Research status of mobile robot path planning based on genetic algorithm

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Abstract: With its strong search ability and other characteristics, the genetic algorithm in mobile robot path optimization has been rapidly developed and applied, and has become one of the most successful algorithms to solve the mobile robot path planning problem. Firstly, this paper introduces the basic principle of genetic algorithm and gives a brief overview of its development and improvement strategies. Then, combining several representative improvement strategies, path planning of mobile robot is explained in detail. Finally, combining the theoretical and applied research results of genetic algorithm, the further development of the algorithm is summarized and prospected.

1. Introduction

With the further development of science, technology and artificial intelligence, robots have been applied to various industries, such as underwater detection, medical robots, path optimization problems, aerospace and other fields. Considering that the path planning of mobile robot is not smooth and distance optimal, researchers have proposed a lot of optimization algorithms for mobile robot paths. As one of the swarm intelligence algorithms, genetic algorithm (GA) has been rapidly applied to mobile robot path planning due to its strong search ability.

Genetic algorithm is a bionic algorithm based on Darwin's natural evolution and Mendel's theory of genetic variation, which simulates the process and mechanism of biological evolution$^{[1]}$. In 1975, J.Holland, a professor from the university of Michigan, proposed a simulated evolutionary algorithm based on the principle of natural selection, adaptive optimization and natural genetic mechanism by referring to the laws of biological evolution$^{[2-4]}$. This algorithm is a heuristic search technology with strong robustness, suitable for parallel computing, and easy to integrate with other algorithms. Therefore, genetic algorithm has been widely concerned by researchers in various fields at home and abroad.

Under the continuous exploration of researchers, genetic algorithm has carried out many improvement strategies. Therefore, the solving performance of genetic algorithm is effectively mentioned. In addition, it has been rapidly practiced in the fields of function optimization, production scheduling, image processing and robot path planning, and achieved certain research results$^{[5]}$. The application of genetic algorithm in path planning of mobile robots has made remarkable achievements. On the basis of the basic genetic algorithm, the researchers improved the genetic algorithm from the aspects of individual coding strategy, operator strategy and integration with other algorithms. Experiments show that these improved genetic algorithms have certain scientific significance in path planning of mobile robots.
2. Introduction to Genetic Algorithm

2.1. Basic Principles and Processes of Genetic Algorithm

2.1.1. Basic Principles of Genetic Algorithm
Starting from a random or specific initial solution, genetic algorithm constructs an appropriate fitness function through the objective function of solving the problem. According to certain genetic operations, such as selection operation, crossover operation and mutation operation, a new generation of individual subset is generated. Then, calculate the fitness function value of each individual, select the superior individual according to Darwin's natural law of "survival of the fittest, survival of the fittest", and gradually evolve the similar solution through multiple iterations. Eventually converges to one or more optimal solutions to the actual problem.

2.1.2. Basic Process of Genetic Algorithm
The design of genetic algorithm mainly includes the following steps to complete the objective function optimization of practical problems.
1) individual coding;
2) initialization of the population;
3) design of fitness function;
4) select operation;
5) cross operation;
6) mutation operation;
7) termination conditions.

2.1.3. Flow Chart of Improved Genetic Algorithm
The flow chart of the improved genetic algorithm is shown in figure 1.

![Flow chart of improved genetic algorithm](image)

Figure 1. Flow chart of improved genetic algorithm

2.2. Development and Improvement of Genetic Algorithm

2.2.1. Development of Genetic Algorithms
Genetic algorithms are the most widely used and successful algorithms. In the late 1960s, professor Holland and his colleagues first proposed. In the early 1970s, a relatively complete bionic algorithm was formed.

In the 1970s, De Jong used genetic algorithm to carry out a large number of functional optimization
simulation calculation experiments on the computer. Finally, De Jong forms the basic framework of genetic algorithm in the research and exploration [3]. In the 1990s, genetic algorithm ushered in a prosperous period, both theoretical and applied fields are very hot topics for researchers.

2.2.2. Improvement of Genetic Algorithm
With the exploration of researchers at home and abroad, genetic algorithm has solved a lot of practical life and production problems, and also produced certain economic benefits. However, due to the shortcomings of the genetic algorithm, such as slow convergence speed and easy to fall into the local optimal solution, the mobile robot did not achieve the desired effect in path planning. In order to avoid these deficiencies and to further improve the efficiency of genetic algorithm in path planning of mobile robots. The researchers improved the genetic algorithm from the following strategies:

1) individual coding strategy;
2) crossover and mutation and other operator strategies;
3) integrate strategy with other algorithms.

According to the above improvement strategy, a series of improved genetic algorithms are proposed. At the same time, simulation results verify the feasibility and practicability of these improved algorithms in mobile robot path planning.

3. Application of Improved Genetic Algorithm in Path Planning of Mobile Robot
The classical application field of genetic algorithm is to solve the problem of function optimization. With the further exploration of genetic algorithm, the theory of genetic algorithm has been improved to a great extent. Genetic algorithm has made great progress in robot path planning because of various strategies. The following is a detailed description of the application of different improvement strategies to the path planning of mobile robots.

3.1. Improvement of Individual Coding Strategies
The premise that genetic algorithm can converge to the global optimal solution is to encode individuals reasonably. Coding is the genetic representation of a feasible solution to a practical problem and is one of the key factors affecting the efficiency of genetic algorithm. Therefore, domestic and foreign scholars have carried out a lot of experiments on the individual coding strategy of genetic algorithm and obtained certain research results.

