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Optimal path planning of robot based on ant colony algorithm[1]

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Abstract. In order to develop a scheme for optimal path calculation of robots, the optimal path planning of robot based on ant colony algorithm is proposed. The path planning of mobile robot is one of the core contents of robot research. It has the characteristics of complexity, constraint and nonlinearity. Ant colony algorithm (ACA) is a bionic optimization algorithm developed in the last ten years. The algorithm has shown its excellent performance and huge development potential in solving many complex problems. On the basis of ant colony algorithm and genetic algorithm (GA), the GA-ACA algorithm and ACA-GA algorithm are proposed and applied to robot path planning. Based on the MATLAB7.5 software development environment, a mobile robot path planning simulation system based on ant colony algorithm is designed. The simulation results verify the effectiveness of the proposed algorithm. After the simulation calculation, it is shown that the GA-ACA and ACA-GA algorithms have better comprehensive performance than ant colony algorithm. Based on the above finding, it is concluded that the optimal path planning of robot based on ant colony algorithm is suitable for the control and tracking of robot during its operation.

Key words. Path planning, ant colony algorithm, genetic algorithm, GA-ACA algorithm, ACA-GA algorithm.

1. Introduction

With the development of computer technology, control theory, artificial intelligence theory and sensor technology, the research of robot has developed to a new stage [1]. Among them, mobile robot, as an important branch, has been paid more and more attention in the field of research both at home and abroad. In recent years, mobile robot technology has played an important role in many fields such as industry, agriculture, aeronautics and space exploration. Because of its broad application prospects, mobile robot technology has become a hot issue at home and abroad. Path planning is the security guarantee for mobile robot to accomplish the task, and it is also an important sign of the intelligent degree of mobile robot. The

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improvement of the path planning algorithm will change the navigation performance of the mobile robot and improve the intelligence level of the mobile robot [2]. At the same time, it will reduce the uncertainty of mobile robot in the course of movement, increase the flexibility of mobile robot movement, and provide a solid foundation for the development of high intelligent mobile robot. The path planning of mobile robot is one of the most important problems in the research of robot control system, and it is also one of the core contents in the field of robot research. The purpose of path planning is to hope that future mobile robots have high-level capabilities such as perception, planning and control. So that it can collect information from the surrounding environment, build a model about the environment, and use this model to plan and execute high-level tasks.

2. Literature review

At home and abroad, the path planning research can be divided into two methods: traditional methods and intelligent methods. Among them, traditional methods include visual graph, free space method, grid method, artificial potential field method and topological method. The intelligent methods include genetic algorithm, fuzzy logic method, neural network method and ant colony algorithm. Ant colony algorithm belongs to a new algorithm. Ant colony algorithm uses distributed parallel computing mechanism, which can effectively find the global optimal solution [3]. It has strong robustness and adaptability, and is easy to combine with other algorithms. However, ant colony algorithm has some drawbacks. Although compared with genetic algorithm, the search time of ant colony algorithm has been obviously shortened, it is still not ideal enough. On the other hand, when the path planning problem is large, the ant colony algorithm tends to stall or sink into the local optimal solution. In order to overcome the shortcomings of the two algorithms and form complementary advantages, genetic algorithm and ant colony algorithm can be combined. Two improved algorithms are proposed based on ant colony algorithm combined with genetic algorithm, which are GA-ACA algorithm and ACA-GA algorithm [4]. And these new algorithms are applied to robot path planning. Based on the MATLAB7.5 software development environment, a mobile robot path planning simulation system based on ant colony algorithm is designed. The simulation results show that the GA-ACA and ACA-GA algorithms have better comprehensive performance than ant colony algorithm.

3. Methods

3.1. Robot path planning based on ant colony algorithm

The establishment of environment model is a very important part of robot path planning. The actual working environment of a robot is a realistic physical space, and the space that the path planning algorithm handles is the abstract space of the environment. Environment modeling is a mapping from physical space to abstract space. The environment model is built by grid method, and the actual working space of robot is simulated. A grid is used to represent the environment map of the robot's work, and complex computation can be avoided when dealing with the boundaries of obstacles. In the application of grid method, the most important part is the partition of grid granularity. The smaller the grid size is, the more accurate the obstacle will be. But at the same time, it takes up a lot of storage space, and the search scope of the algorithm increases exponentially. Grid size is too large, and the planning path will be very inaccurate. The grid granularity is 1×l.

