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Research on Robot Path Planning Based on Grid Model and Improved Ant Colony Algorithm

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ABSTRACT

With the rapid development of robot technology, the research of mobile robot path planning has become a hot topic. Traditional robot path planning algorithm has the problem of large search space, local optimum and low efficiency. In order to improve the efficiency, an improved ant colony algorithm is applied to the robot path planning in this paper. First, the path planning of ant colony algorithm is proposed to establish a grid model in the robot's working environment. Then, determine the location of the obstacle and the interaction between the robot from the starting point and the target point, and remove the obstacles that affect the path planning. The method of grid model and improved ant colony algorithm can be used to reduce the alternative path and find the optimal path in the path planning process. The simulation results show that the proposed method can solve the problem of the effectiveness and accuracy of the robot path planning and improve the overall performance of the robot path planning.

1. Introduction

Robot is a kind of machine with similar human and biological abilities and a high degree of flexibility and autonomy[1]. With the rapid development of science and technology, robot technology has also made great progress and been widely used. Human beings have made great achievements in the field of robotics. At the same time, robots are gradually stepping into human life. The United States has been at the forefront of research and development in the field of robotics and has contributed to the success of robotics today[2]. In the late 1960s, the United States took the lead in completing the lunar exploration program, developing and applying mobile robots[3]. China has also invested a lot of manpower in the research of robots, trying to catch up with the leading world power in the field of robotics[4]. Mobile robot is an integrated system with many functions, such as sensing environment, decision-making dynamics, planning and execution, behavioral control, etc. Mobile robot system has become an important research field, such as automation, computer and artificial intelligence[5]. At present, human beings have achieved fruitful results in the field of robotics research. Meanwhile, robots are gradually stepping into human life. For example, it is applied in industries, agriculture, medical services, space exploration and other fields[6].

As a new research result, it focuses on the research results of sensor technology, information processing, electronic engineering, computer engineering, automation control engineering, artificial intelligence and other fields[7]. It not only represents the highest achievement of electromechanical integration, but also represents one of the most active fields of scientific and technological development. Mobile robots bring great advantages to human beings. They are not only widely used in industries such as industry, agriculture and medical service, but also in fields such as national defense, space exploration and urban security[8].

2. Summary

Path planning of mobile robot is one of the important research fields of robot technology. At present, multi-robot system is a hot topic in the field of robotics. The research on multi-robot system has made great progress and is superior to the single robot system in many aspects[9]. The advantages of multi-robot system mainly include extensive application fields, good fault tolerance, complete complex tasks, low energy consumption, high efficiency, strong scalability, and easy research and development. In the field of multi-robot system, path planning is the basic premise to realize the task[10]. In practical application, multi-robot system mainly works in complex and dynamic environment to achieve self-control and complete complex tasks, which reflects the high degree of automation and intelligence of multi-robot system has important theoretical and practical significance for future dynamic path planning research[11].

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Path planning of mobile robot is one of the most important research fields of robot technology and it has the characteristics of complexity, binding and non-linearity[12]. As the research object of multi-robot system, path planning is mainly aimed at finding a safe and optimal path for each robot from the initial position to the target position. However, it is necessary to ensure that there will be no collision between the robot and the robot at any time and no collision between the robot and the environmental obstacles at any time[13]. At present, there are many solutions to solve this problem, but individual solutions have different efficiencies for different tasks, each with its own advantages and disadvantages, and cannot be widely used. In path planning problem of mobile robot research, many scholars have questions about the robot path planning to do a lot of research work, including the Artificial potential field method, Neural network, A*algorithm, Artificial colony algorithm, Particle swarm optimization algorithm, Genetic algorithm and other intelligent algorithms[14-19]. However, there are some problems with these single intelligent algorithms, such as large search space, low efficiency and local optimization. Based on the path planning problem of frontier mobile robot, this paper proposes a new method for the path planning problem of mobile robot. The grid method and the improved ant colony algorithm are combined to study the path planning of mobile robot.

