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Intelligent Recognition of Transmission Line Inspection Image Based on Deep Learning

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Abstract. Under the background of high-speed development of the power grid, the traditional manual detection method is low efficiency and high cost, which are not able to meet the current requirements. With the development of UAV technology, the method of using UAV to inspect transmission lines has a positive effect on improving detection efficiency and quality. In recent years, deep learning has developed rapidly, which provides a new solution for the analysis and processing of UAV aerial inspection images. This paper focuses on the deep learning algorithm to study the insulator location and fault identification in aerial photographs, which plays an important role in realizing the automation and intelligence of UAV detection.

1. Introduction

In recent years, all countries have invested a lot of manpower and material resources in UAV power inspection research, including UAV flight control technology, target recognition, and fault detection technology of aerial images of the transmission line. As far as the current development situation is concerned, the practical application of the line inspection system is still limited due to the influence of detection accuracy.

With the emergence of high-performance computing hardware GPU and the blessing of global network data interconnection, the deep learning algorithm developed from the neural network has attracted the attention of researchers again. In recent years, a deep learning algorithm has developed rapidly. The difference between deep learning algorithm and traditional machine learning method is that the whole algorithm does not rely on manual feature extraction, but is obtained by network autonomous learning. A deep learning algorithm has stronger expression ability and recognition and classification performance. At present, deep learning has been widely used in many fields. If it can be combined with intelligent inspection of the transmission line, it will provide more favorable technical support for the development of the smart grid.

2. Image recognition method for key equipment of transmission line

At present, there are some common problems in aerial images of transmission lines: The background of aerial images is complex; The shapes, types, and angles of targets are different; the characteristics of fault images are not clear enough; The representation forms of faults are changeable; The location

of faults is uncertain. These common problems make the identified target and fault area not prominent enough in the aerial image, which increases the processing difficulty. The fault detection of the key equipment of the transmission line based on image processing can be divided into two parts: target recognition and fault detection. Fault detection is usually based on target recognition. The quality of target recognition affects the accuracy of fault detection. At present, the target recognition methods for key equipment of the transmission line can be divided into the following four categories:

2.1. Method based on feature description

Feature description includes texture feature description, contour feature description, shape feature description, and so on. Firstly, the basic texture features of insulators are obtained by gray level co-occurrence matrix, and then the target selection method is used to identify the insulators; Next, the segmentation of insulators is converted to the problem of finding the minimum value of energy functional, and the active contour model algorithm is used to detect the insulator contour; The image edge is extracted, and then chain code tracking and corner detection are carried out, Finally, circle contour and center point are determined, and then the end position of the damper is obtained. Finally, the identification of the damper is realized. The above methods can get ideal positioning results when the shooting angle is fixed, but the uncertainty of the related features of the insulator and damper is caused by the variability of the shooting angle and shooting distance of the inspection image, which reduces the accuracy of the feature description algorithm[1].

2.2. Method based on image segmentation

An algorithm combining pixel attribute judgment and local mean method to segment insulator is proposed：The insulator in his color space is segmented according to the empirical value, and the insulator is located by the shape feature of the connected region; The maximum entropy threshold method based on genetic algorithm is used to segment insulator in his space; The Canny operator is used to extract the edge of aerial image to segment the transmission tower. In practice, the influence of light, angle, complex background, and other factors on the target pixel value is very big, and the application conditions of this method are relatively harsh.

2.3. Method based on image matching

There are two kinds of image matching methods: gray-scale matching and feature-based matching. Firstly, the image and template are layered by pyramid nearest neighbor average method, and then normalized cross-correlation is calculated to achieve the goal of fast target matching. The method of corner matching is used to locate the insulator by detecting Harris corner in the image. Through the curve fitting of five different transmission tower heads, and matching the detected tower contour features with the model, the final recognition results are obtained.

The Harris corner feature of the damper is used to replace its edge contour feature to establish the index matching table of the template, and the index matching of the detected image is carried out. These methods have high accuracy in the pure background, but they are easy to detect when there are pseudo targets with similar matching features in the background.

2.4. Method based on feature classifier

The method based on the feature classifier is a supervised recognition method. One is based on Gabor features, using pre-trained SVM classifier to identify insulator and background; by extracting HOG features from a video sequence, and using AdaBoost classifier classifies and identifies the insulator; the other one uses the classifier perception clustering algorithm to construct the structural constraint model to realize the deeper understanding and recognition. Although the method based on feature classifier is more reliable than the previous classification methods, its preparatory work, such as the selection of classification features and the training of classifiers in the later stage, is more complicated. Moreover, according to the different features selected, the classification effect is significantly different.

