A Study on Intelligent Recognition Method of High-voltage Line Faults in Mountainous Areas Based on UAV Aerial Photography

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Abstract: The high-altitude high-voltage line is an important part of the power grid system, which plays an important role in the stable operation of the entire power grid. High-altitude high-voltage lines usually cross various complex terrains such as mountains, rivers, and hills, and suffer from severe weather conditions for a long time. And they are prone to various forms of line failures, such as broken strands, damaged insulators, and suspension of foreign objects. With the rapid development of economy and technology, UAV aerial photography has become an important development direction in the field of aviation aerial photography due to its own characteristics of lightness, high efficiency, convenience, low energy consumption, and clear images, which fully meets the application needs of modern society. Embedding the control program on the UAV platform can realize the intelligence of aerial photography, thereby resolving the inherent disadvantages of the original aerial photography technology, and can especially adapt to the application scenarios that cannot be collected manually due to the complex terrain.

Keywords: Uav Aerial Photography, Intelligent Identification, Line Failure

With the rapid development of China's social economy, China's electricity load is also increasing. Improving the power supply reliability of the power system is a major issue that concerns the overall situation. The inspection of high-altitude high-voltage lines is a basic task in the power industry. The hidden troubles of the lines are identified in the first time, and fault diagnosis and maintenance are performed in time to ensure the normal operation of the power lines. In recent years, various domestic and foreign power industries have used drone aerial photography technology to conduct inspections on high-altitude high-voltage lines, which can properly eliminate hidden line hazards and ensure grid safety and power supply stability. It plays an important role in social and economic development.

1. Status of Application Research of UAV Aerial Photography in Line Inspection

Traditional power line inspection methods include manual periodic inspection, helicopter inspection, line inspection robot inspection, etc., but these three line inspection methods have obvious drawbacks and are difficult to meet the requirements of modern inspection work. With the support of related
technologies, automated aerial photography has developed rapidly and has been applied in many fields. Utilizing the advantages of light, fast, and low cost of UAVs to perform line patrol detection of power line faults represents the future development trend. At the same time, relying on powerful computer vision technology, intelligent fault identification based on power line images obtained by drone aerial photography has sufficient practical feasibility.

1.1. Application Status of UAV Aerial Photography in Intelligent Identification of Line Faults
UAV aerial photography is equipped with multiple sensors on the UAV platform, such as infrared thermal imager, visible light camera, laser scanner, etc. It can collect pictures and video information along the transmission line, and judge the health status of the line through the multiple data obtained. In the 1940s, drones first appeared in the military field. By the end of the last century, the United States had developed the first prototype of a miniature unmanned aerial vehicle. Later, by modifying the micro-unmanned aerial vehicle and carrying various civilian measuring instruments, the micro-unmanned aerial vehicle began to be used in civilian fields, such as post-disaster rescue, power inspection, street shadow aerial photography, environmental monitoring, film and television shooting, etc.

With the continuous research of drone aerial photography technology, power inspection has integrated a number of advanced technologies, including communications, aviation, image processing, etc., which makes power line inspection more intelligent and automated. Foreign research on UAV aerial photography inspection has been earlier, and a complete basic platform has been built, and the technical research is relatively comprehensive. Current research focuses on the processing and analysis of image data obtained from UAV aerial photography. The domestic power industry has also achieved certain results in the inspection of drone aerial photography lines. For example, in 2016, the State Grid Fujian Company used fixed-wing drones to inspect the 1000kV Durong 2 Line Shouning section and successfully established the "Trinity" inspection mode has been implemented to ensure the stable operation of Fujian's main power grid.

1.2. Problems of UAV Aerial Photography in Line Inspection
At present, there are still many problems in the application of UAV aerial photography in high-altitude high-voltage line inspections, but they mainly focus on the processing of aerial images, which are summarized as follows:

(1) Image degradation. Aerial images are prone to degradation, resulting in image distortion,
distortion, blur, and noise interference, thereby affecting image quality and failing to fully obtain useful information from the image. There are many factors that cause image degradation, including image distortion caused by refraction, reflection, diffraction, aberrations of the optical system, etc. Images are disturbed by various noises during the imaging, acquisition and processing process. Posture, the quality of the instrument itself and the image distortion caused by the non-linearity of the photoelectric converter. And the image blur caused by the image focus error.

(2) Fault diagnosis and location: Various types of electrical equipment are equipped in high-altitude high-voltage lines, and the types of possible faults are very diverse, thus creating a variety of fault diagnosis methods. In order to realize automatic fault diagnosis, it is necessary to locate the fault point of electrical equipment.

(3) Target extraction and recognition: The high-altitude high-voltage line is in the wild natural environment. Seasonal alternation, climate change, and landform changes will all affect the background of drone aerial photography. In this case, it is necessary to extract the line target from the image it is more difficult.

2. High-altitude High-voltage Line Fault Identification Algorithm Based on Drone Aerial Photography

2.1 The Overall Process of High-altitude High-voltage Line Fault Identification

Broken strands and suspension of foreign objects are the most common types of faults encountered in high-altitude high-voltage lines. This chapter uses this as an example to discuss. The overall process of fault recognition is: first preprocess the aerial power line image, then use the straight line detection algorithm to extract the power line image, and perform tilt correction on the extracted power line image. Later, locate the suspected fault area, and finally pass the fault recognition algorithm model identify specific faults.