3. Environment Modeling

The workspace of mobile robot is a real physical space, and the space processed by path planning algorithm is the abstract space of the environment, which is called the environment model. In the process of mobile robot navigation, environment modeling is an important link of robot path planning, and accurate environment modeling is necessary[20]. Determine the model of path planning method according to the situation of environmental information and the form of model, accurately judge the location of obstacles in the environment, judge the location from the starting point to the target point and find an optimal planning path. The purpose of environment modeling is to establish an environment model for computer path planning[21]. The main factors to be considered are the geometric characteristics, size and number of obstacles in the robot's environment. Environment modeling is a mapping from physical space to algorithm processing abstract space. The result of path search is usually expressed in the form of environment model. Therefore, the research of environment modeling method is of theoretical and practical significance to the path planning algorithm and location method of mobile robot[22]. For example, the main reference method for environmental modeling is grid model in this paper.

The problem of searching for the optimal path translates into the problem of the shortest distance from the starting point to the target point through these visual lines. Since the vertices of any two lines are visible, it is obvious that all the paths of the mobile robot from the starting point along these lines to the target point are non-collision paths. Search viewable, and use optimization algorithm to remove some unnecessary lines to simplify viewable, shorten the search time, and finally can find an optimal path without touching.

3.1 Obstacle Analysis and Dispose

According to the different shapes and sizes of the obstacles, the distance between the robot and the obstacles is calculated in different ways. Compared with the size of the work environment, under the condition of small size of the obstacles, obstacles for size, shape, are negligible can be seen as a point, distance d for the robot and the obstacle of distance between two points .When the size of the obstacle is large and the shape is irregular, the obstacle needs to be approximately decomposed into a rectangular obstacle. According to the different shapes and sizes of the obstacles, the distance between the robot and the obstacles is calculated in different ways[23]. The formula (1) is $d_{(i,j)}$

$$d_{(i,j)} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \tag{1}$$

In MATLAB simulation, according to the obstacle characteristics, when the obstacle is small, the path is the shortest and the smoothest. when the obstacle is large, it should avoid the obstacle strictly and quickly.

3.2 Grid model building

In his 1968 research, W.E.Howden proposed the famous grid method, which mainly abstracts the range of robot activities into a series of small grid units with two-dimensional information[24]. In the working environment, the position and size of obstacles are consistent with the actual situation and it doesn't change in the environment. When the grid is divided, when the grid is not satisfied, it needs to be filled with a complete cell. In the grid environment information in figure 1, the black grid area is the approximately decomposed obstacle, which is called the unwalkable area and the white grid area is called the free-walking area. In distribution obstacles of business environment, according to the ideas of the grid method, the robot working environment, said in a two-dimensional matrix 0 means can walk freely in the matrix region, 1 said obstacles, thus formed a can describe the working environment of path planning map.

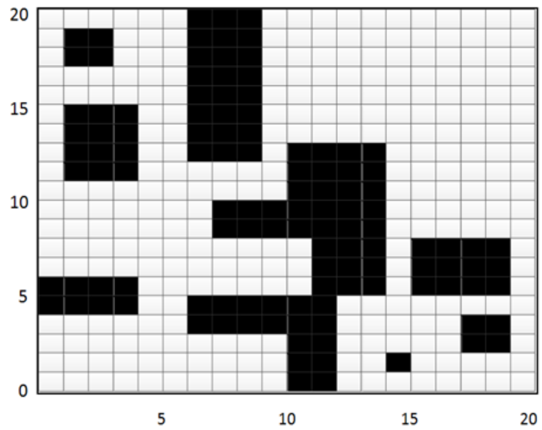

Fig. 1. Obstacle grid map

Assuming that SP is a standard site for robots in a two-dimensional working environment, the site is decomposed into L×W grids. The whole map is composed of obstacle grids and free-walking grids[25]. A=B∪C, where A is the grid set of the robot's moving environment, Where, the obstacle grid set B={B1,B2,B3,……BW-1,BW} and the free-walking set consists of C={C1,C2,C3……CL-1,CL}. A 20 x 20 grid map is established based on environmental information in this paper. Default grid Gstart(0, 20) to start the starting position of the mobile robot, grid Ggoal (20, 20) through obstacles to reach the target location, including Gstart∈C and Gstart∉B and the target location Ggoal

$\in$ C and Ggoal $\notin$ B. However, the starting position of the robot's walking is not consistent with the target position to be reached after passing the obstacle. In the global path search, the search is mainly conducted in octree mode to find an optimal path for the robot to reach the target destination.