Due to the limitation of the performance of the algorithm itself, the subjective judgment of the algorithm designer when selecting features and classifiers, and the complex and changeable background in aerial images, the generalization ability of the above methods is always unsatisfactory.

3. Research status of defect detection of transmission line

At present, there are few research results on fault detection of the transmission line. The position of the insulator is determined by detecting the parallel line segments in the image, and the blocks are divided according to the arrangement direction of the line segments and the distance between the segments and the fault diagnosis of the chip falling is realized according to the texture features between the blocks. However, when the insulators block each other or the shooting distance is long, the segment characteristics of the insulator are very fuzzy, which is easy to cause false detection. In this method, the original image is divided into 10 parts, and seven predetermined texture feature values of each part are extracted respectively. Finally, the fault feature formula is constructed from the three most obvious features to detect the insulator string drop.

As mentioned above, there are many key problems to be solved in the fault detection of the key equipment of the transmission line based on the digital image, such as feature description and expression of the fault area. Due to the long-term exposure of transmission lines to the external environment, the occurrence of equipment faults is diverse and random due to the influence of sunlight, weather, and other factors. It is difficult to achieve the purpose by using traditional feature description methods. Therefore, it is necessary to conduct in-depth research on feature description and extraction of key equipment fault areas of transmission lines.

4. Application of transmission line image intelligent technology based on convolution neural network

Convolutional neural networks（CNN）is a kind of artificial neural network (ANN) and a learning algorithm of deep learning. It has been widely used in image recognition and classification, natural language processing advertising system.

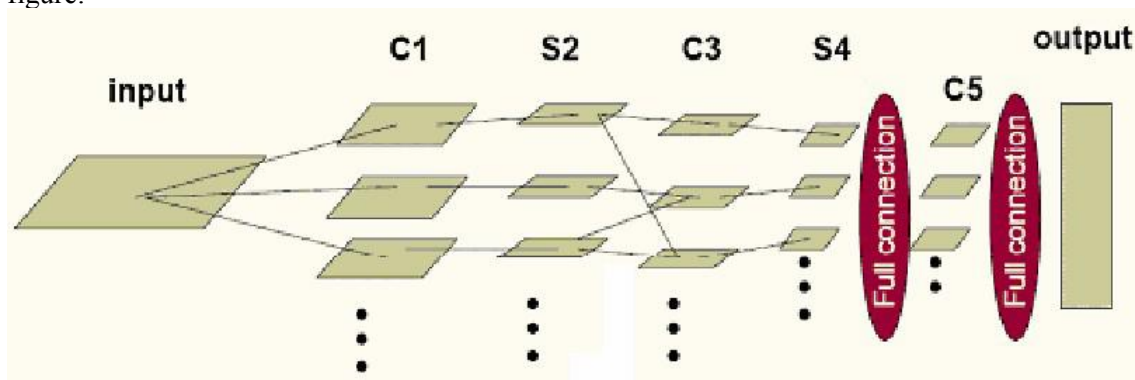The convolution network can be simplified as the model shown in the following figure:

Fig.1 Convolution network

Input to C1, S4 to C5, C5 to output are full connections, C1 to S2, C3 to S4 are one-to-one connections. In order to eliminate network symmetry, S2-S3 removes some connections to make feature mapping more diverse. It should be noted that the size of the C5 convolution kernel is the same as that of S4. Only in this way can the output be a one-dimensional vector.

DetNet (a backbone network for object detection)[2] uses more stages like FPN for objects of different sizes. Even so, it is superior to the Imagenet pre-training model in that it successfully retains the spatial resolution of features, but it also increases the calculation and memory cost of a neural

network. In order to ensure the efficiency of DetNet, we can introduce a low-complexity dilated bottleneck[3]. As a result, DetNet has achieved both higher resolution and a larger receptive field.

Compared with the traditional classification network for object detection, DetNet has the following advantages: The number of DetNet stages is the same as that of FPN, so additional stages such as P6 can be pre-trained in ImageNet; Due to the high-resolution feature map in the final stage, DetNet is more powerful in locating large object bounding boxes and discovering small objects.

