Development Status and Expectation of Transmission Line Patrol Robot Based on Multi-sensor Fusion

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Abstract. Transmission lines are a key link in ensuring electricity consumption, and the frequent occurrence of natural disasters increases the need for power companies to perform effective maintenance. To solve this problem, the researchers focused on developing autonomous inspection robots to improve the overhaul efficiency and safety of transmission lines. Autonomous inspection robots are usually equipped with various sensors to detect the status and potential problems of transmission lines. Robots are often smart enough to plan paths, avoid obstacles, and collect and analyze data to identify parts that need repair. By fusing the data of these sensors together, the robot is able to detect the problems of the transmission line more accurately and make more reliable decisions. This paper analyzes that the inspection robot uses different types of sensors to obtain more comprehensive and accurate information technology. This research focuses on the analysis of many advantages and disadvantages of automatic inspection robot technology.

Keywords: Transmission Line; Autonomous Inspection Robots; Multi-sensor Fusion.

1 Introduction

Transmission line is an important part of the power grid, but also a key step to ensure electricity consumption. Due to the wide transmission line, transmission distance, the meteorological environment, and geographical environment, more complex, suffer from extreme weather probability is larger, coupled with the field running line pollution corrosion, ice jumping flashover and dancing, vibration, wildfires, bird damage easily cause transmission line broken, pine, rust, lack, etc. Therefore, it is necessary to regularly detect and repair the lines to eliminate accidents in the bud. The traditional inspection method mainly relies on optical equipment for observation or some remote areas rely on drones and helicopters. However, the accuracy and efficiency of manual inspection are low, the flight cost of UAVs and helicopters is high, and the flight process is dangerous. In recent years, with the development of science and technology, the line patrol robot has a good application prospect with its advantages of safety and efficiency [1-4]. This paper briefly describes the research results of transmission line maintenance, and introduces the basic structure and

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working principle of a multi-sensor fusion patrol robot, including two technologies obstacle detection and fault detection. The advantages and disadvantages of the multi-sensor patrol robot are discussed. It provides a reference for the development, promotion and application of multi-sensor line patrol robot in the future. At the earliest, the inspection robots mainly relied on the manual control method. With the development of science and technology, many scholars at home and abroad began to study autonomous inspection robots. At present, most of the autonomous line patrol robots are based on a single detection method, each single detection method has its own limitations. So in order to realize the comprehensive detection of all components of the transmission line, a variety of detection sensors need to be integrated into the inspection robot platform.

2 The Development History of the Transmission Line Patrol Robot

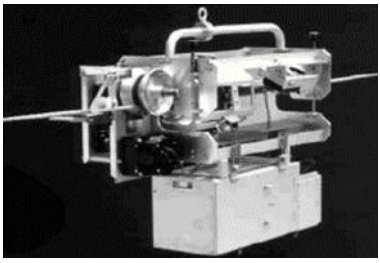

Figure. 1. The earliest inspection robot [5].

Japan's Tokyo Electric Power Company developed the earliest inspection robot. Subsequently, Sato, as shown in Figure 1,Thonburi carried out robot research and made a prototype [5]. This generation of line patrol robots generally has a large structure size, heavy weight and poor practicality. Now,the whole world researchers have made great efforts in the robot of multi-sensor information fusion, but the transmission line inspection is still in the primary research stage. There has been no breakthrough in robot development in recent years. At present, a new line patrol robot named "LineScout" has been developed, as shown in Figure 2. The robot can operate through the remote control on the ground and drive along the wire, which can not only inspect the wire, but also complete the relatively simple line maintenance operations such as wire repair and bolt fastening [5][6]. Foreign research institutes have specially developed the patrol machine "Expliner" for multi-split wire.

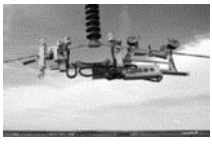

Figure. 2. "LineScout"picture [6].

