Research on Path Planning Method of Humanoid Robot Based on Improved Genetic Algorithm

Xiaoyi Zhan
Department of Robot Engineering, AnHui Sanlian University, Hefei230601, China
1019431983@qq.com

Abstract. Mobile robot is a comprehensive subject developed rapidly in recent years. In the near future, robots may appear in many aspects of your life. Robots can replace humans to complete many tasks, among which it is very critical to accurately reach the destination, so the path planning of mobile robots has become a research hotspot in related fields. In this paper, the path planning technology of mobile robot based on genetic algorithm is studied. Based on the traditional method, some improved algorithms and new solutions are proposed to improve the computational efficiency of the algorithm and search an optimal path between the starting point and the target point.

1. Introduction

With the in-depth research on the path planning of mobile robots, some scholars divide the path planning methods of mobile robots into three types from the perspective of robot's perception of the environment: the planning method based on environmental model, the planning method based on case learning and the path planning method based on behavior. From the perspective of the target range of robot path planning, it can be divided into global path planning and local path planning. In terms of whether the planning environment changes with time, it can be divided into static path planning and dynamic path planning. No matter what kind of system model is adopted, the path planning of mobile robot is that the robot can independently plan a safe running path according to its sensor's perception of the environment and complete the task efficiently. The functions to be completed generally include two layers. The first layer is the so-called path planning. According to certain evaluation criteria in the obstacle environment, the mobile robot looks for a collision free path from the initial state (position and attitude) to the target state (position and attitude). The second layer is tracking control, which requires the mobile robot to design a sequence of control variables to drive the robot to move to the target point safely and quickly according to the path solution obtained by path planning. Path planning of mobile robot mainly solves three problems: it enables the robot to move from the initial point to the target point; a certain algorithm is used to enable the robot to avoid obstacles and complete corresponding tasks through some points that must be passed; on the premise of completing the above tasks, try to optimize the trajectory of the robot.

2. Path Planning Method for Mobile Robots

After decades of development, many effective solutions have emerged. However, due to the limitations of these algorithms to varying degrees, it has become a research hotspot at home and abroad to constantly seek better planning algorithms. At present, path planning methods for mobile robots mainly include the following categories:
Grid method, artificial potential field method, genetic algorithm, neural network, random tree search algorithm, can view the global path planning technology has achieved fruitful research results at present, has been widely used, theoretical research is more mature, but because it is based on robot working environment on the basis of the known, so it is adapt to the scope of relatively limited, especially in complex environment, with all kinds of irregular obstacles is likely to lose its effectiveness. An improved robot path planning method is proposed to achieve better planning results. By using the mathematical morphology method of binary image and the basic transformation of expansion and decay candle, the discrete obstacle individuals are fused into complete obstacle objects, and the complex workspace of the robot is preprocessed. An improved genetic algorithm is proposed, in which the grid method is used to establish the robot workspace model. A new adaptive function is designed, which includes path length information, collision penalty factor and path gap factor. In addition, a reasonable genetic operator and path repair mechanism are designed. This method can search an optimized path between the starting point and the target point.

3. Establish Environment Model
The establishment of environmental model is to use certain mathematical model to represent the working space of mobile robot. In this paper, raster modeling method is adopted. Since raster method is a commonly used environmental modeling method, it divides the robot's workspace into a series of two-dimensional structured Spaces with the same size raster, which is very convenient to determine the location and size of obstacles. There are no obstacles called free grids, and those with obstacles are called obstacle grids. Suppose the robot workspace environment model is shown in Fig 3.1, and the black part represents obstacles. If part of the grid contains obstacles, we also consider the grid to be an obstacle grid. Both free space and obstacles can be expressed as the collection of grid blocks, and the shaded areas in the figure are obstacles.