4. Ant colony optimization algorithm

Ant colony optimization (ACO) is a probabilistic algorithm proposed by professor Dorigo in his doctoral thesis in 1992 to find the optimal path in maps. His inspiration came mainly from an ant's behavior of optimizing its path while searching for food[26]. For example, ant colonies can find the shortest path to the food source in different environments. This is because ants in ant colonies can transfer information through some information mechanism.

And through further study found that ants on the route it to release a substance can be called "pheromone", within the ant colony ant have a perception on the "pheromone", and they will be walking along the "pheromone" high concentration path, and every ant pass by on the road "pheromone", this produces a similar positive feedback mechanism, so after a period of time, the whole ant colony would be along the shortest path to the food source. This algorithm has the characteristics of distributed computation, positive feedback of information and heuristic search, and is essentially a heuristic global optimization algorithm in the evolutionary algorithm [27]. The basic idea of applying ant colony algorithm to solve optimization problems is as follows: the ant's walking path is used to represent the feasible solution of the problem to be optimized, and all paths of the whole ant colony constitute the solution space of the problem to be optimized. Ants with shorter paths release more pheromones. As time goes on, the concentration of pheromone accumulated on shorter paths increases gradually, and more and more ants choose this path. Eventually, the whole ant will focus on the optimal path under the action of positive feedback, which corresponds to the optimal solution of the problem to be optimized. Studies have shown that ants release a specific secretion- pheromone in their pathways as they search for food[28]. Ants pheromone as a medium of indirect exchange of information, perception of pheromone intensity size and determine their own direction and toward a higher path pheromone concentration to find food. When after the ants pass through a lot of the same path, the path of the pheromone strength will increase, so that the later after this path of ants will choose a path pheromone intensity is higher. When an ant encounters an obstacle in this path, it can adapt to the change of the environment and find a new path with high pheromone intensity.

When searching for pheromones, ants will transmit information to other ants through pheromone intensity that realize information exchange between robots. In general, ants choose the unknown path randomly according to the probability[29]. The $p_{ij}^k(t)$ is as follows.

$$p_{ij}^k(t)=\begin{cases}\dfrac{[\tau_{ij}(t)]^\alpha\times[\eta_{ij}(t)]^\beta}{\sum\limits_{S\in a_k}[\tau_{ij}(t)]^\alpha\times[\eta_{ij}(t)]^\beta},\ j=a_k\\ 0,\ j\in otherwise\end{cases} \tag{2}$$

In formula 1, α is a heuristic factor; β is the expected heuristic factor; τ_{ij} is pheromone intensity on edge (i,j); a_k represents the grid collection that the robot has not walked through in the grid map; η_{ij} is a heuristic function, and its size is mainly related to the distance between i and j. According to formula $\eta_{ij}=1/d_{ij}$,

According to formula 1:where the formula 1is the coordinate of the two points in the grid, the smaller the value of d_{ij} is, the closer the relationship between i, j will be; otherwise, it will be estranged[30].

