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Summary of Application of Image Processing Technology in Power Line Inspection

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Abstract

Among the various obstacles that cause helicopter accidents, the power line can be said to be one of the most dangerous objects. Improved power line detection technology can greatly improve the safety of helicopters under low visibility conditions. In recent years, image recognition and detection technology has developed rapidly, and the recognition and extraction of overhead power lines based on visible light has also been extensively studied. This article gives a general introduction to the application of image processing technology in power line detection, and summarizes the advantages and disadvantages of several power line detection algorithms, and points out some problems in this field and the outlook for the future.

Keywords

Power Line, Power Line Identification, Image Processing.

1. Introduction

Power line detection plays a very important role in the flight safety of low-altitude aircraft, such as helicopters and unmanned aerial vehicles[1]. Since the advent of the helicopter, it has been widely used in many fields with its excellent flight performance and unique aerodynamic characteristics[2]. However, with the widespread use of UAVs, its safety issues have gradually emerged[3].Among the various obstacles that cause helicopter accidents, power lines can be said to be the most dangerous[4].This is because the power lines are too small compared to other objects and often cross the flight path. It is usually difficult for pilots to detect these small power lines with the naked eye[5]. According to statistics, the impact of high-voltage lines on aircraft in helicopter navigation accidents accounted for 30%.

Compared with other inspection technologies, the cost of visible light cameras is lower than other equipment such as lidar and infrared cameras, and with the rapid development of machine vision in recent years, the accuracy of automated fault diagnosis has also been greatly improved. Therefore, it is more and more common to realize the detection of power lines based on visible light aerial images[6]. Automatic identification of overhead high-voltage lines from visible light images belongs to image detection and identification technology[7], and there have been some reports at home and abroad in recent years. The basic idea is: first read in and convert the color digital image captured by the visible light camera into a gray image, and perform image enhancement[8]; then perform image segmentation[9] to extract features such as geometry, brightness, edge, contour, and piecewise linearity, and divide it into Target area and background area; then automatically count and identify the features in the area, scan and filter one by one, eliminate suspected targets that do not have the characteristics of the infrared image of the high-voltage line, and get the initial pixels of the overhead

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high-voltage line image; denoise the target area[10] and output through the high-voltage line pixel mark The module outputs the image pixels of the overhead high-voltage line after display processing.

This article first starts from the image target detection, briefly introduces the development and application of image processing technology in power line extraction, and then summarizes the advantages and disadvantages of some of these algorithms on this basis, and finally points out some problems existing in the current power line detection and makes some comments on it.

2. Image target detection

Image target detection technology is a kind of image processing technology, its purpose is to separate the target of interest from the image, and give the attribute description of the target (such as category, location, etc.), it is the basis for the realization of many high-level visual tasks (such as target tracking, action recognition and behavior understanding, etc.)[11]. The traditional target detection algorithm is based on sliding window traversal for region selection, and then use HOG[12], SIFT[13]and other features to extract the features of the image blocks in the sliding window, and finally use SVM[14], AdaBoost[15] and other classifiers to classify the extracted features. The manual construction of features is more complicated, the detection accuracy is limited, and the calculation complexity of the sliding window-based algorithm is also high, so the development of this type of method is hindered. In recent years, with the rapid development of machine learning, the method based on machine learning has not only become the current mainstream method of target detection, but also the most commonly used detection method for current power inspection target detection[11]. The general process is to prepare a certain amount of training data in advance, extract features from the training data, and then use these features to train a classifier with learning capabilities to obtain a detection model with specific target detection capabilities. In terms of technological development, the development of target detection has experienced “bounding frame regression”, “emergence of deep neural networks”, “multi-reference windows (also known as Anchors)”, “difficult sample mining and focusing” and "Multi-scale multi-port detection" has several milestone technological advancements[16].

3. Power line detection

In the visible light aerial image, the main problems in the extraction of the power line are as follows: (1) In the aerial image, the power line target is relatively thin, and its width pixel is relatively small. (2) Due to the complicated environment in which power lines exist, aerial images may contain other objects with the same linear edge features as power lines. (3) Due to some uncontrollable factors such as weather, light, etc., aerial images may have a variety of noise effects. These factors all increase the difficulty of power line extraction.

In response to the above problems, domestic and foreign scholars have successively proposed a variety of power line extraction algorithms, which can be roughly divided into three directions. The first is to first perform edge detection on the power line image, and then extract the line segments from it through various algorithms, and finally optimize to get the power line. The second is to find objects or information that coexist with power lines, and assist in detecting power lines by locating these objects or information. The third is to detect power lines through deep learning, which is also the most researched direction in recent years. Through training a large amount of data, a model that can detect power lines is obtained.

