Research on path planning algorithm of intelligent inspection robot

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Abstract: With the development of intelligent inspection robot technology, inspection robots are widely used in substations to complete the inspection work of substations and move toward intelligent inspection. At present, substations begin to reduce the number of inspection personnel, reduce labor costs, and improve inspection efficiency and ensure the safe operation of electrical equipment in substations by using inspection robots to conduct intelligent inspection of substation equipment. The algorithm is used to realize the path planning of the inspection robot and model the substation environment.

1. Introduction
Nowadays, the rapid development of intelligent algorithms has contributed to the development of artificial intelligence. The power grid is also developing in the direction of large-scale, intelligent and interconnected. It is expected to apply the inspection robot produced by artificial intelligence to carry out intelligent inspection of the substation. In real life, electricity consumption is huge, so the demand for substations is great. Therefore, substation plays a vital role in our life. In recent years, China Academy of Electric Power Sciences made statistics on the losses caused by substation and power grid faults. China's annual economic losses caused by power faults were as high as 2.6 billion yuan which were all caused by the untimely or inaccurate inspection of substation faults [1]. For large power systems, small local failures or misoperations are not enough to cause serious accidents. However, other equipment was implicated in the failure due to the late or improper follow-up processing. The substations or even the entire power system will be paralyzed [2]. Therefore, it is necessary to inspect substation equipment.

With the development of robot industry, people hope to use some kind of machine instead of human work. In recent years, the development of substation inspection robot has achieved good results with the full support of the state. The requirements for substation inspection are: high efficiency, accurate record, safety, etc., which determines that robots are more suitable for this work than human officers. Robots can play a more important role by replacing people to complete the complex inspection work. The freed personnel will participate in the power grid system switching operation, system accident handling, equipment inspection and maintenance [3]. The most important one is to carry out path planning for the inspection robot. Mobile robot path planning needs the support of algorithm. The current trend of social development is artificial intelligence and it will be the development stage of artificial intelligence for a period of time or even longer in the future which is naturally inseparable from the algorithm. The development trend of algorithm in robot path planning technology is as follows: algorithm fusion for learn from each other to achieve optimal path planning; And the objective function is improved to promote the performance of the algorithm [4]. At present,
A-star algorithm, Dijkstra algorithm, genetic algorithm, ant colony algorithm, artificial potential field method [5] are widely used in mobile robot path planning.

2. Path planning method

In recent years, with the deepening of research and the progress of science and technology, more and more methods have been proposed to solve the path planning problem of mobile robots. These methods can be roughly divided into two categories: traditional algorithm and intelligent optimization algorithm.

2.1 traditional algorithm

Traditional path planning methods for mobile robots include Dijkstra, A* algorithm and potential field methods.

Dijkstra algorithm was proposed by E.W. Dijkstra in 1959 [6]. It is a typical shortest path algorithm for solving the shortest path problem in directed graphs. Each edge of a graph consists of two vertices to form an ordered pair of elements and the value of the edge is described by a weight function. The algorithm sets two vertex sets A and B and the initial set A is empty. The selected vertex is guaranteed to have the minimum sum of all edge weights from the beginning to the end when one vertex in B is moved to A at each time. Therefore, the algorithm needs to traverse more nodes. In the case of a large number of nodes, its computing speed will be significantly reduced so its efficiency is not high and it will be greatly restricted in practical application.

A* algorithm [7] is one of the path planning algorithms widely used and can be used to measure or topology configuration space. The algorithm combines heuristic search and shortest path based search and considers the distance from the current position to the adjacent position and the distance from the target position to the adjacent position. The core idea is:

$$f(v) = h(v) + g(v)$$

Where, $v$ is the current position, $f(v)$ is the evaluation function of the current position. $h(v)$ is the distance between the current position and the target position which is the most important part of the evaluation function. It is very important to select the appropriate $h(v)$ one for the efficiency and optimization accuracy of A* algorithm. $g(v)$ is the distance from the initial position to the current position. However, when the environment becomes complex, A* algorithm will be unable to perform, the memory cost will become larger and the optimization time will be longer.

