutation operators still can not effectively solve the path planning. Only through crossover and mutation, feasible solution can not be effectively obtained through evolution in complex environment. In a relatively simple

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environment, although it may get feasible solution, its quality can not be guaranteed, and the spent time will be very long. Therefore, for this particular problem, three special operators (insertion operator, delete operator, improved operator) are used in this paper to enable the proposed immune genetic algorithm more effective, and these operators will be described in details hereinafter.

Crossover Operator

Crossover operator is to randomly select one or some nodes from the parent a and b respectively, then exchange the second half of the node. Check the two offspring and delete parts between the same two nodes, as shown in Figure 1. Because the length of antibody is variable, different intersection selected from different parents can contribute to the variability of antibody length, so as to be benefit for the exploration of solution space.

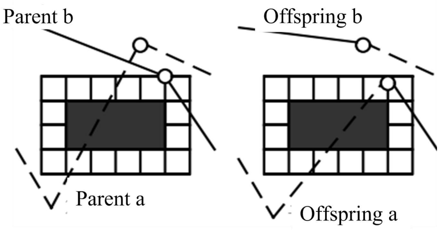

Figure 1. Crossover operator.

Mutation Operator

Mutation operator is to randomly select one node from parent, and then randomly select a node that is not included in the parent to replace this node. Mutation operator plays an important role in maintaining the diversity of solution. However, individual after mutation does not necessarily have better quality than the original individual. Figure 2 illustrates the mutation process.

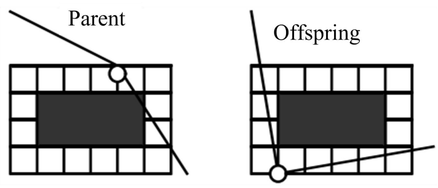

Figure 2. Mutation operator.

Insertion Operator

Insertion operator is to through inserting an appropriate node in both ends of the infeasible line nodes to make the path is of feasibility and continuity. Usually use the following steps to get the insertion point coordinates:

Step one, adjacent. First, determine whether two grids that the individual numbers are X and Y are adjacent with formula (1).

$$\beta = \max\{abs(x_2 - x_1), abs(y_2 - y_1) \tag{1}$$

Wherein $(x_2 - x_1)$ and $(y_2 - y_1)$ are respectively coordinates of X and Y. If $\beta = 1$, X and Y are adjacent, if not, calculating the candidate insertion point N with formula (2):

$$\begin{aligned} x_3 &= (x_1 + x_2)/2 \\ y_3 &= (y_1 + y_2)/2 \\ N &= x_3 + n * y_3 \end{aligned} \tag{2}$$

If the calculated insertion point coordinate fall on the free grid, this grid can be directly inserted as a new node; otherwise, adopt the principle of proximity, search free grid around N, insert as a candidate point until each nodes are adjacent between in the path.

Step two, serialization. As described in Figure 3, the positional relationship between the adjacent grids is not unique, and there are 3 (a) and (b) two cases. For Figure 3(a), number-3 grid should be inserted so that the path is not in contact with an obstacle and continuous; and for Figure3(b), this path should be classified as a viable path and be deleted.

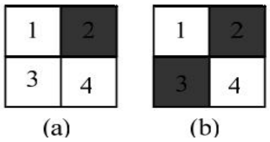

Figure 3. Positional relationships between adjacent grids.

Delete Operator

Delete operator is applied in both infeasible path and feasible path, its main idea is to randomly select a node in the path, then check the two nodes adjacent to this point and the line connecting them. If it is beneficial to delete the node (such as: infeasible path can become feasible path, or reduce the cost, etc.), the node can be removed, as shown in Figure 4.

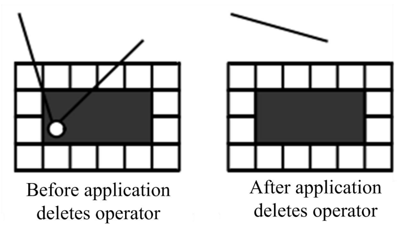

Figure 4. Delete operator.

Improved Operator

Improved operator is specifically designed for feasible solution. Randomly select a node in the path, local search around this node, and then move the node to the best place. Improved operator can be actually seen as a fine tuning for feasible solution, as shown in Figure 5.

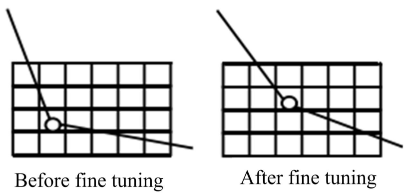

Figure 5. Improved operator.