The task of insulator state detection of the transmission line can be divided into two aspects: first, target detection, that is, to locate the insulator target in the image, which needs to overcome the adverse factors of complex background and low image resolution; second, classify the status, such as surface pollution, cracks, damage and so on. How to extract the features that can fully identify the fault is a hot research topic.

The insulator positioning method can accurately locate the insulator string, with a low error rate and short time consumption. We divide the insulator string after positioning into several images of the shed plate, so we can judge the fault type of each umbrella plate. The types of insulators used in different environments and voltage levels are also different. As shown in the following figure (insulators of different materials, from left to right are composite, glass, and ceramic), all kinds of insulators have different materials and shapes. We need to design diagnosis algorithms for them respectively in traditional methods. The current insulator state diagnosis methods based on manual features have poor robustness, complex calculation, and single fault type. Inspired by the uniqueness of deep features, we first applied the deep convolution neural network (DCNN) to the fault diagnosis of transmission line insulators and used the depth network to explore the corresponding expression of insulator fault.

Fig. 2 Insulators of different materials

After positioning, the insulator image is binarized, and the insulator image is scanned according to the line, and the pixel points of each line of the insulator image are counted, as shown in the following figure (insulator string segmentation), the trough of pixel points is taken as the segmentation line, and the segmented insulator image is multiple insulator umbrella plate images.
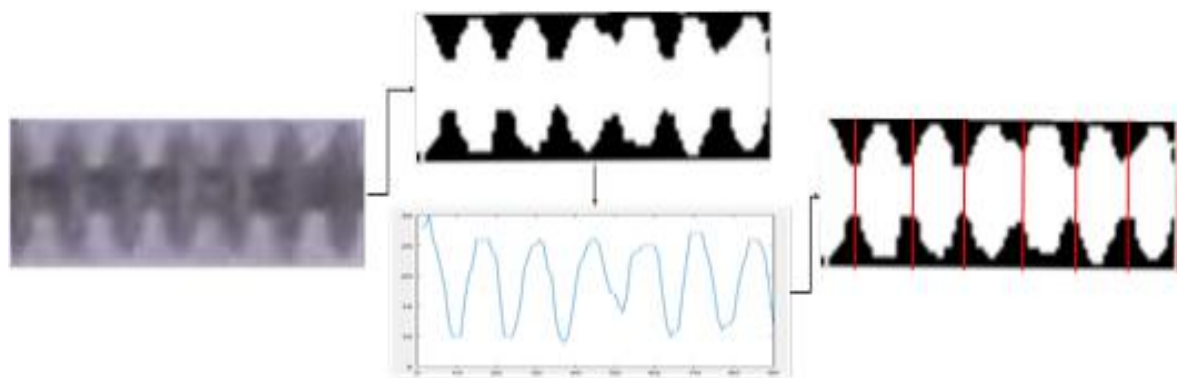
Fig. 3 Insulator string segmentation

We need to establish the aerial image database of insulators include normal, damaged, cracked, polluted, and self-exploding images of the insulator.

We use DetNet (NAS for object detection) [4]neural network to classify, and IOU-Net is used to accurately locate and calculate the target, then randomly generate 10 patches on the original image, carry out forward calculation for each patch, and calculate the average value of the obtained features. For the obtained multipatch features, the SVM classifier is trained.

The accuracy of fault diagnosis can be improved by extracting the features of multiple patches for pooling. However, the actual insulator target has different angles and shapes in the transmission line, and only fully connected is used The features in the layer can not fully express the target attributes, so we also understand and model the features in the intermediate convolution layer, and make full use of the relationship between the multi-layer depth model. Some intermediate results are visualized and feature maps of different layers are extracted for analysis. The neurons in different layers have different responses to insulator targets, and the activation response of neurons shows sparsity and selectivity.

5. Conclusion

Object detection is the key technology of the intelligent monitoring system of the transmission line. Firstly, the input image is segmented to complete the extraction of candidate regions, and then each candidate region to be classified is input into a convolutional neural network to extract features, and then the classification is carried out according to the features, finally, the types of objects and the specific coordinate positions are obtained. The image recognition model based on this technology can intelligently identify the potential safety hazards in the field environment of transmission lines. This system has established a new intelligent monitoring mode of front-end image acquisition, data wireless transmission, background identification and analysis, and directional pushing of hidden dangers. It can continuously monitor the transmission line site for 24 hours and call an image recognition program to analyze the site situation in real-time, automatic push hidden danger warning, greatly improve the efficiency and quality of supervision and prevention of large machinery damage, improve the operation of transmission lines.

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