With the increasing strength of the pheromone left by the robot in the path search, it is necessary to update the pheromone on each side of the path when the robot completes each search[31]. The calculation formula is as follows:

$$\tau_{ij}=(1-\rho)\tau_{ij} \tag{3}$$

In formula 2, $1-\rho$ represents the factor coefficient of pheromone residue, ρ represents the volatility coefficient of pheromone and $0\le\rho\le1$.

$$\Delta\tau_{ij}(t)=\sum_k^m\Delta\tau_{ij}^k(t) \tag{4}$$

In formula 4, $\Delta\tau_{ij}(t)$ represents an increment of pheromone released by the first ant on the cyclic path (i,j), and $\Delta\tau_{ij}^k(t)$ represents the increment of pheromone released by the k-th ant on the cyclic path (i,j).The new pheromone model is shown below:

$$\Delta\tau_{ij}^k=\begin{cases}Q/L_K\ \text{If the edge (i, j) is on path T}^K\\ 0, Othersituations\end{cases} \tag{5}$$

In formula 5, Q represents the strength of pheromone, and L_K represents the total length of all paths taken by the k-th ant in this circular search.

5. Improved Ant Colony Algorithm

5.1Restriction of pheromone concentration

As the scale of the test problem increases, the performance of traditional ant colony algorithm will decrease, the efficiency will be low, and stagnation will easily occur. According to the rules of the ant's advance, if the ant keeps choosing the path with high pheromone intensity, it is easy for the ant to fall into the local optimum and cannot continue to search for the global optimal path. However, when there are obstacles or narrow channels in the workspace, the traditional algorithm will consume a long computing time and even cannot find the appropriate results. In order to avoid the premature convergence of the traditional algorithm to the local optimal solution, the traditional algorithm is improved in this paper and the new algorithm introduces maximum-minimum ant system[32].

The maximum - minimum ant system uses interval limited pheromone range to control the pheromone concentration of each path within the range $[\tau_{mim},\ \tau_{\max}]$.The value beyond this range will be forced to be $\tau_{\min}$ or $\tau_{\max}$. The specific expression is as follows:

$$\tau_{ij}=\begin{cases}\tau_{\min},\tau_{ij}\le\tau_{\min}\\ \tau_{ij},\tau_{\min}\le\tau_{ij}\le\tau_{\max}\\ \tau_{\max},\tau_{ij}\ge\tau_{\max}\end{cases}\tag{6}$$

The Max - min ant system limit pheromone concentration, which can effectively avoid a certain path pheromone concentration is greater than the rest of the path, and makes the optimal path and the other path pheromone concentration difference is not too big, can to a certain extent, reduce the ant chooses the path of the optimal probability, and can guarantee the ant chooses the path of least probability is low, avoid the ants are concentrated in one path.

5.2 Improvement of update mode of pheromone concentration

Ants will search for different paths during their journey. When an optimal path is found, the optimal solution can be found around the path with the maximum probability. By controlling the intensity of pheromones, we can guide ants to search for pheromones in the vicinity of the optimal solution. The improved ant colony is applied to the path planning of mobile robot in this paper. In order to accelerate the convergence speed of the improved ant colony algorithm, the search range of ants is concentrated around the optimal path[33]. After each iteration, in order to make better use of the historical information, only the pheromones on the path of the optimal solution need to be updated. All pheromones on the path of the optimal solution are updated every time the ant completes an iteration. The improved update method of global pheromone concentration is shown in formula 4 and 5.

$$\tau_{ij}(t+1)=(1-\rho)\times\tau_{ij}(t)+\Delta\tau_{ij}^{best}(t),\rho\in(0,1)\tag{7}$$

$$\Delta\tau_{ij}^{best}=\begin{cases}\dfrac{Q}{L^{best}},(i,j)\text{on theoptimalpath}\\ 0,others\end{cases}\tag{8}$$

Setting the path that allows updates is usually the optimal solution for this iteration or the global optimal solution. Generally, the value of information volatility ρ is small and the range is between (0,1) at the initial time of ant colony algorithm. By improving the updating method of global path pheromone concentration, it is convenient for ants to find the optimal path near the optimal solution, narrow the search scope and improve the search efficiency. The performance of the algorithm is improved as a whole.

