A Cooperative Path Planning Algorithm for Handling Robot

Li Cai¹, XiaoLing Zhu², Jingchuan Li³

¹School of Electrical and Mechanical Engineering, Wuhan Polytechnic, Wuhan, China
²School of Electrical and Mechanical Engineering, Wuhan Polytechnic, Wuhan, China
³School of Electrical and Mechanical Engineering, Wuhan Polytechnic, Wuhan, China

¹li2020@wtc.edu.cn, ²40820770@qq.com, ³43334538@qq.com

Abstract—Path planning is one of the core research fields of the handling robot, which has the characteristics of complexity and constraint. Ant colony algorithm is a search algorithm developed in recent years, which has good performance and development potential in solving many complex problems. In this paper, ant colony algorithm and workspace modeling are used to determine the optimal path for the global path search algorithm of the handling robot. The results of spatial modeling and software simulation show that the ant colony algorithm has advantages in the path planning of the handling robot. This path planning algorithm can provide the corresponding solutions for the search path problem of the complex robot.

1. INTRODUCTION

With the continuous improvement of modern automation level, most manufacturers use handling robots as auxiliary equipment to improve the production efficiency of products, so that the degree of material automation continues to improve. As an important equipment of material transportation automation, material handling robot is widely used in foreign countries, especially in developed countries such as some European countries, the United States, Japan and South Korea, with rapid development and wide application. In China, the research on the design and manufacture of material handling equipment in recent years has gradually increased. Many scholars have put forward advanced algorithms in the research of robot path planning. Yu etc. presented a practical cooperative path planning algorithm for a multiple mobile robot system (MMRS) in a dynamic environment by a distributed prioritized scheme to realize cooperative path planning. To minimize the path length for MMRS, a least path length constraint was added. The priority value was also calculated by a path cost function that took the path length into consideration[1]. Utkal designed a smart path guidance system containing a smart sensor logic system through several experiments[2]. Liu proposed a special map-matching algorithm by probabilistic and verified the matching precision and time complexity through experimental analysis[3]. Zhou proposed an improved ant colony algorithm to solve this problem, which is effective and simple, the improved ant colony algorithm was compared with the classic ant colony algorithm through the experiments. The simulation results verify the correctness and effectiveness of the proposed algorithm[4]. Fatima used ant colony algorithm to find the optimal path from an initial to a final position in the robot environment. The algorithm has been tested in simulation and the obtained results show the efficiency and reliability of the proposed method[5]. In addition, there are some other robot path planning algorithms, such as graph theory algorithm, A* heuristic algorithm, genetic algorithm,
etc[6]-[9]. In this paper, combined with ant colony algorithm, the shortest path algorithm is discussed by modeling the global path for the handling robot.

Aiming at the path planning application, the robot environment discussed in this paper is a static global environment. In a given robot workspace model, ant colony algorithm is used to simulate ant foraging behavior. According to the optimization conditions, an optimal or nearly optimal path from the specified starting point to the end point is found. The robot uses its own sensors to automatically navigate according to the optimal path and move to the target point. Section 2 explains the hardware system design of the handling robot. Section 3 introduces the principle and simulation steps of the ant colony algorithm, and then through the MATLAB platform simulation, the results show that the algorithm can quickly plan a better global path when the obstacles of environmental controls are known, and the algorithm is simple and effective. Compared with the traditional search algorithm, it can avoid falling into premature convergence, and can achieve the best path and avoid obstacles in a short time.

2. HARDWARE SYSTEM DESIGN

The handling robot is an important part of the logistics system in the manufacturing workshop. It is equipped with automatic guidance devices, such as electromagnetic induction or optical induction, which has the function of safety protection. Most of them are mainly wheeled walking. Compared with non wheeled mobile robots such as walking, crawling, etc., it has faster action, higher working efficiency and simple structure. The common material handling robot is composed of frame, battery, control unit, driving unit, steering device, sensor guiding device, etc. The principle of walking is as follows: when the carrying robot receives the command from the control computer to move to a certain target point B through the control unit, it first sends its position state A to the control computer, and the control center computer searches the position of the target point according to the path planning algorithm, and sends out the walking command, and the robot control unit receives the command and controls it to move forward through the drive unit.

The walking path of the handling robot in the manufacturing workshop is closely related to the layout of the working space. It is necessary to maintain the safety of efficient and smooth handling of equipment. Path planning refers to finding the optimal path from the starting point to the target point in the workshop environment with obstacles. First, set up the working environment of the handling robot: set the handling working space as two-dimensional space, and the obstacles as workshop equipment. During the movement of the robot, the obstacles are stationary, fixed in size and position. Then, according to the grid method to divide the work space, the grid without obstacles is feasible grid, the grid with obstacles is not feasible grid. In addition, in order to avoid collision between the mobile robot and the obstacle, the grid occupied by the obstacle can be expanded to occupy more than one grid while occupying the original grid. This partition method is simple and practical, which can satisfy the actual environment model, so that the mobile robot can pass smoothly in the path planning.

3. SOFTWARE SYSTEM DESIGN

3.1. The principle of ant colony algorithm

The ant colony algorithm is proposed by Marco Dorigo[10]. It is a bionic optimization algorithm to simulate the foraging behavior of ant colony. It uses biophermone as the basis for ants to select subsequent behaviors. In the process of finding the optimal path, ants find the optimal path through the common behavior of ant colony. Ants leave pheromones on their path, and then ants choose their path according to the intensity of pheromones. Each ant will respond to the biological hormones distributed in a certain range by other ants, and make corresponding probability judgment for multiple paths of each intersection according to its intensity. Through this information exchange, ants can choose the shortest path to find food. Ant colony algorithm is a kind of optimization algorithm to simulate the foraging behavior of ant colony.