Literature [8] proposed a method of path planning for mobile robots based on improved genetic algorithm. Firstly, the coordinate value of each point on the moving path of the mobile robot and the connectivity of the point are used as the real encoding of the variable length of the gene. Then, the fitness function is determined by path shortest, path smoothness and path safety to optimize the path of mobile robot. Finally, the simulation experiment shows that the algorithm can improve the convergence speed of solving the path of mobile robot. At the same time, the motion path of mobile robot becomes much smoother due to the existence of smoothness factor.

In literature [9] proposed a path planning method for mobile robots based on improved genetic algorithm. The improved genetic algorithm converts complex two-dimensional individual coding into simple one-dimensional individual coding, and the path planning specific correction factor is introduced to optimize the path of mobile robot. The experimental results show that the algorithm overcomes the deficiency of premature convergence of the basic genetic algorithm and improves the evolutionary efficiency of the algorithm.

In addition, many improved algorithms for individual coding strategies have been proposed by scholars. For example, variable length coding strategy of integer coding is adopted [10], the individual coding strategy was carried out by using raster ordinal [11], and binary individual encoding with variable length is adopted [12] etc. These strategies improve the algorithm, to some extent, improve the convergence speed of the algorithm in solving the path of mobile robot, and shorten the time for the algorithm to reach the global optimal solution.
3.2. Operation Operator Policy
In genetic algorithms, operators generally include selection operators, crossover operators and mutation operators. The improvement of these operators can not only accelerate the speed of genetic algorithm to reach the optimal solution, but also improve the searching ability of the algorithm to some extent. Therefore, starting from the strategic direction of the improved operator, the researcher also proposed a series of improved algorithms to solve the path optimization of the mobile robot.

Literature [13] proposed an adaptive genetic algorithm for the deficiency of crossover operator and mutation operator in the basic genetic algorithm to keep constant in the whole evolution process. The crossover probability and mutation probability are automatically adjusted by the fitness function value of each individual. Let the crossover operator and mutation operator of each generation of population be in a dynamic process, overcome the shortcomings of the basic genetic algorithm, such as easy to fall into the local optimal solution. Through simulation and comparison of experimental data, it is shown that the improved genetic algorithm improves the path quality to a certain extent. Meanwhile, the feasibility of this algorithm in solving the shortest path of mobile robot is also verified.

In literature [14] proposed a new mutation operator. Any node is assumed to be a mutation node, the fitness function value of the mutation node and its surrounding free nodes is calculated synchronously, and the optimal node is selected as the new mutation node, so as to calculate the shortest path of mobile robot. The simulation results show that the improved genetic algorithm has higher convergence speed, more accurate convergence accuracy and fewer iterations.

Other operator improvement strategies include, using tournament selection operator and multi-point crossover operator to make the algorithm search more efficient[15], and A new operator is used to plan the path of mobile robot[16] etc. Through continuous improvement of operators, improve the convergence speed and efficiency of the algorithm, but also improve the global search ability of the algorithm, and verify the feasibility of the algorithm.

3.3. Fusion Strategy with Other Algorithms
The genetic algorithm has good optimization ability and can converge to the optimal solution quickly. By combining genetic algorithm with other algorithms and learning from each other. The improved genetic algorithm can not only improve the path quality, but also improve the convergence speed. Therefore, researchers have proposed many fusion algorithms with better performance to solve the path optimization of mobile robots.

Literature [17] proposed an algorithm combining genetic algorithm and simulated annealing algorithm. The fusion algorithm USES simulated annealing algorithm with strong local search ability, which improves the solution efficiency of the whole fusion algorithm. At the same time, the precocity of basic genetic algorithm is avoided. Experimental results show that the fusion algorithm is effective and feasible in path planning of mobile robot.

Literature [18] proposed an algorithm combining genetic algorithm and particle swarm optimization algorithm. In the early stage of evolution, the velocity and position of particles are updated by establishing dynamic linkage relationship between inertial weight coefficient and learning factor. In the late stage of evolution, crossover and mutation operations of genetic algorithm were introduced to enhance the global search capability of hybrid algorithm. The simulation results show that the fusion algorithm has the advantages of good convergence performance, strong convergence efficiency and short path search.

In addition to the fusion of the above algorithms, many fusion algorithms for path planning of mobile robots have been proposed by scholars, such as the fusion of genetic algorithm and fuzzy logic control [19], the fusion of genetic algorithm and artificial potential field method [20], etc. By merging with different algorithms and combining the advantages of other algorithms to make up for the shortcomings of the genetic algorithm, a better fusion algorithm can be obtained.

4. Summary and Outlook
This paper introduces the research status of genetic algorithm in path planning of mobile robot. The
genetic algorithm is used to solve the problems of uneven trajectory and uneven path in path planning of mobile robot, which brings great convenience to people. However, in some research fields, the application of genetic algorithm needs further research and exploration. For example, it is expected to become the main research direction in the future for the research on swarm robots and communication problems. Therefore, the development trend of mobile robot in path planning is as follows:

1) Path planning technology for group robots
   With the rapid development of mobile robot technology, it is difficult for a single robot to complete certain tasks. Genetic algorithm can be used to control multiple mobile robots to avoid obstacles and then plan an expected optimal path, which is expected to become a research hotspot.

2) Sensor fusion technology
   Multi-sensor fusion technology is also one of the key technologies in mobile robot technology, since a single sensor may have delay or uncertainty in transmission to the environment around the mobile robot; in order to avoid unnecessary damage caused by communication delay of mobile robot, it can be solved by multi-sensor fusion technology, and then realize real-time communication of mobile robot.

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