In the grid environment with n of total grid, the steps of ant colony algorithm for robot path planning are as follows:

Step 1: Set initial parameters and initialize ant colonies.

Step 2: An ant is transferred to the next grid.

Step 3: The step 2 is repeated until all dead ants complete the selection of the subsequent grid.

Step 4: Local pheromones are updated.

Step 5: Step 2, step 3, and step 4 are repeated until all ants are moved to the target grid.

Step 6: The shortest path, the length of the shortest path, and the average length of the path taken by all ants in the cycle need to be calculated.

Step 7: The global pheromone is updated.

Step 8: The tabu table is cleared, the number of cycles is $Nc = Nc + 1$, if $Nc = Nc_{\max}$ was transferred to step 2; If $Nc > Nc_{\max}$, jump out the entire loop, output the optimal path and the optimal path length.

3.2. Robot path planning based on genetic algorithm

Genetic algorithm (GA) is a global optimization algorithm based on natural inheritance and natural selection proposed by Professor J. Holland from America in 1975. It has implicit parallelism, good global optimization ability, and strong robustness and flexibility. The main operations of genetic algorithm are selection, crossover and mutation. The core contents are parameter coding, generation of initial population, design of fitness function, design of genetic operators and setting of control parameters. The concrete steps are as follows:

Step 1: The solution space of the problem is encoded.

Step 2: The initial population is randomly generated and the fitness function of all individuals in the population is evaluated.

Step 3: Determining whether the convergence criteria of genetic algorithms are satisfied. If satisfied, output search results; otherwise, continue with the following steps.

Step 4: According to the size of the fitness function, copy operations are performed in a certain way.

Step 5: Cross operation is performed according to cross probability Pc.

Step 6: According to the mutation probability Pm, the mutation operation is performed.

Step 7: Go to step 2.

3.3. Robot path planning based on GA-ACA algorithm

In order to overcome the shortcomings of ant colony algorithm and genetic algorithm, the genetic algorithm and ant colony algorithm are fused to complement its advantages. Firstly, the initial pheromone distribution of the problem is generated by the stochastic search, rapidity and global convergence of the genetic algorithm. Then, the parallelism of the ant colony algorithm, the positive feedback mechanism and the high efficiency of the algorithm are fully utilized to solve the problem. The algorithm is superior to genetic algorithm in solving efficiency, and is superior to ant colony algorithm in time efficiency. A heuristic algorithm for solving both efficiency and time efficiency is proposed. The algorithm, which uses genetic algorithm to generate the initial pheromone distribution, and then uses ant colony algorithm to solve the problem, is called GA-ACA algorithm. The concrete steps are as follows:

Step 1: The grid sequence number in the grid environment model is used as the path encoding, that is, the path individuals are represented by the grid sequence number. In addition, the barrier, the grid number and the repeated grid serial number are not allowed in the sequence. The initial path population is generated randomly, and the fitness function related to path length is chosen.

Step 2: The fitness function of the path individuals in the path population is calculated, and the individual path of crossover and mutation is selected by roulette wheel according to fitness function.

Step 3: Cross probability Pc is used to perform crossover operations on path individuals. The concrete method is to randomly generate a random number $Rand$ between 0 and 1. If $Rand < Pc$, cross operation is performed, otherwise, the operation is not performed [5].

Step 4: The mutation is performed for the path individual according to the mutation probability Pm. The concrete method is to generate a random number $Rand$ between 0 and 1 randomly. If $Rand < Pm$, the mutation operation is performed, otherwise it will not be executed.

Step 5: The step 2 to step 4 is repeated until a set of convergence conditions is reached or the set cycle times are generated, and several groups of optimized path individuals are generated.

Step 6: According to the optimized path generated by step 5, the initial distribution of pheromone is formed, and the initial parameters of ant colony algorithm are set up. All ants are placed in the initial grid of the path planning, and the initial grid is added to the ant tabu list.

Step 7: Each ant chooses the next grid according to the state transition rule and the next grid is added to the ant's tabu list.

Step 8: The step 7 is repeated until the ant constructs a path to update the pheromone locally.

Step 9: Step 7 and step 8 are executed repeatedly until all ants build a good path to update the pheromone globally.

Step 10: The tabu list of all ants is cleared, and step 7 to step 9 are repeated until the desired cycle number is reached or certain termination conditions are met.