The shorter the path, the more ants there are, and the greater the intensity of information left on the path, the greater the probability of choosing this path. Pheromones are randomly selected. When ants
arrive at an unpaved intersection, the number of pheromones is inversely proportional to the length of the path. With the passage of time, the number of pheromones in the shorter path will increase, while the number of pheromones in the longer path will decrease. Finally, ants will find an appropriate optimal path.

In general, ant colony algorithm is a heuristic search algorithm with strong robustness and distributed computing ability. The rules for ants to look for food are as follows: ants can look for food in their own senses, and if there is no pheromone to guide them, they will move in their own direction. If there are pheromones on the path, ants will compare them and finally choose a path with more pheromones. If each path has the same amount of information, choose the next path based on the probability. Probability is a function about the distance between the nodes and the amount of residual information. At a time, transition probability \( P^k_{ij} \) of ants from one node \( i \) to another node \( j \) is expressed as follow:

\[
P^k_{ij}(t) = \frac{\tau^a(i,j)\eta^\beta(i,j)}{\sum\tau^a(i,s)\eta^\beta(i,s)}
\]

(1)

In the formula, \( \eta_{ij} \) is on behalf of visibility from one node \( i \) to another node \( j \). There are two important parameters about information intensity and visibility: \( \alpha \) represents the impact factor of the amount of information \( \tau_{ij} \) for choosing the sections and \( \beta \) represents the impact factor of visibility \( \eta_{ij} \).

In fact, ants communicate and cooperate through secretions. Ant colony algorithm fully embodies the optimization mechanism of information exchange and coordination among individuals, and has strong optimization ability. The more paths a pheromone has, the more likely it is to be chosen. To a large extent, the selection of the optimal path in the path planning process of the transport robot is very similar to the foraging process of the ant. Therefore, the ant colony algorithm is applied to the intelligent path planning. According to the environment information, many feasible paths will be generated during the movement, and the shortest path will be found through the ant colony algorithm.

The simulation steps of general ant colony algorithm are shown in figure 1.

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**Figure 1 Flow chart of the ant colony algorithm**
First, according to the actual problems, initial parameters need to be set to initialize the raster-like environment of the mobile robot. The information is represented by a matrix composed of the numbers 0 and 1: the number 0 means the grid can be passed through, and the number 1 means the grid occupied by obstacles. Initialize optional path nodes, set the number of ants, information heuristic factor, expectation heuristic factor and iteration times. Select the grid number of the starting point and the target point, and place the colony at the starting point.

Second, the path is constructed through the application of repeated state transition rules. After a search is completed, the pheromone is updated.

Third, modify local update rules. The global update rule is applied to the update of pheromone concentration ion after searching for the optimal path for several times under the condition of satisfying the termination condition.

3.2. Simulation of ant colony algorithm

In order to study the effectiveness of the algorithm, this paper designs and implements a path planning simulation experiment system for the handling robot. The ant colony algorithm was used to make the global path planning for the handling robot, and the simulation experiment was carried out for two different working environments under the Matlab software platform. According to the simulation steps, assuming that the static environment is known, the ant colony algorithm is used to find the global optimization path, and the path to the target point that most ants choose is obtained, that is, the mobile path of the robot. At the same time, the convergence curve of the shortest path with the number of iterations is obtained.

At present, there is no strict theoretical basis for the optimal parameter allocation method in ant colony algorithm. The setting of parameters also mainly depends on the statistical data of simulation experiment to study the path planning in two environments (as shown in Figure 2). Shadow represents the obstacle grid. The coordinates of starting point is S in the upper left corner of the work environment, and the coordinates at the end is T in the lower right corner of the work environment. The more ants there are, the better the global search ability and the stability of the algorithm. However, in practical application, the number of ants increases and the convergence speed slows down, which affects the relevant information on the search path, makes the change tend to average, and weakens the positive feedback effect of information. In this experiment, the initial parameters are set as follows: the number of ants is 100, the number of iterations is 100, and the heuristic factor coefficient is 1. The initial grid position of environment information is 1, and the target grid position is 400.

![No. 1 work environment](image_url)
The simulation sets up two different environment models, and the results are shown in figure 2. It can be seen from the figure 2 that the mobile robot can find a globally optimal path to avoid obstacles from the starting point by the ant colony algorithm, which is the shortest path that can be found in this environment, as shown in the dotted blue line. The orange symbol ‘*’ in the upper left corner of the work environment represents the start point, and the orange symbol ‘*’ in the lower right corner of the work environment represents the end point.

Figure 3 shows the total length of path planning under different iteration times. The simulation results in figure 3 show that the path search model of the transportation robot using ant colony algorithm shows a trend of convergence in general. At the beginning of the search process, there are some fluctuations, but with the changes of the fluctuations, the search path becomes shorter and shorter. In the middle and later period of search, the number of random searches is reduced and the optimal path is flattened. Due to the positive feedback mechanism of pheromone concentration, the search path converges to the shortest path after the ninetieth and eightieth iterations, respectively.
4. SUMMARY
In view of the limitation of the path planning application, this paper studies the workspace modeling of material handling robot in manufacturing workshop and the shortest path solution method based on ant colony algorithm. Workspace modeling can not only reduce the influence of many factors on the algorithm, but also make the search algorithm accurate and simple. The raster method is used to model different working environments of the handling robot, and the main parameters of the ant colony algorithm are set, such as the ant colony number, heuristic factor, etc. The influence of path planning efficiency is analyzed by simulation experiment. Finally, experiments show that increasing the number of ants can improve the stability of the ant colony algorithm, but when the number of ants increases to a certain extent, the convergence rate of the algorithm will be slowed down and the change of information tends to average. Therefore, it is feasible to introduce ant colony algorithm into the path planning of handling robot.

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