The basic idea of potential field method [8] is to make the robot move to the direction of the fastest potential field decline through gradient descent search method. In other words, it is assumed that this is a robot moving in a virtual manual force field. There is a repulsive force between the obstacle and the robot. The target is attractive to the obstacle. In the potential field method, an attraction field is simply generated towards the interior of the target and a repulsive field is created around each obstacle. A repulsive force will pull it away from the obstacle when the mobile robot approaches the obstacle.

Attraction field and repulsion field: $U(q) = U_{at}(q) + U_{rep}(q)$

Where, $U_{at}(q)$ is the attraction field approaching the target and represents the repulsive field avoiding obstacles:

$$U_{at}(q) = \frac{1}{2} \delta \cdot \rho^m(q, q_T)$$
\[ U_{rep}(q) = \begin{cases} 
\frac{1}{2} \alpha \left( \frac{1}{\rho(q, q_{obs})} - \frac{1}{\rho_a} \right)^2 \rho^\ast(q, q_T) & \text{if } \rho(q, q_{obs}) \leq \rho_a \\
0 & \text{if } \rho(q, q_{obs}) \geq \rho_a 
\end{cases} \]

\[ F_{att}(q) = -\nabla U_{att}(q) \]
\[ F_{rep}(q) = -\nabla U_{rep}(q) \]

Where, \( \delta \) is a positive scaling factor, \( \alpha \) is a repulsion factor, \( \rho(q, q_T) \) is the distance between the current position and the target position, \( \rho(q, q_{obs}) \) is the distance between the current position and the obstacle, and \( \rho_a \) is each repulsion shadow range.

Rapidly expanding Random Tree (RRT) Sampling based Rapidly expanding Random Tree (RRT) method has been widely used in path planning due to its probability completeness and outstanding expansibility [9]. RRT algorithm is the starting point in the problem space as a root node and then through specific incrementally expand new nodes. Finally generate a random extended tree. Meanwhile, we judge the tree have sampling points including target or within the range until meet the conditions, random tree will spread quickly space coverage will start and end of all position. The path is found when the trees grow well and there is only one path from the beginning to the end.

RRT is under knowing all environmental information by using the method of sampling to extend the search and other than the larger image search algorithm. Its advantage is fast so in solving the problem of multi degree of freedom robot planning application more widely but also obvious deficiencies such as planning the path is not smooth or not optimal. RRT is probably can't find the path to the actual if there is no search after many times of iteration.

### 2.2 intelligence algorithm

Traditional methods show great deficiencies in solving complex path planning problems, and self-intelligent optimization algorithms appear and are applied. After that, it made up for these deficiencies and achieved better results. The following are several commonly used intelligent optimization algorithms:

1. **Ant colony Algorithm**

   ACO algorithm is derived from the behavior of ants in the process of looking for food. Ants are typical social animals [10]. Individual ants have a clear division of labor and can efficiently complete assigned tasks through mutual cooperation. Special substances called pheromones have been found to help ants communicate with each other and guide certain behaviors. The higher the pheromone concentration, the better the path is, the more ants it attracts. The end result is that all the ants choose this path. The more ants there are, the more pheromones they leave behind, creating a positive feedback mechanism. It can be seen that ACO algorithm randomly selects the search path at first without any prior knowledge. With the understanding of the solution space, the search gradually becomes regular until the approximate global optimal solution is found. ACO algorithm is a method with strong robustness and solving ability but when the initial pheromone is insufficient it needs a long search time and is easy to fall into stagnation.

2. **Firefly Optimization Algorithm**

   By observing firefly courtship and foraging behavior, researchers proposed a new intelligent optimization algorithm name firefly optimization algorithm. The main idea of FA algorithm is to regard the position of a firefly as a solution vector and the target model determines the brightness of the light and its attraction to other fireflies [11]. The intensity of the light corresponds to the quality of the position. The stronger the light, the better the position. The algorithm involves two key factors that relative fluorescence intensity and relative attraction. The brightness of fluorescence is affected by the target location emitted by fireflies. The higher the brightness, the better the target location. Attraction
and brightness go hand in hand, the brighter the firefly, the more attractive it is. The less bright firefly moves in the brighter direction. Both brightness and attraction are inversely proportional to distance, decreasing as distance increases. Finally, the brightest location where fireflies gather is the optimal solution to the problem. The process of FA algorithm is easy to implement and requires few parameters to be adjusted. However, it still has disadvantages such as slow convergence and inaccurate solution in the face of complex problems.