The general direction of the method of identifying power lines through edge detection is: first, an edge detection algorithm is used to obtain the edge map from the image, such as the commonly used Canny operator, Robert operator, Sobel operator, Laplacian operator, etc[17]. Then use the line segment detection algorithm to obtain the line segments in the obtained edge map. The commonly used line segment detection algorithm is Hough transform[18]. For example, paper[19] proposed a method of power line detection in the background of complex ground objects. First, the original image is image equalized to enhance the contrast between the power line and the background, and then the

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Hessian algorithm is used to extract and compare the edge of the power line, and further use Hough transform realizes the extraction of power lines.Paper[20] uses the Canny operator to extract the edge of the image, and then uses the Hough transform to generate broken line segments, and then restores the complete power line according to the geometric characteristics of the power line. In the paper[21], after filtering the background noise and enhancing the edge of the power line, the Canny operator is used to detect the edge of the power line and smooth it, and finally the Hough transform is used to extract the power line. There are also literatures showing a line segment detection algorithm called LSD algorithm[22], this algorithm can obtain sub-pixel-level precision detection results in linear time, it can be applied to any digital image without tuning parameters, and it can also be used on its own. Control the number of false detections, and the speed is faster than Hough. Finally, the parameters are adjusted in various ways to suppress the noise on the image, and finally the power line target image is obtained. In recent years, many researchers have continuously improved the edge detection and line extraction algorithms based on the two core steps of edge detection and line segment extraction, and finally achieved relatively good results. Generally speaking, the overall model of the method based on edge detection and line segment extraction is relatively simple and easy to implement, but if the image background is more complex, the linear edges in the image increase, which brings interference to the extraction of power lines, and the accuracy of the extraction may be Will decrease accordingly[23]. Therefore, this type of algorithm is only applicable to images with clear power lines and relatively little interference information for power line detection. In addition, some scholars have introduced prior knowledge[24] to extract power lines based on edge detection and line segment extraction methods. This type of algorithm constructs appropriate classification criteria by introducing certain a priori characteristics of the power line itself to classify the power line and other non-power line line structures. Such algorithms usually redesign or improve the edge detector based on prior knowledge, and suppress non-power line pixels while extracting edge points. The advantages of this type of algorithm are that the structure model is simple, the amount of calculation is small, and it can achieve accurate and automatic extraction of power lines. In addition, it also has the effect of suppressing other interference noises. It can be applied to some aerial images with more complicated backgrounds. To extract the power line. However, due to the influence of many uncontrollable factors, the prior knowledge introduced by this type of algorithm cannot match all the data, which reduces the stability of this type of algorithm and also weakens the performance of this type of algorithm.

The general direction of the power line extraction method by looking for auxiliary materials: combine the line segment detection with the detection of other coexisting objects on the power line picture, such as tower poles, insulators, etc., and then build a power line extraction model, such as the common Bayesian grid power line extraction model[25]. This model can distinguish power lines and non-power lines based on the input joint features. This type of algorithm can increase the precision and accuracy of power line extraction, but it also has a certain range of limitations. When there are no other coexisting objects in the power line extraction image, only the power line, the effect of this type of algorithm will be greatly reduced, or even no longer applicable. This type of algorithm is a supervised learning algorithm, which requires training the model in advance, and also has certain requirements for the sample size of the data set. If the sample size is insufficient or small, the performance of this type of algorithm may also be reduced. In addition, it is also possible to combine line detection and context information algorithms to achieve the extraction of power lines[26]. This type of algorithm is based on the characteristics of the power line itself, then combines the context information of the power line image to define the features, and finally builds a suitable classifier based on these joint features to realize the distinction and extraction of power lines and non-power lines. The stability of this type of algorithm is stronger than that of the previously described algorithm, and the applicable scenarios are also wider, and the development space and prospects are relatively good.

Power line recognition using deep learning: In recent years, many researchers have used deep learning to identify power lines. First, they train a large number of power line image samples and extract

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common power line features, and then use these features to train the classifier. This classifier With learning ability, after training, a model with the ability to identify power lines can be obtained. For example, there is a literature that proposes an accurate and robust method. This method first extracts the edge features of the power line from the test image, then uses the CNN classifier to remove the background noise, and finally uses the Hough transform-based fine selection module to perform the power line position[27]. Other documents adopt end-to-end design ideas, but the main network uses the structure of VGG-19 and ResNet-50, and then uses a randomly initialized softmax layer to replace the last layer of the CNN network, and finally forms a model to correct power line identification[24]. However, the current CNN-based power line classification method only stays at classification and recognition[28], and more research needs to be invested in the realization of power line target detection. Compared with other methods, the power line detection model based on deep learning is more complex and requires data training. The construction of a database requires not only sufficient sample data, but also power lines with complex and diverse backgrounds. At present, the use of deep learning for image processing applications has been very extensive, such as the R-CNN algorithm for target detection, the Mask-RCNN algorithm for image detection and segmentation, etc. [29], and the YOLO series of algorithms[30] , It regards the target algorithm as a regression problem. YOLO is an end-to-end network that can complete the input from the original image to the output of the object position and category. This type of algorithm is fast, but its accuracy is not very high.

4. Conclusion

In recent years, due to the rapid development of deep learning, the detection of power lines based on deep learning methods has become more and more popular. Methods based on deep learning can make up for the shortcomings and shortcomings of some traditional methods, but due to various potential factors, in fact It is impossible to manually develop an algorithm that can detect and locate the entire conceivable error range, and deep learning requires training a large amount of sample data. How to build such a sample database with sufficient samples and covering various complex backgrounds is also a problem. As visible light aerial images also have limitations, visible light images can be combined with infrared images or data detected by radar to perform fusion detection of multi-source information. This can not only make up for the shortcomings of detection technology based on a single type of sensor, but also greatly improve the robustness of detection, which is an important development direction for power line detection in the future.

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