The overall process of high-altitude high-voltage line fault identification is shown in Figure 2:
2.2. Several Types of Typical High-voltage Line Fault Identification Algorithms

2.2.1. Identification Algorithm for power Line Breakage. High-altitude high-tension lines are prone to broken strands in natural environments. At present, the identification of broken strands in the line involves two steps. First, extract the power lines in the aerial image, and then select the appropriate identification algorithm according to the characteristics of the strands. This section mainly selects the appropriate recognition algorithm based on the characteristics of broken shares. The following analyzes the characteristics of power line breakage:

(1) The power line adopts the structure of steel stranded wire, and the branch will appear when the strand breaks, which will appear as a cross point on the aerial image.

(2) The gray value of the position where the strand is broken is low.

(3) The thickness of the power line at the position where the strand is broken is smaller.

(4) The image gradient of the position where the strand breaks occurs increases.

(5) The power lines in the aerial image are in the form of parallel lines, and there is no cross phenomenon.

Combining the characteristics of the above-mentioned power line breakage, the detection of the intersection of the power line breakage is a breakthrough, and the intersection is regarded as the identification target, so as to realize the transformation from the identification problem of broken stock to the identification of the intersection. On this basis, the target is quoted The recognition algorithm recognizes the intersection point, which can accurately detect the position of the broken strand of the high-altitude high-voltage line.

The core formula of the target recognition algorithm is as follows:
\[
\text{abs} \left( \alpha^a - \alpha^b \right) \leq \theta_{thr}
\]  \hspace{1cm} (1)

2.2.2. **Anti-vibration hammer recognition algorithm based on local contour features.** The intersection of the anti-vibration hammer and the broken strand have certain shape characteristics, so the above formula (1) can be applied when identifying the anti-vibration hammer, but the value range of the \( \theta_{thr} \) threshold in the formula is different. The steps to identify the anti-vibration hammer are as follows:

1. Decompose the overall template contour of the anti-vibration hammer shape object, and count all possible 2AS or 3AS local contour features of the shape object.
2. Based on the defined 2AS semantic model, realize the detection of local contour features by shape.
3. Establish a feature database.
4. Recognition of anti-vibration hammer.

3. **Fault Diagnosis and Analysis of Dangerous High-altitude High-voltage Lines in Mountainous Areas**

3.1. **Diagnosis Mechanism**
Generally speaking, if the high-voltage line has an abnormal state of operation, it will usually cause heat loss of electrical equipment. Using an imager to present this infrared energy in the form of an image, the operating state can be judged.

1. Contact failure
   The heat generated by the contact fault of the high-voltage line follows the law that is, the resistance and current jointly determine the heat generated by the contact fault. For example, if a high-voltage line is short-circuited, the open circuit current is extremely large, causing sudden heating of electrical equipment, and the line fault can be determined based on this.

2. Media failure
   The heat generated by the dielectric failure of the high-voltage line follows. And the voltage has a key influence on the heat generated by the dielectric failure. What’s more, the tangent of the dielectric loss angle is determined by the material. For example, the performance of transformers with aging materials has decreased, leading to increased insulation loss, accompanied by equipment heating failures.

3. The phenomenon of increased sink current caused by the abnormal state of the equipment itself, leading to local failures, manifested as poor temperature distribution, is common in insulator strings and lines with lightning arresters.

4. The circulating eddy current in the circuit increases the heating loss of the equipment through the action of the magnetic field.
   All in all, the temperature of the equipment under normal operation is generally within a specified range. If the equipment fails, temperature abnormalities will generally occur. Therefore, a thermal imager is configured on the drone platform to collect infrared images of high-altitude high-voltage lines. It can help staff judge the operating status of high-altitude high-voltage lines, predict and solve upcoming or existing line defects.

3.2. **High-voltage Line Fault Diagnosis Method Based on Drone Aerial Photography**
   The fault types of dangerous high-altitude high-voltage lines in mountainous areas can be described as diverse, and fault diagnosis is easily affected by climatic conditions and the detection environment. In view of this, in the actual fault diagnosis of high-altitude high-voltage lines, the data obtained by a single method cannot be used to directly judge the state, but a variety of methods should be integrated for analysis and comparison. The following describes several common fault diagnosis methods:

1. Comparing similar equipment
   The high-altitude high-voltage line is transmitted in the form of three-phase electricity. Generally
speaking, under the normal operation of the transmission line, the three temperature rises are relatively stable. Take multiple aerial sampling of the high-voltage line to be tested, compare the temperature rise at different times, and compare the temperature rise of each phase under three-phase operating conditions.

(2) Surface temperature discrimination method

Using various measuring instruments to test the temperature on the surface of the high-voltage line to be measured, and then compare the relevant operating specification documents, you can judge the possible faults. This method has advantages of direct and simple, but the reliability of the judgment results is not very well. So it is difficult to meet application scenarios that require high accuracy.

(3) Determination of relative temperature difference

Carry out local key inspections on detected high-voltage lines that may have faults, compare and analyze the temperature distribution under normal conditions, and consider the impact of the operating environment. Finally we can determine whether they are faulty. The algorithm for solving the relative temperature difference is as follows:

\[ \sigma = \frac{\tau_1 - \tau_2}{\tau_1} \times 100\% \]  

4. Conclusion

Fault identification and diagnosis of dangerous high-altitude high-voltage lines in mountainous areas is an important part of the work content of the power industry. Using reasonable fault identification and diagnosis methods can effectively improve the power supply reliability of the power system and improve the power quality. High-altitude high-voltage line faults are affected by many factors. Identifying fault defects from drone aerial images with complex backgrounds is of great significance for fault diagnosis. This article first introduces the application research status of UAV aerial photography in line inspection, and then reveals the problems of UAV aerial photography in line inspection, and analyzes the fault identification process and typical algorithms of high-altitude high-voltage lines based on UAV aerial photography. On the basis of this, a feasible method for high-voltage line fault diagnosis based on drone aerial photography is finally proposed.

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