5.3 Improved state transition rules

In order to improve the performance of ant colony algorithm and reduce the blindness of the search, when the ant walk to a road, to select a node of the initial points (i,j) is likely to reach, and on the basis of these nodes pheromone intensity to compute the probability of arrived at nodes, adopting roulette algorithm to improve the state transition rules and work out the initial point of the next step[34].

$$p_{ij}^{k}=\begin{cases}\dfrac{[\tau_{ij}(t)]^{\alpha}\times[\eta_{ij}]^{\beta}}{\sum\limits_{k\in\{N-tabu_k\}}[\tau_{ij}(t)]^{\alpha}\times[\eta_{ij}]^{\beta}},j\in\{N-tabu_k\}\\ 0,others\end{cases}\tag{9}$$

In formula 9 $\tau_{ij}(t)$ represents the concentration of pheromone on arc (i,j) in the map. η_{ij} represents the heuristic information associated with arc (i,j), α and β respectively represent the weight parameters of $\tau_{ij}(t)$ and η_{ij}. It can solve the problem that the algorithm falls into the local optimal solution to some extent by adopting wheel disk algorithm in the state transfer formula[35].

6. Simulation test and analysis

Mobile robot path planning is an important research field of robotics, it requires that the robot in its working space to find a can avoid obstacles from initial state to the target state of the optimal path. When solving the path planning problem in complex environment at present, the conventional algorithm has many defects, such as poor robustness and low efficiency. This paper puts forward the grid method and the improved ant colony algorithm with the combination of optimization algorithm mainly includes two steps: the first step is to create a space environment of mobile robot model - grid model; The second step is to introduce the Max - min ant system, improvement of pheromone update methods, improvement of state transition rules of ant colony algorithm is applied to the mobile robot path planning to find the global optimal path[36]. The main steps of solving the path planning problem of mobile robot with improved ant colony algorithm are as follows:

a: The mobile robot needs to find the optimal path of the map represented by a matrix of 0 and 1, as shown in figure 1. In the matrix, 0 means that you can walk freely, and 1 means that you are an obstacle. Thus, the matrix shown in figure 1 is as follows:

```
G=[ 0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0
    0 1 1 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0
    0 1 1 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0
    0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0
    0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0
    0 1 1 1 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0
    0 1 1 1 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0
    0 1 1 1 0 0 1 1 1 0 1 1 1 1 0 0 0 0 0 0
    0 1 1 1 0 0 0 0 0 0 1 1 1 1 0 0 0 0 0 0
    0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 0 0 0 0 0
    0 0 0 0 0 0 0 1 1 1 1 1 1 1 0 0 0 0 0 0
    0 0 0 0 0 0 0 1 1 1 1 1 1 1 0 0 0 0 0 0
    0 0 0 0 0 0 0 0 0 0 0 1 1 1 0 1 1 1 1 0
    0 0 0 0 0 0 0 0 0 0 0 1 1 1 0 1 1 1 1 0
    1 1 1 1 0 0 0 0 0 0 0 1 1 1 0 1 1 1 1 0
    1 1 1 1 0 0 1 1 1 1 1 1 0 0 0 0 0 0 0 0
    0 0 0 0 0 0 1 1 1 1 1 1 0 0 0 0 0 1 1 0
    0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 1 1 0
    0 0 0 0 0 0 0 0 0 0 1 1 0 0 1 0 0 0 0 0
    0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0];
```

b:Enter the initial pheromone matrix, select the initial point Gstart (0,20) and target point Ggoal (20,20) and set the parameters. Main parameters mainly include: set the number of iterations K = 100, number M = 50, the ant pheromone importance parameter Alpha = 1, heuristic factor Beta = 7 parameters, pheromone volatilization coefficients Rho = 0.3, pheromone increases strength coefficient Q = 1 and set all the location of the initial pheromone is equal.

c:Each ant calculates the next node according to the improved state transfer rule formula 5 and uses the roulette algorithm to select the initial point of the next stage.

d:According to the improved pheromone update formula, the pheromones that pass through the section are updated, that is updated path and path length.

e:Repeat step c and step d until the ant reaches the target point or reaches the dead end point.

f:Repeat steps c through e until the end of a generation of m ants.

g:Update the pheromone matrix according to formula7 and 8, and do not deal with the unarrived ants.

h:Repeat steps c through g until the end of the path search for the Nth generation ant iteration.