All of these operators combine together to make the solving of path planning more effective, and the obtained quality of solution are also higher. Mutation and crossover operator bring new individuals to the populations, while insertion operator makes the path continuous and also makes infeasible path become feasible, and delete operator and improved operator adjust the solution. In the environment with many obstacles, the proportion of feasible solutions in initial population is very small, mutation and crossover operator is far from those tasks that infeasible solution evolve into feasible solution, at this time, insert, delete, and improve these special operators and to be introduced into the algorithm is extremely necessary.

ALGORITHM PROCESS OF MOBILE ROBOT PATH PLANNING

In summary, the use of AIGA for robot path planning simulation algorithm process is as follows:

1) Modeling robot working environment with grid method and initializing the related parameters;

2) Randomly generate initial population of bag M antibody (or individual), and operate these individuals with insertion and delete operators to ensure the feasibility and continuity of the path;

3) Calculate the fitness value of each antibody, and store the most outstanding individual as elite individual into a proprietary variable;

4) Determine whether the population is the first generation, if it is, perform crossover and mutation operation on antibody populations; otherwise, continue;

5) Calculate the fitness value of each antibody again. If there is no fitness value of antibody that is better than the elite antibody in population, the antibody with the smallest fitness value in population replaces the elite individual. Otherwise, continue;

6) If there is a better antibody than elite individual in population, copy this antibody to proprietary variable to replace the previous elite individual, and then put forward the next step; otherwise, continue;

7) Determine whether the preset stop criterion is satisfied, if it is, stop and output the optimal solution; otherwise, back to 5), and continue iteration.

SIMULATION EXAMPLE AND RESULT ANALYSIS

In order to verify the effectiveness of the improved AIGA proposed herein, it will be simulated in a dynamic environment. The program for simulation is written by Visual C ++ 6.0 and runs in WIN7 operating system.

In reality, the work environment of robot is often unknown. It requires the robot effectively complete the task in a dynamic environment that is a sudden increase of obstacles, obstacles moving, and under the circumstance of target point moving, the robot is still able to find a best path. AIGA will be used in these three dynamic environments for test simulation, the test environments are unified as grid map with size of 15 * 15. It is noted that a changed obstacle in the following simulation map will be marked in red to be distinguished from ordinary black obstacles. S in upper left corner is the starting point, and E in lower right corner is the destination point.

The Number of Obstacles is Changed

Figure 6 is used for this test environment map; Figure 7 is its original motion path that is the obstacles do not change at this time. As shown in Figure 7, AIGA find the best path.

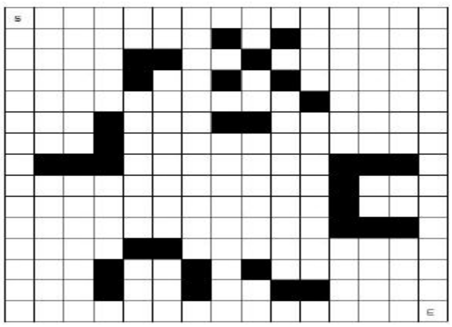

Figure 6. Simulation test map.

Figure 8 and Figure 9 show that after a sudden increase of obstacles (red obstacles), AIGA path optimization simulation map, and it is easy to know that the best path both figures are looking for is the best path. In simulation, the position obstacle increased is random. Select and show the two graphs are because in comparison with the original motion path, the position obstacles increased in above two figures has more persuasive for the proving of effectiveness of the algorithm AIGA.

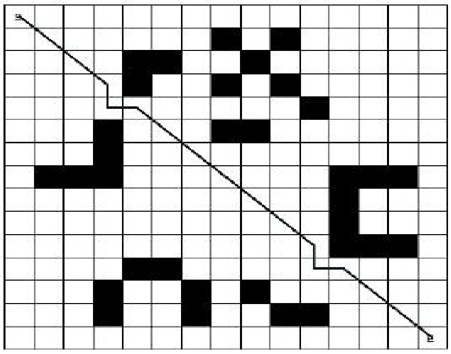

Figure 7. Original motion path.

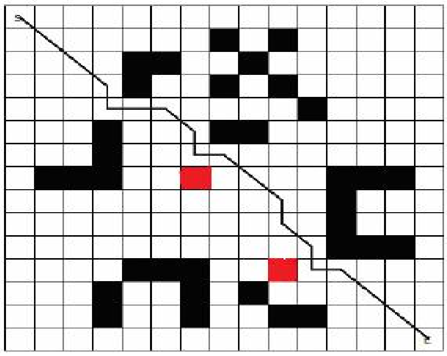

Figure 8. Sudden increase of obstacles simulation map.