(3) Fruit fly optimization algorithm

FOA algorithm is a new method proposed inspired by the foraging behavior and optimization evolution of fruit flies in nature. Fruit flies have a powerful sense of smell and vision. They can hunt for food up to 25 miles away, have very sharp vision and are extremely sensitive to the smell of things. All flies will fly in that direction if the location of an individual is found. The algorithm first initializes the initial position coordinates of the drosophila population, then gives the random direction and distance according to the behavior of drosophila searching for food and introduces the value of flavor concentration. This value is represented by the reciprocal of the origin position of fruit flies to a distance and take the taste concentration determination value to the density determination function. Then, find the individual taste concentration of fruit flies, identify the best taste concentration of fruit flies and find the optimal value. Finally, the optimal concentration value of fruit flies and their position coordinates are preserved. That's when the number of flies goes up to this point.

FOA algorithm can be divided into the following three parts: (1) initialization of parameters and population position; (2) Olfactory search; (3) Visual based search. The fruit fly optimization algorithm is simple and easy to implement which can solve complex optimization problems. However, it still has disadvantages such as it is not suitable for solving problems with negative independent variables because the determination function of taste density can only deal with problems with positive independent variables. In solving the path planning problem of mobile robot it has strong optimization ability and high precision, but when the environment is very complex, this method is not very stable in dealing with path planning.

3. Path planning development trend

At present, the society is developing in the direction of intelligence with the progress of science and technology. Mobile robots will be more widely used in all walks of life, the difficulty of completing tasks is also increasing. At the same time, people's requirements for mobile robot path planning are becoming higher and higher, the future will show the following development trend:

(1) Improve the measurement standard of the quality of path planning.

These criteria are generally the real-time performance, accuracy and feasibility of the algorithm. In the actual situation, the environment of the mobile robot is always changing. The robot will collide when it encounters obstacles suddenly if the algorithm can not change the path in real time. The efficient accuracy can make the robot reach the target point quickly and accurately and improve the efficiency of the path planning algorithm. Feasibility is the most basic requirement in path planning if the path planned by the algorithm is not feasible and cannot reach the target point.

(2) Path planning for multi-robot cooperation.

Nowadays the application of mobile robot is more and more wide, the work environment is complex. Only relying on low efficiency single robot work to finish the arranged tasks is very difficult in a short time, or even can not be completed. Therefore, it is the future trend to use multi-robot cooperation to complete work tasks and the problem that needs to be solved is how to achieve path planning for multi-robot.

(3) Hybrid algorithm to solve path planning.

Although the intelligent algorithm is effective in solving the problem of path planning and has greater advantages than the traditional method. The single algorithm always has some shortcomings such as poor global search ability and easy to fall into the local optimal value. Therefore, it is necessary to select the algorithm that can complement the length to combine effectively and the optimization ability of the hybrid algorithm will be strengthened. Although there are many proposed
methods which have been proved to be effective in path planning through tests there is no unified standard for these methods. Many methods can only be used in specific environments and relevant theories need to be further improved.

4. Conclusion
Path planning is to find the optimal path from the starting point to the end point according to certain constraints such as the shortest distance and the shortest time. The process must also avoid obstacles. According to the known environment information, it can be divided into global path planning and local path planning. An important basis for path planning is environment modeling. Among the common methods, grid method has the greatest advantage and is good at dealing with complex environment so its application is wider. However, grid size design is also an important part of the algorithm. There are many methods to solve the path planning problem which can be roughly divided into traditional algorithm and intelligent algorithm.

This Paper introduces several traditional algorithms including Dijkstra algorithm, A* algorithm and potential field method. The intelligent algorithms, including ACO algorithm, FA algorithm and FOA algorithm, and analyzes the implementation of these algorithms. It can be seen that the implementation of intelligent algorithm is simpler than the traditional algorithm and more adaptable to the problem. Finally, the future development trend is introduced from three aspects of algorithm performance, multi-robot cooperation and hybrid algorithm.

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