Main grid graph method is used in the article, environmental modeling, modeling show ground environment influence on braking distance path extension, combined with the grid graph method combined with improved ant colony algorithm, the method of path rules was studied for the mobile robot. In order to further test this article improved ant colony algorithm in path planning of mobile robot in efficiency, based on improved ant colony algorithm to solve the path planning problem of mobile robot main steps, built by MATLAB simulation platform, set up the simulation environment, further compare the advantages and disadvantages of traditional algorithm and improved algorithm,Figure2 and Figure3 are the optimal path search results of the traditional ant colony algorithm and the improved ant colony algorithm after running the program in the working environment of Figure1.

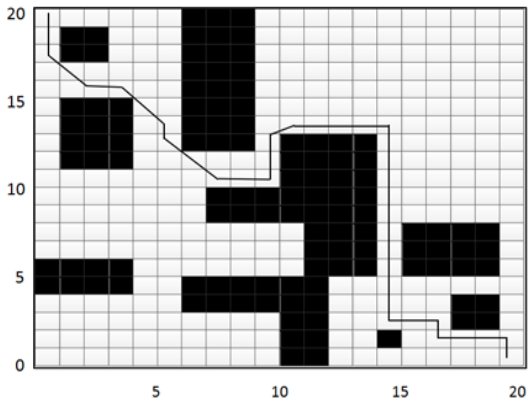

Fig.2. Optimal path search of traditional ant colony algorithm

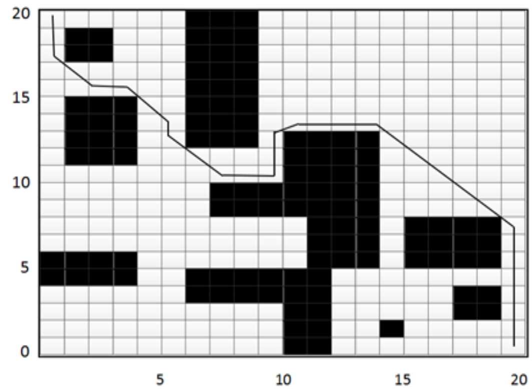

Fig.3. Optimal path search for improved ant colony algorithm

Through computer simulation experiment, we can conclude from figure 2 that the traditional ant colony algorithm is a precocious phenomenon, can only get the local optimal solution and the search path to spend a long time. After about 65 iterations, the length of the search path stability around 44, is not the global optimal solution and find. In figure 3 shows the improved ant colony algorithm by improving the state transition rules, improving way of updating pheromone concentration, limit the pheromone concentration to make algorithm is optimized, avoid falling into local optimum, jump out of the current local optimum to find the global optimal solution and greatly shorten the time of the optimal path search. After about 40 iterations, the optimal path length was found to be around 38.According to the result of simulation analysis, compared with the traditional ant colony algorithm, the proposed method has a strong dynamic convergence characteristics, and to shorten the time of searching the optimal path and improve the efficiency and robustness of the optimal path search.

7. Conclusion

Robot path planning is an important topic in robotics. Grid method and improved ant colony algorithm are rapidly developing modern intelligent optimization algorithms. Grid method can optimize the data and obtain the minimum expression according to the information provided by itself. Ant colony algorithm is a bionic algorithm, an improved ant colony algorithm is based on the traditional ant colony algorithm for state transition rules of improvement, the improvement way of updating pheromone concentration, limit the pheromone concentration of the improved algorithm. The improved ant colony algorithm combined with grid method and their respective advantages to solve the traditional ant colony algorithm slower path planning and obstacle avoidance ability poor problem, has a lot to improve on the speed of planning, programming environment is also more complex. The algorithm to make use of the software simulation analysis, the results show that the algorithm has a strong dynamic convergence characteristics and the advantages and the ability to map in a complex environment with higher efficiency to get the optimal path, proved that the improved ant colony algorithm is more suitable for mobile robot path planning research.

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