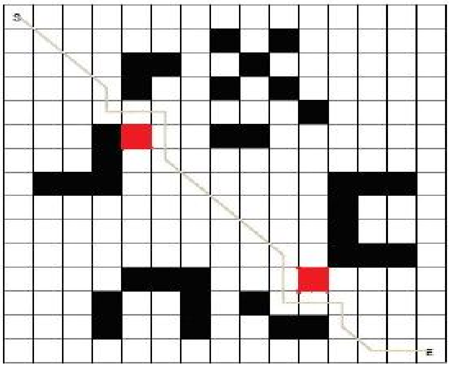

Figure 9. Sudden increase of obstacles simulation map.

Obstacles Move

In robot actual operations, obstacle movement is normal, such as a home service robot servicing in the living room, there must be someone walking up and down from time to time, which requires the robot can accurately avoid pedestrians (obstacle) to reach the target point for service operation. Figure 10 is a test map of moving obstacle, in which the red obstacle will be moved in the simulation process, moving interval is set to 2 seconds, and moving a total of three times. The motion path before obstacles moving is shown as Figure 11. In moving, path optimization results are shown in Figure 12, Figure 13 and Figure 14, which is easy to verify that in three movements, paths found by AIGA are all the optimal paths.

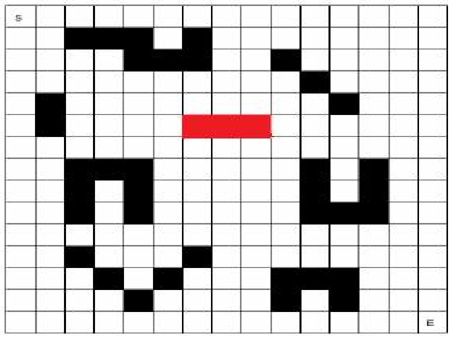

Figure 10. Simulation test map figure.

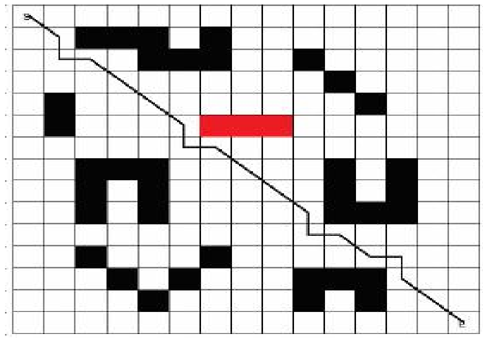

Figure 11. The motion path before obstacles moving.

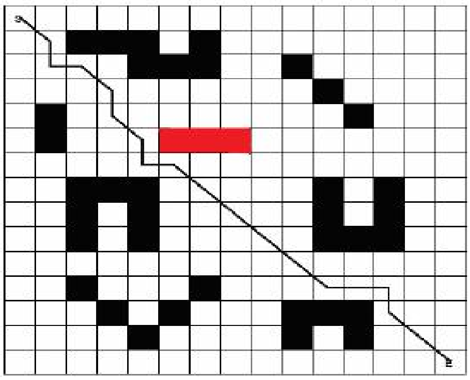

Figure 12. After obstacles moving to the left one space.

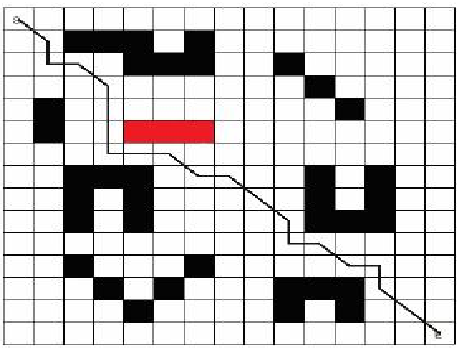

Figure 13. After obstacles moving to the left two spaces.

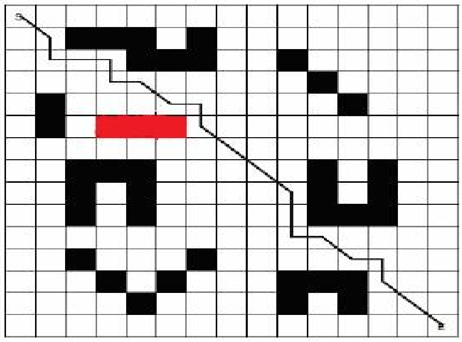

Figure 14. After obstacles moving to the left three spaces.

