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Overview of the Development Status and Path Planning Technology of Power Inspection Robots

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Abstract

The substation is an important part of the transmission and transformation process of the power system, however, the traditional manual inspection of substation equipment will inevitably lead to some problems. With the development of intelligence in various fields in China, substation inspection robots will gradually replace manual inspection, and the article collates and analyzes the current situation of domestic and foreign research on power inspection robots, and analyzes the principle of the robot path planning method to facilitate the reference of readers engaged in research in related fields.

Keywords

The Substation Inspection Robots; Path Planning Method.

1. Introduction

The continuity and stability of power transmission is of great significance to national economic construction and people's production and life. In the process of power system transmission and transformation, substation is a very important part, and its reliability and safety are always a concern. At present, the increasing number of substations in China meets the daily demand for electricity, but also brings great pressure to the inspection work of substations. The inspection task of substation accounts for a large proportion of the whole substation operation and maintenance, and the inspection work is mainly done manually.

Manual inspection will inevitably have the following problems: First, many substations are built at the edge of the city or off the beaten track, inspection work is tedious, plus when encountering bad weather inspection difficulty will also skyrocket, workers are less motivated to inspect. Second, the substation inspection area is large, inspection projects, so the inspection cycle is also long, usually only once a day for inspection work, so many unexpected conditions cannot be found in time. Third, the manual inspection to determine the abnormal way to rely on workers' experience, it is difficult to implement to the detailed indicators, so it will cause some errors. With the continuous development of machine technology, various fields are promoting the development of intelligence. The power grid is also constantly promoting intelligent and digital transformation, the future substation operation and maintenance in the state of less people or unmanned multiple machines will be an inevitable trend.

2. Status of Research on Power Inspection Robots

2.1. Status of Foreign Research

Foreign research on robots started early, and in the late 1960s, Nils Nilssen et al. developed a robot named Shakey, which can autonomously identify objects and perform autonomous path planning, Due to the limitations of computer technology at that time, Shakey was slow to model

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the environment and took a long time for path planning [1]. With the development of computer technology, the robot technology also became more mature.

In the 1980s, Tokyo Electric Power Company and Mitsubishi Corporation collaborated to develop a 500 kV substation inspection robot [2]. The robot used magnetic rails for navigation and carried an image collector and optical camera to obtain real-time image information of power equipment, as well as infrared sensors, microphones, and anomalous pulse detectors.

In 2012, the New Zealand Power Grid Corporation and Massey University jointly developed a substation inspection robot that works by remote control and is equipped with a camera that transmits real-time images and video information of power equipment, as well as special sensors for emergency obstacle avoidance.

In the same year, Canada's Beaudry et al. [3] developed an autonomous navigation robot based on the A200 motion platform and using LIDAR. It is equipped with an infrared thermal imager and a camera that can detect the temperature and instrument status of the equipment, and subsequently Beaudry installed a robotic arm that can perform simple maintenance on the equipment.

In 2016, the substation inspection robot launched by the U.S. company FPL is not only equipped with infrared imager, LIDAR and high-definition camera, and adds some professional algorithms compared with the original robot, so that it can realize more inspection functions, such as: early warning function, etc.

2.2. Domestic Development Status

The domestic research on electric power inspection robots is relatively late, but the development momentum is rapid. 1999 Shandong Luneng Intelligent Technology Co., Ltd. began the earliest research on substation inspection robots, and the State Grid Electric Power Robotics Laboratory established in 2002 developed the first prototype of substation inspection robots in China in 2004, and then developed a series of substation inspection robots through continuous innovation. After continuous innovation, a series of substation inspection robots have been developed [4]. The robot can recognize the opening and closing of the switch of substation equipment and the reading of meters [5].

After the national "863 plan" project for the substation inspection robot was proposed, it received positive responses from many institutions and universities. Ltd., Shenyang Institute of Automation, Chinese Academy of Sciences, Chongqing University and Beijing Electric Power Company.

The substation inspection robot developed by Shenyang Institute of Automation, Chinese Academy of Sciences can carry out substation inspection in snow and ice [6]; in 2012, the substation inspection robot jointly developed by Chongqing University and Chongqing Electric Power Company was put into operation in 220kV Dashi intelligent substation, and this robot can work in substations with steps [7]; in 2014, the trackless robot launched by Zhejiang Guozhi Robot Technology Co. In 2015, the substation inspection robot designed and developed under the auspices of State Grid Beijing Electric Power Branch was put into operation in Zhichunli 220 kV substation, and then gradually put into use in more than twenty 220 kV substations in Beijing.

3. Current Status of Path Planning Research

Path planning is a core technology of robot motion, which is mainly responsible for delivering the robot from the starting point to the target point. According to whether the map information is known or not, path planning can be generally divided into global path planning and local path planning. Global path planning requires all the map information to be known, and the algorithm connects the points that need to be reached to complete the connection from the starting point

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to the target point. Local path planning is usually to find the optimal path from the start point to the target point in the local environment when the map information is not completely known, and the surrounding environment needs to be detected with the assistance of sensors to determine the feasible area.