Step 11: The optimal path is output.

3.4. Robot path planning based on ACA-GA algorithm

The operation of ACA-GA algorithm is to select two paths of ants randomly after the ant colony completes a cycle. The two paths are crossed according to a certain cross probability. If the crossover produces a path that is superior to the optimal path of the iteration, the pheromone is released on the better path. The crossover operation of genetic algorithm is introduced into ant colony algorithm, which can increase the diversity of solution and accelerate the speed of problem solving. The concrete steps are as follows:

Step 1: The initial parameter is set and the ant colony is initialized. All ants are placed in the initial grid of the path planning, and the initial grid is added to the tabu list of all ants.

Step 2: Each ant chooses the next grid to move according to the state transition rule, and the next grid is added to the tabu list of the ants.

Step 3: The step 2 is repeated until the ant constructs a path to update the pheromone locally.

Step 4: Step 2 and step 3 are executed repeatedly until all ants build a good path.

Step 5: The optimal path in the iteration is selected, and then another path in the iteration is selected randomly to perform cross operation according to the given cross probability.

Step 6: The pheromone is updated globally and the tabu list of all ants is removed. Step 2 to step 5 is repeated until the desired number of cycles is set or certain termination conditions are met [6].

Step 7: The optimal path is output.

4. Results and discussion

In order to verify the ACA-GA algorithm, the genetic algorithm, ant colony algorithm and ACA-GA algorithm are simulated, respectively. Figures 1, 2 and 3 are the optimal path evolution maps searched by genetic algorithm, ant colony algorithm and ACA-GA algorithm, respectively [7].

From the results depicted in Figs. 1, 2, 3 and simulation, it is shown that the genetic algorithm finds the sub-optimal path after 5 iterations and converges to the sub-optimal path after 20 iterations [8]. The ant colony algorithm finds the optimal path after 6 iterations, and converges to the optimal path after 30 iterations. The ACA-GA algorithm finds the optimal path after 3 iterations and converges to the optimal path after 15 iterations. Compared with the three algorithms, the ACA-GA algorithm can converge to the optimal path in the least number of iterations.

In order to verify the GA-ACA algorithm, the genetic algorithm, ant colony algorithm and ACA-GA algorithm are simulated, respectively. Figures 4, 5 and 6 are the optimal path evolution maps searched by genetic algorithm, ant colony algorithm and GA-ACA algorithm respectively [9].

From the results in Figs. 4, 5, 6 and simulation, it is shown that the genetic algorithm finds the sub optimal path after 3 iterations and converges to the suboptimal