Targets Move

In many cases, the target point is moving in path planning process, such as: in robot soccer, football (target point) is constantly on the move; when the war robot performs tasks, the enemy is also constantly moving. So in the study of path planning, target movement is of practical meaning. Figure 15 is a test map of targets move, and Figure 16 is the best path found by original target point. Figure 17, Figure 18 and Figure 19 are simulation map after target point moving, and the simulation interval is set that target point moves up one space for each 5 seconds. It is not difficult to verify that after the target point moving, AIGA is still able to obtain the optimal path.

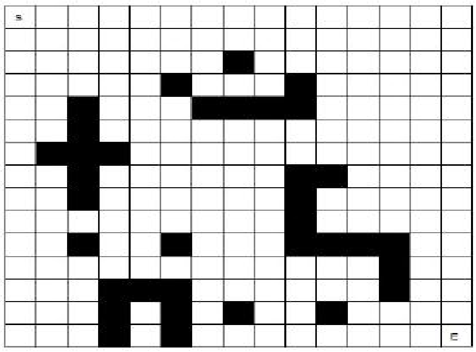

Figure 15. Targets move test map.

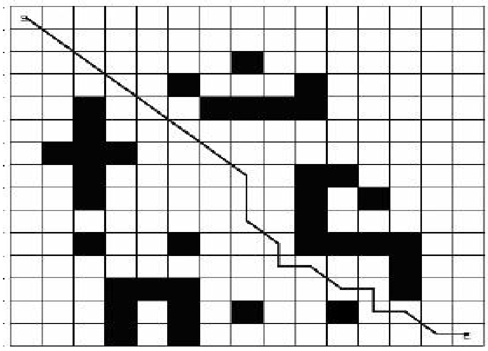

Figure 16. Simulation of target unchanged.

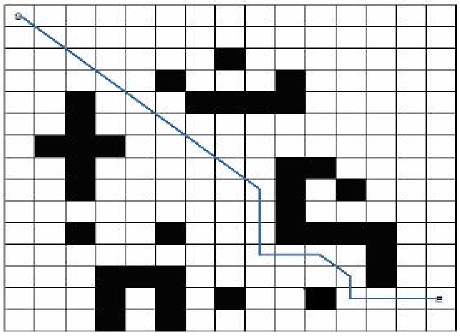

Figure 17. Simulation of targets moving one space.

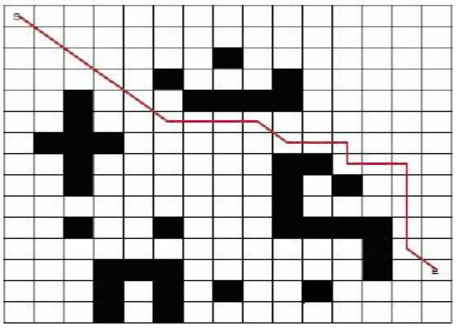

Figure 18. Simulation of targets moving two spaces.

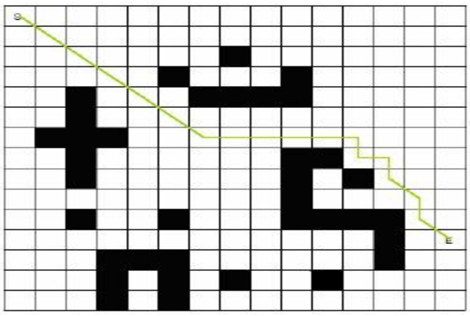

Figure 19. Simulation of targets moving three spaces.

The simulation of traditional genetic algorithm with elitist strategy (EGA) and general immune genetic algorithm (IGA) in dynamic environments is not provided, because their operation effect in this environment is not significant, but in a static simulation both methods can not obtain feasible path planning. The above simulation diagrams show that the simulation effect of AIGA in various dynamic environments is very significant, real-time is strong, and can be qualified for path optimization work of complex environment.

CONCLUSION

This study elaborates crossover operator, mutation operator, insertion operator, delete operator, and improved operator applied in mobile robot path planning. Then the algorithm process of mobile robot path planning is provided in details. Finally, the mobile robot path planning is simulated in dynamic environment, and the results are analyzed in-depth. Through simulation, it is not difficult to find out that: in dynamic path planning, AIGA can effectively carry out path planning, while EGA and IGA are not.

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