We start counting from the upper left raster (marked as 0) of the spatial model. Each raster corresponds to an ordinal number. If one is added gradually from left to right and from top to bottom, then each ordinal number corresponds to a grid. It is shown in Fig.3.1.
3.1. Complex obstacle grid processing

After the above grid method is used to modeling, the next step is to deal with the obstacles, in practical application scenario there are often many small discrete and irregular obstacles, so at this point the discrete through the gaps between the obstacle and is small enough to robot, but if we are in accordance with the above method modeling, the gap is still free lattice, when generating the initial population so late so some infeasible individuals. At this time, we can use the mathematical morphology method of binary image to eliminate these free grids by combining discrete obstacle individuals into complete obstacle objects by using expansion and corrosion two basic transformations. Expansion operation and corrosion operation are opposite operation methods. The expansion of obstacle grid is the corrosion of free grid, and the corrosion of obstacle grid is the expansion of free grid. For example, the map before processing is shown in Fig. 3.2 (a), and the map after processing is shown in Fig. 3.2 (b). Through expansion operation and corrosion operation, the discrete obstacle information is fused into the overall information, which provides convenience for the path planning of mobile robot.

4. Path planning of genetic algorithm

4.1. Individual coding

The individual of the algorithm can be represented as a feasible path of the robot. According to the ordinal method of the previous environment modeling, this paper adopts the ordinal method to encode the individual path. For example: [0, 8, 21,355, 56, 65, 82, 99] is an individual.

4.2. Population initialization

Genetic algorithm population initialization is to generate a certain number of individuals in a population, each individual is a feasible solution. That is, a feasible path, that is, from the beginning of the path to the end of the path, without obstacles. Path initialization can be divided into two steps: the first step is to generate the path of the only node, that is, randomly select a node in the only line and then connect the nodes. The connected path is discontinuous. And then you connect these discontinuities, and because in the connection path, it's so hard to get around obstacles, and if you get around obstacles, you lose your direction and you can't get back. Therefore, in the connecting nodes connected by midpoint method, but the midpoint, to get a skill, can take three or four in the midpoint lattice, and then found in the grid free grid, such as probability choice, if there is the worst-case scenario, the midpoint lattice is all obstacles, is in the grid probability to choose a medium as a path, so the method to ensure the continuity of the path, but there may also be a barrier path, and the disorder of path can be punished in the fitness function. After the above initialization path, simplify the path operation, that is, if there are two identical nodes in the path, remove a segment between the
same nodes, and the population initialization ends.

4.3. Determination of fitness function

First, an optimal path must be the shortest path that can be executed without touching and without interruption. Therefore, the path individual adaptability function should contain path length information, collision free information and path uninterrupted information, so the adaptability function is defined as follows:

\[ f(p) = w_d D(p) + w_p P_E(p) + w_c c(p) \]  \hspace{1cm} (4.1)

Where, \( w_d, w_p, w_c \) weight factor; \( D(p) \), \( P_E(p) \) and \( c(p) \) are path length function, collision penalty function and path gap function respectively, which are defined as follows:

\[ d(p) = \sum_{i=1}^{n-1} l(s_i) \]  \hspace{1cm} (4.2)

Where, \( l(s_i) \) is the distance between adjacent nodes, and \( n \) is the number of path nodes.

\[ P_E(p) = \sum_{i=0}^{m_0} a \cdot \max(0, r - h_i) \]  \hspace{1cm} (4.3)

Where, \( h_i \) is the distance between the center of the grid of obstacles and the path when the robot colliding with the obstacle, \( r \) is the radius of the obstacle, \( m_0 \) is the number of obstacles when the robot colliding with the obstacle, and \( a \) is the penalty constant.

\[ c(p) = \sum_{i=1}^{n-2} c^{\alpha(g-i)} \]  \hspace{1cm} (4.4)

Where, \( \alpha \) is the constant coefficient and \( g_i \) is the distance between the road section I and the nearest obstacle, and \( g_i \) represents the ideal path clearance distance.

