

Research and prospect of intelligent workshop

AGV path planning algorithm

Abstract: Path planning algorithm is one of the core algorithms for automatic guided vehicle (AGV) to complete the autonomous task of intelligent workshop. The research status of grid method and viewable method in environment modeling at home and abroad is described. The research results of traditional path search algorithms such as artificial potential field method, Dijkstra algorithm and A* algorithm are analyzed and compared with intelligent algorithms such as particle swarm optimization algorithm, ant colony algorithm and genetic algorithm. The analysis found that in the face of complex workshop environment, multi-factor influence and complex obstacles, relying only on the traditional algorithm can not achieve the work effect. Therefore, starting from algorithm improvement, it has become the focus of research to realize AGV operation efficiency and efficient obstacle avoidance by integrating intelligent algorithm with traditional algorithm. Finally, combined with the existing problems in the current AGV path planning research, the research trend of intelligent development and integrated development is prospected.

Key words: path planning; automatic guided vehicle (AGV) ;algorithm improvement

1.INTRODUCTION:

At present, with the continuous progress of human science and technology, factories in the traditional sense consume too much manpower and material resources, and the corresponding work cost of enterprises has also increased. This traditional work mode is no longer applicable in the face of a large number of complex work tasks. With the introduction of intelligent machines in various fields, their work efficiency is greatly improved compared with human labor. Many jobs with high risk factors are also replaced by intelligent machines, which greatly protects the personal safety of workers. Therefore, AGV has become an indispensable part of many smart factories, and AGV is currently being more combined with the Internet and big data technology, so that the perception ability and independent decision-making ability of the logistics system can be improved. The first AGV was born in 1953, it was a simple AGC product tractor modified, its cargo needs to be transported through the air wire, then AGV-related research began. The United Kingdom was the first to develop electromagnetic induction guided AGV, soon Europe installed a variety of forms, different levels of AGV, early AGV as shown in Figure 1, by the mid-1970s, due to the popularity of microprocessor and computer technology, servo drive technology mature design more flexible AGV.



Fig. 1. Agvs for early factory applications

Path planning is the key to the implementation of AGV tasks, and also the main challenge in its engineering application, which has attracted extensive attention from scholars at home and abroad^[1]. In this paper, AGV path planning algorithms are divided into two categories: environment modeling and path search. Reasonable environment modeling method is helpful to reduce the number of path search, and different path search algorithms are based on different environment models. The common environment modeling methods are: grid method, viewable method and so on. Path search algorithms mainly include artificial potential field method, genetic algorithm, particle swarm optimization algorithm, ant colony algorithm and so on. The core of AGV path planning technology is the design of algorithm.

2.Path planning algorithm based on environment modeling

For the processing of environmental information, through the construction of effective mathematical models, environmental information can be better understood, effective analysis and optimization of the environment can be realized, environmental problems can be modeled and solved by mathematical optimization methods, and paths can be searched and optimized. A reasonable modeling method is helpful to reduce the calculation amount of path planning, thus speeding up the calculation speed.

2.1Grid method

Grid-based Method (Grid-based Method) is a commonly used mathematical modeling method, which was first proposed by W.E. owden in 1968, and is generally used as an environmental modeling technique for path planning. Especially suitable for processing spatial information and geographic information. In environmental information processing, the grid method divides the space area into regular grids or cells, and stores the corresponding information in each grid or cell, which is to simulate the obstacles into a collection of small squares, equivalent to the binary substitution of all things in the scene, with obstacles as 1 and non-obstacles as 0. The modeling of intelligent workshop environment is shown in Figure 2. This method can be used in map making, geographic information system (GIS), environmental simulation and other fields. In the raster method, each grid or cell usually represents a specific region of space with a certain size and properties. By storing environmental information in each grid or cell, the discrete representation and processing of spatial information can be realized. If the grid is small, the environmental information represented by the grid map will be very clear, but because more information needs to be stored, the storage cost will increase, and the interference signal will increase, the planning speed will be correspondingly reduced, and the real-time performance can not be guaranteed. On the contrary, due to the small amount of