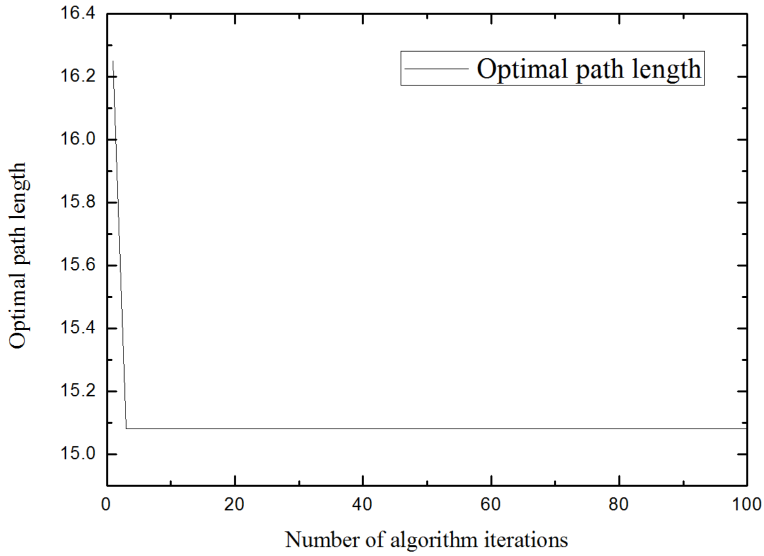

Fig. 1. Optimal path evolution of genetic algorithm

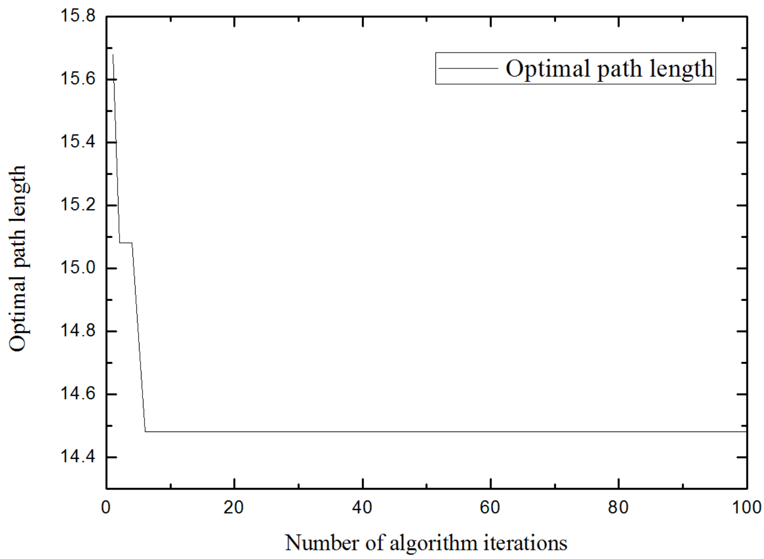

Fig. 2. Optimal path evolution of ant colony algorithm

path after 60 iterations. The ant colony algorithm finds the optimal path after 5 iterations, and converges to the optimal path after 50 iterations. The GA-ACA algorithm finds the optimal path after 3 iterations and converges to the optimal path after 10 iterations. Compared with the three algorithms, the GA-ACA algorithm can converge to the optimal path in the least number of iterations [10].

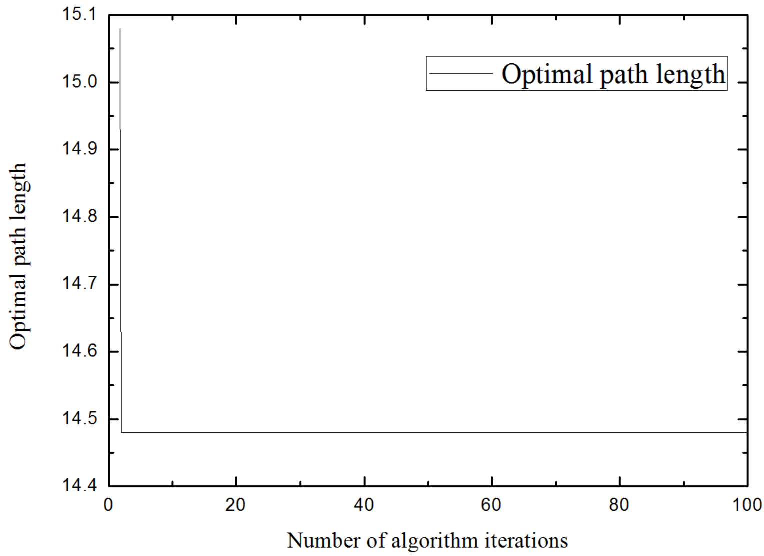

Fig. 3. Optimal path evolution of ACA-GA algorithm

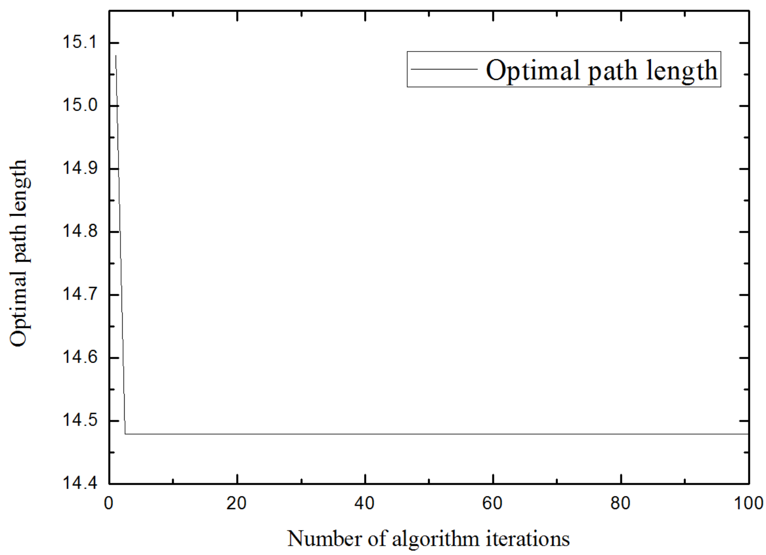

Fig. 4. Optimal path evolution of genetic algorithm

5. Conclusion

On the basis of ant colony algorithm and genetic algorithm, two improved algorithms are proposed, which are GA-ACA algorithm and ACA-GA algorithm, and they are applied to robot path planning.