4.4. Genetic operations

4.4.1. choice

According to the fitness of each individual, the roulette method is adopted to select some excellent individuals from the population \( P(t) \) of generation \( t \) to inherit to the next generation \( P(t+1) \) according to the probability. The optimal preservation strategy is adopted to select the individuals with the highest fitness in the current population not to participate in the crossover operation and mutation operation, but to replace the individuals with the lowest fitness in the current generation population after crossover, mutation and other operations, so as to prevent them from being destroyed in the subsequent crossover and mutation operation.

4.4.2. improved cross operation

This article cross the cross method for single point crossover operation, and the crossover operation of individual species selection for intersection immediately, if and only if for crossover operation of two individuals in the cross position of grid number only for crossover operation at the same time, through this method to ensure that after the crossover operation of individual path for continuous feasible still.

In order to avoid genetic algorithm falling into local optimal, this paper proposes a new crossover method. Namely before crossover operation according to the size of the population fitness value of each individual, it can be divided into high fitness value and low fitness value group, and then were randomly selected from the high and low two groups an individual species to the genetic operation, the cross so you can make a better individual populations and poor populations have larger probability of crossover genetic operation, and makes the population evolution in the most optimal direction faster.

After crossover operation, to the last generation of individuals and individuals fitness value size comparison, evolution rule is used to select individuals, the progeny generation on the fitness value of the individual and the larger the larger individual fitness value, if the individual child is better than the previous generation, individuals will be used, for a generation to replace individuals; Otherwise, you don't replace, you keep the previous generation. Through this operation, we can avoid the crossover operation in the basic algorithm directly, regardless of whether the offspring individuals are good or
bad, the replacement of the last generation of individuals occurs, which ensures that the evolutionary direction of genetic algorithm is always toward the optimal.

4.4.3. improved mutation operation
Since the initial path generated by the individual is a continuous robot path, if the general mutation operation is adopted, the path break point will inevitably be generated, which will damage the superiority of the individual and inevitably cause the degradation of the population. In order to overcome this shortcoming, this paper conducts mutation operation on the premise of path continuity. The specific process is as follows:

(1) according to the probability of variation, individuals to be mutated are randomly selected from the population;
(2) randomly select a grid in the population and remove it as an obstacle grid, so as to divide the path into upper and lower segments;
(3) the end grid of the above half path is taken as the starting point of the path, and any grid of the following half path is taken as the end point of the path. Random search algorithm is used to connect the two disconnected paths to form a continuous path as individuals in a new generation of population.

4.5. elite preservation strategy
Due to the improvement of the adaptive adjustment of genetic parameters, the excellent individuals in the population can participate in the genetic operation at the early stage of evolution, so that the excellent individuals are more vulnerable to damage. In order to protect the excellent individuals and let them enter the next generation, this paper adopts the elite preservation strategy, and the specific steps are as follows:

(1) Find out the individual alpha with the highest fitness value in the contemporary population;
(2) Compare the fitness value of this individual with that of the optimal individual A so far, if alpha is superior A, alpha is denoted as A to complete the preservation of the optimal individual;
(3) Replace A with the individual with the lowest fitness value in the contemporary population.

5. Simulation experiment and result analysis
In this paper, MATLAB was used for simulation. In order to test the feasibility and effectiveness of the improved algorithm, the following 5.1 map was set. Comparison with the basic genetic algorithm: map size: 10*10 grid; Starting point: green dot; End point: red dot; Obstacle density: 24%
In order to compare with the basic genetic algorithm, the improved genetic algorithm and the basic genetic algorithm were used to simulate map 5.1 twice and 10 times respectively. The results are shown in table 1 and table 2.