information storage, the anti-interference ability is enhanced, and the planning speed is increased, but the division of environmental information will become fuzzy, which is not conducive to the effective path planning. Jiang L^[ii] et al. built raster maps, randomly set obstacle information to simulate the actual working environment, and designed a full-coverage path planning method based on neuron excitation network method, which can realize large-scale coverage of farmland plots and achieve independent optimal path planning for obstacle maps of different complexity. Qiu T^[iii] et al. divided the map by grid, and divided the threat level of grid according to the obstacle area in the grid, and then used different sampling strategies to connect sampling points, no longer traversed all points, but only connected with nearby grids. The results showed that the operation time was reduced and the success rate was increased. As a common AGV path planning algorithm, raster method is difficult to solve the complex environment information problem directly, and generally needs to be combined with other path search algorithms for path planning.

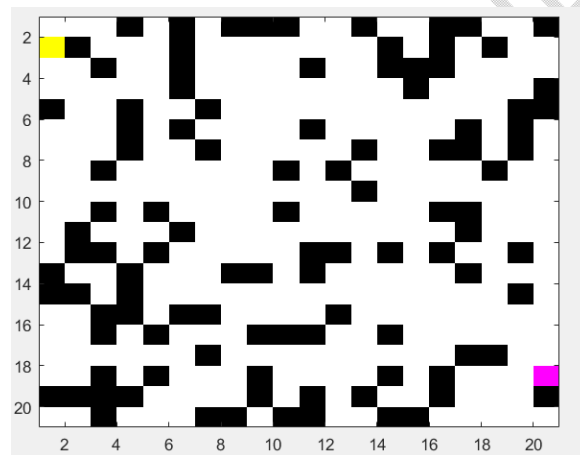


Fig. 2. Smart workshop environment map

2.2 Viewable method

Viewable method, proposed by Lozano-Perez and Wesley in 1979, is a classical algorithm for robot global motion planning. In viewable method, robots are described by points and obstacles by polygons. The starting point S, the target point G and the vertices of the polygon obstacle are combined and connected, requiring that the lines between the starting point and the vertices of the obstacle, between the target point and the vertices of the obstacle, and between the vertices of the obstacle can not cross the obstacle, that is, the straight line is "visible". The viewable method is shown in Figure 3. However, if the starting point and the target point change, the viewable must be reconstructed, and the complexity of the algorithm is proportional to the number of obstacles, viewable method is usually suitable for polygonal obstacles, for circular obstacles failure, can be improved by tangential graph method and Voronoi diagram method. Chen C^[iv] et al. realized accurate positioning through the joint application of UHF radio frequency identification system and low frequency radio frequency identification system, and combined viewable method and A* algorithm to improve the search efficiency and ensure the feasibility of the planned path. Liu Y^[v] combined the viewable method with the convex point method to optimize the initial path, generate the optimized path for the shortcomings, and then perform the secondary optimization. Each node in the path generated

for the first optimization is sequentially selected as the new starting point and end point to generate a sub-optimized path to get a better path.

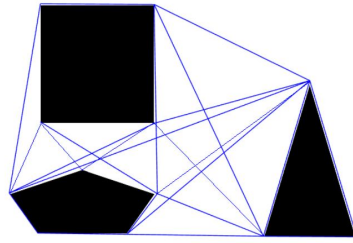


Fig.3. Viewable method

With the increase of AGV computing speed and the need for the integrity of shop environment information, 3D environment modeling will become one of the focuses of AGV path planning algorithm research. The advantages and disadvantages of the above common environmental modeling methods are shown in Table 1.

Table 1. Comparison of common environment modeling methods

| method | advantage | shortcoming | reference | Scope of application |
|-----------------|---|--|-----------|---|
| Grid method | Simple and effective, with scalability, visualization and interpretability, simple modeling process | The space and calculation cost are large, the accuracy is limited, the data update is difficult, and it is not suitable for large-scale spatial search | [2][3] | Autonomous driving, robot positioning and path planning, building the geographic layout of the game world |
| Viewable method | Intuitive concept, Simple implementation, easy to find the shortest path | Long search time, lack of flexibility, local path planning ability is poor | [4][5] | Geographical scenario prediction of outdoor environment, Marine environment modeling |