Through the ground remote control operation, to achieve the straight pole tower and interval help [7]. In addition, the organization developed a patrol robot to detect the deterioration and damage of transmission line insulators and used the patrol robot to carry an infrared thermal imager or signal spectrum analysis, so as to realize the state detection and real-time evaluation of the insulator string of transmission equipment [8][9].

3 The Body Structure of the Line Patrol Robot

3.1 Basic Structure

Patrol robots are divided into suspended robots and other types of robots, such as climbing robots and insulator robots. The climbing robot adopts the arc arm crossing mechanism simulated like human climbing, whose posture control is more complex and is not suitable for long-distance transmission inspection. Only suspended robots are involved in this paper. The specific structure of the suspended robot is the wheel arm composite structure and the working control box respectively. The wheel arm composite structure is responsible for realizing the rapid movement of the robot on the line and over the shock hammer, or other obstacles caused by weather reasons, such as ice, frost, wildfires, etc. The work control box contains the power supply, navigation, information transmission system, and control system, responsible for the control of the whole robot and the data transmission function of the ground base station [10].

3.2 Distribution of the Patrol Robot Sensors

The sensors of the patrol robot mainly include internal sensors: an encoder, temperature sensor, current sensor, gravity sensor, inclination sensor, and so on. Internal sensors sense the operating state of the robot and the state of external sensors such as visual and contact sensors. Mainstream external sensor settings for each arm end set laser sensor with the photoelectric sensor contact sensor mounted at the front and back ends of the fixture. The visual sensor includes a flat-tilt zoom camera mounted at the front [11][12]. In this way, the robot can locate and real-time visual information feedback to guide the robot to avoid obstacles. Bottom of the robot: Some ground contact sensors are usually installed to detect the distance and attitude of the robot from the ground to ensure that the robot remains stable and safe while moving [13]. The current sensor hardware accuracy can guarantee the daily inspection tasks.

4 The Research about Status of Multi-sensor Robots

4.1 The Main Principle of Obstacle Avoidance

Research Status of Obstacle Avoidance of Autonomous Line Patrol Robot for Transmission Lines. The most important step is to identify obstacles. Since the development of an independent line patrol robot, researchers at China and other countrys have conducted many researchs on the identification of obstacles. The earliest Peungsun-goal et al. used cameras to complete the identification of insulators on transmission lines. According to the structural characteristics of high-voltage transmission lines, Zhang Yunchu et al. designed an obstacle identification algorithm based on structural constraints. Hu Caishi et al. proposed an obstacle detection and identification method for the patrol robot based on visual information. First, to reduce the noise interference of the collected images, the images were treated with expansion, corrosion, and Gaussian smoothing. Then, the Otsu algorithm with an improved Canny operator is used to extract the effect of image light change. Finally, structural constraints are applied in the graph base of the extracted edge image to realize the inspection and recognition of obstacles. This is the mainstream direction of the research of cao civilization of the original obstacle image median filtering, expansion corrosion, and then the Otsu threshold optimization calculation, through the wavelet mode maximum algorithm to extract the image edge, calculate the obstacle edge of the joint constant moment features, then the value input the wavelet neural network obstacle image classification recognition. The identification of three kinds of obstacles: shock hammer, overhang clip and tension resistance clip is realized.

The Specific Process of Obstacle Avoidance. Xiang Automatic Obstacle-Crossing Planning for a Transmission Line Inspection Robot Based on Multisensor Fusion.The first is the process of obstacles, as shown in Figure 3. To ensure that the robot can accurately identify and locate the obstacles, the first step is that the robot must be able to accurately extract the distance information of the obstacles. In the situation of approaching obstacles, the need for real-time and high-precision data is particularly urgent. Currently, mainstream positioning technologies combine cameras, lidar, and infrared photoelectric sensors to achieve an efficient detection of the distance between obstacles and robots. In addition, in order to approach the obstacles more smoothly, the robot also adopts the data of the contact sensor and the encoder, and integrates the data. The contact sensor is mainly responsible for detecting whether there is a collision between the robot and the obstacle, while the encoder monitors the speed of the motor rotation, the current sensor is responsible for detecting the current size of the motor. When the front walking wheel of the robot touches an obstacle, the external sensor will detect the change and respond accordingly. Adjust the speed of the motor according to the resistance of the walking wheel to ensure a safe approach to the obstacle [10][12]. After locating the obstacle, the category and size of the obstacle should be identified. When the robot identifies obstacles, the existing camera image characteristics are used to classify and identify obstacles. At present, there are mainly four obstacles in transmission lines: spacers, overhang line clips, drainage and