| run number | evolution algebra | the length of the path | the number of grids passed | solution time (ms) |
|------------|-------------------|------------------------|----------------------------|-------------------|
| 1          | 45                | 13.4247                | 5                          | 988               |
| 2          | 43                | 13.4247                | 5                          | 976               |
| 3          | 46                | 13.4247                | 5                          | 954               |
| 4          | 44                | 14.2913                | 6                          | 991               |
| 5          | 43                | 13.4247                | 5                          | 945               |
| 6          | 42                | 13.4247                | 5                          | 943               |
| 7          | 42                | 13.4247                | 5                          | 972               |
| 8          | 43                | 13.4247                | 5                          | 987               |
| 9          | 44                | 13.9241                | 6                          | 1011              |
| 10         | 41                | 13.4257                | 5                          | 965               |

| average length | 13.5614 | average solution time | 973.2 |

Table 2 simulation results of basic genetic algorithm for 10 times

| run number | evolution algebra | the length of the path | the number of grids passed | solution time (ms) |
|------------|-------------------|------------------------|----------------------------|-------------------|
| 1          | 45                | 15.8687                | 7                          | 1324              |
| 2          | 43                | 16.2458                | 8                          | 1389              |
| 3          | 46                | 15.8687                | 7                          | 1364              |
| 4          | 44                | 15.8687                | 7                          | 1321              |
| 5          | 43                | 15.8687                | 7                          | 1376              |
| 6          | 42                | 16.2153                | 8                          | 1412              |
| 7          | 42                | 15.8687                | 7                          | 1332              |
| 8          | 43                | 15.8687                | 7                          | 1335              |
| 9          | 44                | 15.8687                | 7                          | 1342              |
| 10         | 41                | 16.3156                | 9                          | 1431              |

| average length | 15.98576 | average solution time | 1362.6 |

According to the comparison between table 1 and table 2, the optimization success rate of the improved genetic algorithm is 80%, while that of the basic genetic algorithm is only 70%. At the same time, the improved genetic algorithm proposed in this paper is superior to the basic genetic algorithm in terms of average solution time, population evolution algebra and optimal path length.

6. Conclusion

Of the robot path planning, this paper puts forward a kind of improved genetic algorithm for path planning strategy, put forward and studied the processing of complex obstacles, and to simplify the path planning problem for algorithm optimization problem, through the improvement of crossover
operation, effectively solves the premature path into local optimum, through the improvement of mutation, effectively protect superior individuals will not be destroyed. Experimental results show that the improved algorithm is more efficient than the basic genetic algorithm.

Acknowledgments
This work was financially supported by Natural Key Projects of Education Department of Anhui Province (KJ2018A0606).

References
[1] Li lei, ye tao, tan Ming, et al. Research status and future of mobile robot technology [J]. Robot, 2002, 24 (5): 1-5
[2] Sun shudong, qu yanbin. Application of genetic algorithm in robot path planning. Journal of northwest polytechnic university, 1998, 16(1): 79–83.
[3] Xu meiqing, sun chenliang. Genetic algorithm path planning based on raster map [J]. Science and technology information, 2011, (31): 76-77
[4] Tian xin. Research on path planning of mobile robot based on improved genetic algorithm [D]. Zhengzhou university, 2016.
[5] Lin qinglin. Application research on path planning of mobile robot based on intelligent algorithm [D]. Kunming university of science and technology, 2016.
[6] Shao weiwei, wu yuxiu, fan dongdong. Overview of path planning technology for mobile robots [J]. Journal of tongling vocational and technical college, 2008, 17(03): 57-60.
[7] Jin xiaofei, wang hao, zong weijia, wang pengcheng, wang ze. Research status of obstacle avoidance technology for autonomous mobile robots [J]. Sensors and Microsystems, 2008, 37(05): 5-9.
[8] Ge yong, niu chengshui, du meiyun, xu Juan, zhang yuan. Research on path planning of mobile robot based on improved genetic algorithm [J]. Journal of qinghai university, 2008, 36(02): 33-40.
[9] Jiang h h, yan z r, guo q. Robot path planning based on improved genetic algorithm [J]. Journal of natural science, heilongjiang university,