3. Path planning algorithm based on path search

The path search algorithm is based on the established environment model to obtain a shortest path between the beginning and the end of the search path. There are a lot of path search algorithms, according to their own characteristics, the application field is also different. Traditional optimization algorithms are generally aimed at structured problems, with more clear descriptions of problems and conditions. Many traditional optimization algorithms belong to the category of convex optimization, and have the unique and clear global best advantage. With the progress of science and technology, traditional path search methods no longer meet the increasingly sophisticated work requirements. Although the theory is relatively perfect, there are shortcomings such as poor search ability, etc., while intelligent optimization algorithms are mostly targeted at multi-extremum problems. How to avoid falling into local optimal and find

global optimal as much as possible, traditional algorithms are often combined with intelligent algorithms. Or on the basis of the original algorithm to improve to adapt to the specific scene of the work.

3.1 Traditional path search algorithm

The traditional path search algorithm is simple and easy to implement, but it also has some problems such as poor path optimization effect (poor feasibility), slow processing speed and insufficient dynamic obstacle avoidance ability. The traditional path search algorithms commonly used in AGV include artificial potential field method, Dijkstra algorithm, A* algorithm and so on.

3.1.1 Artificial potential field method

Artificial potential field method is a virtual force method proposed by Khatib for robot motion planning. The basic idea is to concretize the effect of objects and obstacles on the robot's motion. Low potential energy at the target, high potential energy at the obstacle. This kind of potential difference produces the attraction of the target to the robot and the repulsion of the obstacle to the robot, which together control the robot to move towards the target point along the negative gradient of the potential field. The artificial potential field method is easy to calculate, and the obtained path is safe and smooth, but the complex potential field environment may produce local minima outside the target point, causing the robot to fail to reach the target. In order to solve the local minimum point problem of artificial potential field method, scholars have proposed various improved methods. It is divided into two directions: one is to construct a suitable potential function to reduce or avoid the occurrence of local minima; The other is to combine other methods to make the robot leave the local minimum after the robot encounters the local minimum. Saravanakumar^[vi] et al. introduced a directed search method on the basis of the traditional APF algorithm to sample the potential field. By determining the point where the minimum potential energy exists, the vehicle can be moved to the point in three-dimensional space to analyze the local minimum problem. By reducing the proportional factor of the fine-tuning potential function, the burden of the local minimum is avoided. Local minima in three-dimensional space can therefore be avoided. Yan^[vii] et al. proposed a dynamic formation model in a complex underwater environment to further improve the artificial potential field method and combine it with the variable dimension particle swarm optimization algorithm to find an optimal path by dynamically adjusting the number and distribution of path nodes. Zhang G^[viii] et al. proposed an improved artificial potential field algorithm based on fuzzy control and virtual target points to solve the local minimum trap and path redundancy problems existing in robot local path planning. The improved APF algorithm can quickly get rid of the trap, reduce redundant paths, improve path smoothness and reduce planning time.

3.1.2 Dijkstra algorithm

Dijkstra algorithm was proposed by E.W. Dijkstra in 1959. The algorithm adopts a greedy mode, which can calculate the shortest path from one vertex to the other vertices, and solve the shortest path problem in the power graph. The main feature is to start from the starting point, adopt the greedy algorithm strategy, and traverse the adjacent nodes of the closest and unvisited vertices to the starting point every time until extended to the end point. Due to the shortcomings of traditional algorithms such as less than ideal time complexity, Huang Y and Yu Y^[ix] proposed an improved algorithm of Dijkstra algorithm to find the shortest anti-conflict route

for multi-UAV. The shortest route was obtained by introducing variable length backtracking array and time window conflict judgment model, and then feasible non-conflicting routes were found from the shortest route. Sun N^[x] et al. proposed an optimized scheduling scheme based on the enhanced Dijkstra algorithm to solve the problem of long waiting time and low traffic efficiency when vehicles pass through the intersection without signal lights. Wang X^[xi] et al. improved the traditional Dijkstra algorithm by using the adjacency list and binary sort tree structure, which enabled the emergency command vehicle to solve all kinds of emergencies in a timely and effective manner on crowded urban roads.