GA-ACA algorithm uses genetic algorithm to generate the initial pheromone

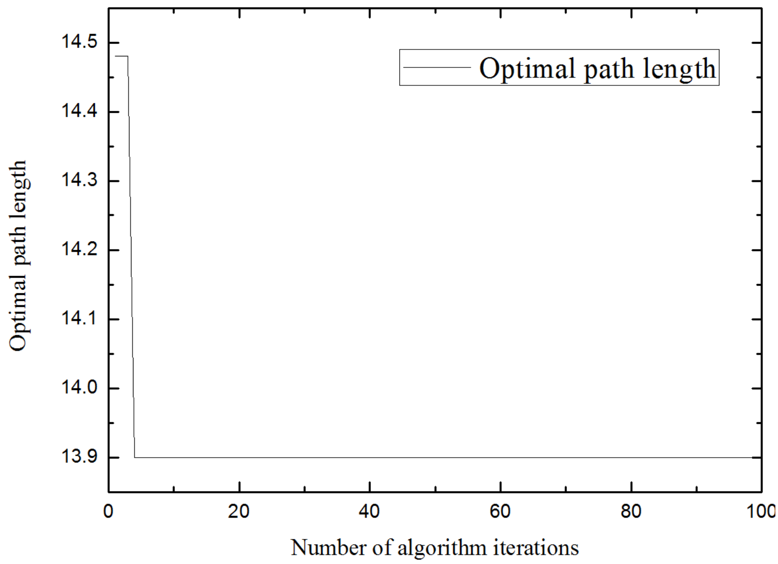

Fig. 5. Optimal path evolution of ant colony algorithm

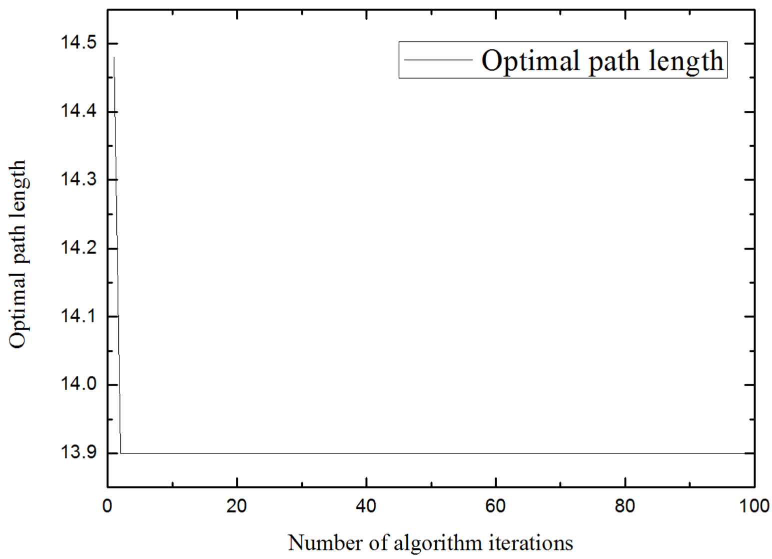

Fig. 6. Optimal path evolution of GA-ACA algorithm

distribution, and then uses ant colony algorithm to solve the problem, that is to say, different algorithms are adopted in different stages. In the initial stage of solving some problems, ant colony algorithm lacks the effective guidance of pheromone, which leads to the same algorithm as greedy algorithm, and the convergence speed is not fast. Based on the GA-ACA algorithm, the ant colony algorithm is effectively guided by pheromone at the beginning of the solution, and can quickly converge to the optimal solution. Simulation results show that the performance of GA-ACA algorithm is better than ant colony algorithm.

ACA-GA algorithm introduces the crossover idea of genetic algorithm into the ant colony algorithm. After the ant colony completes each cycle, the path of the optimal ant is chosen. Then, another path is chosen randomly. The two paths are crossed, and if the crossover produces a better path than the best path in this cycle, the pheromone on the better path is updated. The ACA-GA algorithm increases the diversity of knowledge. Simulation results show that the performance of ACA-GA algorithm is better than ant colony algorithm.

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