shockproof . The recognition process uses the wavelet matrix features of the edge of the image. The wavelet moments of the edge have constant translation, rotation and scale factor, which can obtain the full and local features of the image. The main methods are as follows: the first collected images are preprocessed. The second uses the Canny operator to extract the edge wavelet moment from the image.

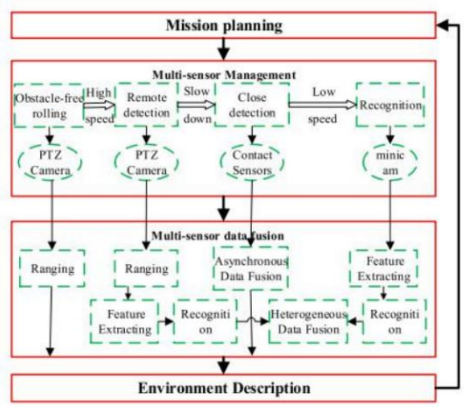

Figure. 3. Flow chart across obstacles [13].

Third, extract the features of the modified image edge wavelet matrix, and use the classifier for classification and identification, in figure 3 [13]. After obtaining the category of the obstacle, the size identification method of the obstacle is that when the sensor detects the obstacle, sum the corresponding different sensors of the obstacle according to the weight, and calculate the data fusion. Sensors with high reliability have high detection weight, and the same sensors have roughly the same weight to different obstacles. Finally, the corresponding eigenvalue matrix can be obtained to obtain the corresponding obstacle size. The last step is the strategy of crossing the obstacles. After the classification and identification of obstacles by multi-sensor information fusion technology, the robot will carry out the obstacle crossing process of the four main obstacles . The whole process of the obstacle movement of the robot will be divided into simple movement process and complex movement process, in which the complex movement has a decisive impact on the success of the robot, while the simple movement mainly follows the preset process to complete the obstacle task. For the two metal obstacles, the overhang clip and the spacer bar, the motion design is similar in the overall idea as see Figure 4, but the details will be adjusted according to the size of the obstacles.

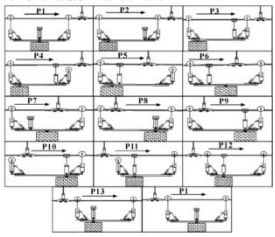

Figure. 4. Cross flowchart across the overhang clamp and spacer bars [13].

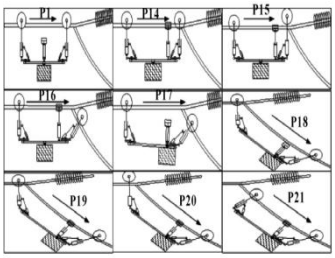

Figure. 5. Cross flow chart of drainage line and shock hammer [13].

The one shown in the figure is a cross-movement design for these two obstacles. For the other two metal obstacles, the motion design is also the same as shown in Figure 5, but the robot also needs to process various sensor information during the movement to prevent the obstacle and use the fuzzy neural network algorithm to make necessary minor adjustments [13]. According to the research status, it can be learned that the current barrier technology has been improved on the basis of ordinary patrol robot barrier technology, and the patrol robot can rely on sensors to overcome common obstacles. In the face of extreme weather and the popularity of the power grid, the number and number of obstacles have begun to increase. Including but not limited to flames, ice, animals, and rocks. Therefore, it is necessary to improve the diversity of barrier technologies and choose different strategies according to different barriers.