3.1. Global Path Planning

The generalized path algorithm refers to the global path algorithm, which aims to find a path from the starting point to the target point in a known environment. Depending on the purpose, the shortest distance can be chosen as the most preferred condition, the shortest time consuming can also be chosen as the preferred condition, and safety is also given priority in special environments. At present, according to the basic principle of the algorithm, the global path algorithm can be divided into two kinds as follows.

3.1.1. Heuristic Search Algorithm

The heuristic algorithm, as the name suggests, uses a heuristic function to guide the search direction of the algorithm, followed by a distance estimation from the current robot location to the location of the target point. The specific process is that when the robot is at a certain location, it searches all the locations that can be reached next and then evaluates them according to the function and chooses the best one. When it reaches the next position it repeats the previous step to reach the target point. The heuristic algorithm is the oldest path planning algorithm.

3.1.2. Intelligent Optimization Algorithm

Traditional heuristic algorithms are inefficient in large-scale map simulation, and with the development of intelligence, intelligent optimization algorithms were applied and born in the late twentieth century. At present, the common intelligent optimization algorithms in path planning are ant colony algorithm, simulated annealing algorithm, genetic algorithm, particle swarm algorithm and so on. Compared with the traditional heuristic algorithms do not need to build a mathematical model, but also have higher search efficiency, but sometimes fall into the trap of local optimum, and in some special cases the efficiency will be more inefficient.

3.2. Local Path Planning

The difference between local path planning and global path planning is that local path planning does not need to know all the map information, and only makes judgmental navigation based on the information around the robot's current point until it reaches the next target point. However, if local path planning is connected one by one, it is global path planning, so many local path planning algorithms can also be used for global path planning navigation. The algorithms currently applied to local path planning can be further divided into two categories according to the environment: the first category is local path planning algorithms applied to static environment, such as artificial potential field method [8], genetic algorithm [9] and fuzzy logic algorithm, etc., and the second category is local path planning algorithms applied to dynamic environment, such as velocity Obstacle method and reciprocal Velocity Obstacle method, etc.

3.2.1. Local Path Planning Algorithm for Static Environment

The core idea of the artificial potential field method is to consider the robot in the map for path planning as a moving charge, the target point has an attractive force on the robot according to the gravitational function, and the obstacle has a repulsive force on the robot according to the repulsive function. The combined force of attraction and repulsion has a traction effect on the robot until it reaches the target point to complete the path planning. Due to the simplicity of the algorithm and its easy implementation, it has gained a lot of applications. However, its drawback is obvious: it is easy to fall into the local extremum point, i.e., the combined force on the robot is zero before reaching the target point, so it cannot reach the target point.

Genetic algorithm solves the problem that the artificial potential field method falls into local extremes during path planning. Its basic idea is to use the selection of superiority and inferiority in nature, and to use genes as the basic condition for the operation of the algorithm for path planning. Its main drawback is its high configuration requirements, as its algorithm is slow and takes up a lot of space.

The fuzzy logic algorithm requires a lot of learning up front to learn the obstacles in the environment and the path characteristics to generate a table of learning outcomes. It determines which obstacles and which paths are passable by comparing the detected environmental information with the learning result table to complete the path planning work. Its advantage is also from the algorithm level to solve the traditional artificial potential field method algorithm will be trapped in the local extreme point of the disadvantage, but its disadvantage is also obvious, because the need to learn, it can only identify the learned objects, can not be processed for unexpected situations, so poor adaptability is its main disadvantage.

3.2.2. Dynamic Environment Local Path Planning

Compared with the static environment where the position of obstacles is fixed and the robot only needs to recognize and avoid them, the dynamic environment is more complex and variable. In addition to fixed obstacles, there will be other robots or moving objects in the environment, which undoubtedly increases the difficulty of obstacle avoidance as well as path planning work for robots.

In 1998, Fiorini et al. proposed the velocity obstacle method (VO) for local path planning. Compared with previous algorithms that use mathematical models for obstacle avoidance, the concept of velocity obstacle cone proposed by the velocity obstacle method pioneered the use of geometric approach for obstacle avoidance, which is simple in principle and fast in obstacle avoidance calculation. den Berg et al. proposed the mutual velocity obstacle method (RVO) in 2008 after solving the oscillation problem of VO algorithm in obstacle avoidance. More so, many scholars have applied RVO to many occasions that require dynamic obstacle avoidance, such as Xueli Wu et al. applied the improved mutual velocity obstacle method to UAV conflict resolution. Wenyao Xu et al. applied the improved velocity obstacle method to underwater robots.

4. Conclusion

The article analyzes the domestic and international development status of substation inspection robots to give readers a better understanding of the development status of substation inspection robots: together with the analysis of the principles of various algorithms for inspection robot path planning, it helps readers to conduct further research on substation inspection robot path planning problems in order to achieve the goal of substation automated inspection.

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