3.1.3A* algorithm

The A* algorithm, originally published in 1968 by Peter Hart, Nils Nilsson and Bertram Raphael at Stanford Research Institute, is an efficient search algorithm for solving the shortest path in static networks. In order to better solve the problems of large extended search range and easy path collision in global path planning, Zhang W, Zhang Z and Wang W^[xii] proposed an improved A* algorithm with adaptive search distance. In the process of path extended search, the original fixed search distance is replaced by an adaptive adjustment of search distance mechanism in eight directions, so as to reduce the number of extended search nodes and reduce search time. Shi X^[xiii] et al. proposed a robot navigation method based on the improved A* algorithm, which uses the nth-order Bessel curve to smooth the path twists caused by the small-range A* algorithm, and only uses the small-range A* programming. The cost of the heuristic path obtained by using A* algorithm is low, and its advantage is that it can be interrupted and restored in time during the planning process.

The research on the above commonly used traditional search methods is shown in Table 2

Table 2. Comparison of traditional search methods

| Traditional algorithm | advantage | shortcoming | reference | Research characteristics | Research problem |
|-----------------------------------|--|--|-----------|--|------------------------------|
| Artificial potential field method | It has good robustness, simple and intuitive, and good real-time performance | There is the problem of unreachable target, which is easy to fall into local optimal and local minimum | [6] | Potential field sampling to avoid local minima | Overcoming local optimality |
| | | | [7] | In combination with particle swarm optimization, the path nodes are dynamically adjusted | Optimal path |
| | | | [8] | Fuzzy control combined with virtual target points to improve APF | Local path planning |
| Dijkstra algorithm | The algorithm is simple and suitable for most scenarios | The time complexity is not ideal and there are negative loops | [9] | Variable length traceback array | Anti-conflict, Shortest path |
| | | | [10] | Dynamic grid weight assignment, shortest path global search | Shortest travel time |

| | | | | | |
|--------------|--|--|------|---|-----------------------------------|
| | | | [11] | Improved by adjacency list and binary sort tree structure | Shortest path |
| A* algorithm | High efficiency, enlightening and expandable | The evaluation function is not accurate and the space complexity is high | [12] | Adaptive search, global path planning | Search efficiency, anti-collision |
| | | | [13] | Euclidean distance, Bessel curve | Path real-time |

3.2 Intelligent path search algorithm

Because the traditional path search algorithm has some problems, such as poor path optimization effect and slow processing speed, intelligent bionics path search algorithm has gradually become the mainstream algorithm when dealing with the path planning problem under complex dynamic environment information. At present, the commonly used intelligent bionics path search algorithms include particle swarm optimization algorithm, ant colony optimization algorithm, genetic algorithm, etc., but intelligent algorithms also have some problems such as slow convergence speed, too long calculation time and easy to fall into local optimality.

3.2.1 Particle swarm optimization algorithm

Particle swarm optimization (PSO), originally proposed by Kennedy and Eberhart, is a parallel algorithm. Based on the observation of the activity behavior of animal clusters, it makes use of the information sharing of individuals in the group to make the movement of the whole group evolve from disorder to order in the problem solving space, so as to obtain the optimal solution^[xiv]. From the perspective of quantum mechanics, Sun J^[xv] et al. proposed an improved particle swarm optimization algorithm with quantum behavior combined with the idea of quantum physics, and focused on the current local optimal position information and global optimal position information of each particle when updating particle positions. Biswas S^[xvi] et al. proposed a path planning algorithm for multi-agent systems based on particle swarm optimization algorithm for collision avoidance in dynamic environments, and obtained a high-quality solution with fast computing speed. The traditional particle swarm optimization algorithm has some defects, such as low precision and local optimum. In order to improve the performance of the algorithm, it is necessary to improve the particle swarm optimization in different aspects.

3.2.2 Ant colony optimization algorithm

Ant colony optimization (ACO) algorithm is a meta-heuristic algorithm proposed by Italian scholar Dorigo inspired by the foraging behavior of ant colonies. In recent years, many scholars have studied the path planning problem based on ant colony algorithm, and improved ant colony algorithm from many aspects. In consideration of path smoothness, Zeng Y^[xvii] et al. introduced a smoothing function into the state transition probability, and proposed a segmental pheromone update method based on entropy weight to improve the convergence speed of the algorithm. The improved ant colony algorithm planned a shorter, smoother path and a faster convergence speed. As the ant colony algorithm has problems such as poor global search

ability, few initial pheromones and weak optimization ability, etc., and can not well meet the purpose of path optimization, Zhou J^[xviii] et al proposed a multi-factor improved ant colony algorithm. By changing the initial pheromone concentration distribution and changing the heuristic function, the improved algorithm has better path and fewer iterations. Robustness and optimization are also improved.