4.2 Research Status of Detection Technology

For transmission line detection, evaluation is one of the most important work, the main task of robot patrol is to carry all kinds of obstacles to transmission line real-time detection, the detection method is main method of optical image detection, image detection method is inspection robot carrying optical image sensor to observe the transmission line, the transmission line wire, hardware and insulator defects, using digital technology for image processing analysis, is a conventional method of patrol robot detection transmission line. The conventional processing and analysis techniques include: edge detection technology of the image, the normal and defective insulator and make the difference to identify the defect information, the second-order

spline double orthogonal wavelet to extract the edge of the image of the main transformer, and scan the geometric size characteristics of the crack, and propose the diagnostic scheme [14-16]. The second common test method is to use ultrasound. Ultrasonic decay is slow, and when it travels in elastic media, reflection, refraction, and pattern transformation. When the material has a defect, the defective reflected wave will be generated at the corresponding time of the ultrasonic propagation. The damage can be judged by the size of the reflected wave of the ultrasonic signal and the time position of the reflected wave [17-19]. Second can use the robot to carry infrared device, and then according to the theory of electromagnetic radiation transmission line running hundreds and thousands of amps current, resistance loss can make wire heat current transmission process, transmission line wire broken, hardware damage or insulation degradation crack, defective parts and defect part of the thermal conductivity, surface heat rate, and infrared radiation emissivity is different, lead to the temperature and infrared radiation distribution is not continuous. The key is to use the infrared thermal potential sensor or infrared thermal imager to detect the temperature field distribution on the surface of the wire to determine whether the transmission line components have defects [20-21]. The above three kinds are the more common detection methods. Next, a relatively rare method is the resistance measurement and detection method. There are many connectors (such as pressure control) for overhead high voltage lines. Many factors will lead to the aging of the connector, leading to the increase of resistance at the contact, local overheating. If not timely, the maintenance will increase the power loss of the line, and even lead to line disconnection and power failure. In view of this problem, the patrol robot carries a micro ohm meter to measure the resistance of a section of live wire or the connector, compare the measured value with the normal value, and evaluate the status of the wire or connection device. As we can see, the current single detection technology can be used in the normal inspection process. Relying on the sensor carried by the robot, the inspection personnel can rely on the combination of a variety of detection technologies to judge. However, the current inspection robot cannot independently detect the fault, and due to the limitations of a single detection method, it still needs to judge by the inspection personnel. This will greatly increase the time and cost of the inspection, and affect the city's power supply. Therefore, the research needs multi-sensor based on multi-detection method fusion technology to make the robot can judge the fault.

5 Conclusion

One of the basic tasks of patrol robots is to carry sensors to detect various defects in transmission lines, which are currently targeted for transmission

There are many detection methods for each element of the line, each has its own characteristics, The appropriate methods can be selected according to the specific environment and conditions, while the detection method based on multi-sensor information fusion technology can realize all-round and high-precision detection of transmission lines. Therefore, the future research and development direction can be to

develop a detection method based on multi-sensor information fusion technology. The body structure and obstacle crossing technology of line patrol robots are relatively mature worldwide.

Relatively mature, some robots can carry sensors to overcome obstacles and detection, but in the face of more and more complex inspection environment, power companies also need to rely on different robot structures and obstacle-crossing technologies to complete the maintenance of transmission lines according to different situations. Therefore, it is also a good way to develop sensors with higher accuracy and more suitable for the natural environment. Patrol robot can carry special tools instead of artificial completion of transmission line maintenance and repair work, the robot is also simple to remove obstacles, unable to repair other faults, also need a lot of human resources to repair, so the robot autonomous maintenance technology is also need to focus on the direction. After consulting the data, I can find that the mainstream new inspection robots including multi-sensor robots have only achieved success in the laboratory, and rarely have experience in real high-voltage scenes and field experiments. This has a great impact on the promotion and application of robots. Therefore, in the future, cooperation with electric power companies is needed to experiment and develop autonomous inspection robots together to achieve a win-win situation.

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