3.2.3 Genetic algorithm

Genetic algorithm(GA)^[xix] is a heuristic random search algorithm based on the concepts of biology, genetics and evolution. Through the process of biological evolution in nature, genetic algorithm has evolved into a solution that is more and more adaptable to the environment. Genetic algorithms can provide high-quality solutions to a variety of problems involving search, optimization, and learning, and they are similar to natural evolution, so they can overcome some of the obstacles encountered by traditional search and optimization algorithms. Genetic algorithm has some defects, such as premature convergence and low computational efficiency. In order to improve the performance of genetic algorithm in path planning, researchers have improved the algorithm. Chen L^[xx] et al. proposed to improve it by using a variety of grid selection models and priority heuristic search algorithm to find the shortest path and reduce the number of turns. Sun B^[xxi] et al. proposed an improved adaptive genetic algorithm, which introduced the idea of simulated annealing into the selection operation of genetic algorithm, and improved the self-adjusting strategy of crossover and mutation operators, so as to improve the global search ability and convergence speed of the algorithm. In order to solve the problem of reducing the proportion of infeasible paths when the initial population is generated by random method, Wu M^[xxii] proposed an obstacle avoidance strategy based on Cost-Gain algorithm to improve the genetic algorithm, and the obtained path length is shorter and the convergence speed is faster.

The research pairs of the above commonly used intelligent algorithms are shown in Table 3.

Table 3. Research comparison of intelligent algorithms

| Intelligent algorithm | advantage | shortcoming | reference | Research characteristics |
|-----------------------|--|--|-----------|---|
| PSO | Simple and easy to implement, Fast convergence | Easily fall into local optimality | [15] | Quantum physical thought |
| | | | [16] | Dynamic environment reprogramming |
| ACO | Good robustness, Low implementation cost | The convergence speed is slow, and it is easy to fall into local optimal | [17] | Secondary optimization, path smoothing processing |
| | | | [18] | Multi-factor optimization |
| GA | Strong adaptability, global search ability and scalability | Premature convergence, low computational efficiency, easy to fall into local optimal | [20] | Full cover path |
| | | | [21] | Anti-collision, smooth path processing |
| | | | [22] | Anti-collision, Cost-Gain algorithm |

3.2.4 Other algorithms

In recent years, with the continuous exploration and development of AGV, some new

algorithms have been widely applied to the AGV path planning problem because of their excellent characteristics, and have achieved good results. These algorithms generally have strong path search ability, such as D* algorithm, pigeon colony algorithm, gray Wolf algorithm, artificial bee colony algorithm, etc.

4. Conclusion and prospect

AGV path planning algorithm plays an important role in intelligent workshop. In this paper, common AGV path planning algorithms are divided into two categories: environment modeling method and path search algorithm. This paper introduces the research status of AGV path planning algorithms in detail, analyzes the advantages and disadvantages of each algorithm, and compares their real-time performance, algorithm complexity, environment adaptability and planning path stationarity. It is found that in the face of complex workshop dynamic environment, how to improve the practicability of the algorithm in 3D environment, so as to achieve efficient obstacle avoidance and energy saving is the most important thing in AGV path planning. Traditional path planning methods are difficult to meet today's complex shop operations, and AGV's own dynamic model and environmental information are difficult to describe accurately. Therefore, applying emerging artificial intelligence algorithms to AGV path planning and further improving the intelligence level of AGV will become the focus of future development.

At present, the research of AGV path planning algorithm has made great progress, but there are still some shortcomings in each specific planning algorithm, so the focus of the path planning field is still the research of new and efficient path planning algorithm and fusion algorithm. In recent years, with the gradual application of some new algorithms (technologies) to path planning, this complementary algorithm fusion has also promoted the development of algorithms, through learning from each other, resulting in a series of more excellent algorithms. For example, the dynamic window method is combined with A* algorithm, or the intelligent algorithm is fused into a hybrid algorithm, which fundamentally solves the local optimal problem of AGV path planning algorithm, and makes the application prospect of AGV more broad.

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