Research on Image Recognition Algorithm Technology for Power Line detection

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Abstract. Based on the analysis of power line features in aerial images, this paper proposes a power line detection algorithm for aerial images based on adjustable direction filtering. The thesis first performs directional filtering on the image and calculates its directional energy function and ridge energy function, then combines the image local and global information to fit the line segments in the image, and finally verifies the reliability and real-time performance of the algorithm through experimental methods. The calculation of this algorithm is about half of the ED Lines algorithm. Experimental results show that the algorithm can detect power lines in aerial images better, and the algorithm is not complicated, which is suitable for real-time detection of power lines.

1. Introduction
The continuous advancement of miniaturization and low-cost sensor technology provides a hardware basis for autonomous obstacle avoidance of drones. However, the current sensors and algorithms are mainly oriented to obstacles such as buildings and trees in the environment with large image areas and many textures. Object detection. There are few researches on the detection of line obstacles with small image area and few textures such as power lines in complex environments. At the same time, the existing drones have practical significance for the detection of line obstacles such as power lines in complex background environments. The background of the image obtained by the UAV inspection is complex, the contrast between the small parts and the background is low, the background of the different regions in different seasons is very different, and there is a lot of interference. Traditional power component recognition algorithms mainly use SIFT edge detectors, HOG, etc., which are not very suitable for power components. The segmentation algorithm used is mainly based on the peripheral contour skeleton of the component, adaptive threshold and so on. These methods lack comprehensive utilization of low-level features to achieve the goal of global optimal recognition. This paper analyses the morphological characteristics of the electronic line different from other objects in the scene, and proposes a power line detection algorithm for aerial imagery based on directional filtering [1].

2. Filtering algorithm of image recognition algorithm

2.1. Least mean square error (LMS) algorithm
The criterion of the LMS algorithm is the minimum mean square error, that is, the expected value of the square of the difference $e(n)$ between the ideal signal $d(n)$ and the filter output $y(n)$ is the
smallest, and the weight coefficient \( w_i(n) \) is modified according to this criterion. The resulting algorithm is called the minimum mean square Algorithm (LMS) [2]. Most research on adaptive filters is based on the LMS algorithm proposed by Windrow. This is because the design and implementation of the LMS algorithm are relatively simple and are very suitable for many applications.

The experimental verification comparison analysis of the algorithm in this paper and the traditional Canny algorithm is shown in Figure 1, where (a) is the original image under different lighting, (b), (c) are the Canny algorithm under different lighting and the edge of this paper the effect diagram of the extraction method. Figure 1 shows that the method in this paper has better edge point extraction under the change of illumination, in which the straight-line edge point extraction is complete, and the power line detection under the change of illumination can be realized [3].

![Figure 1](image-url)

**Figure 1.** Comparison of algorithm edge detection effects

2.2. Analysis of RLS adaptive filtering algorithm

The power line can be determined by extracting the ridge points of the line-shaped objects in the image. At present, the method based on edge detection is more commonly used, but due to the relatively large width of the power line taken at close range (more than 3 pixels), it is easy to make mistakes after edge detection It is judged as two parallel power lines. In addition, the edge objects in the aerial image with complex background are easy to be detected, which is not conducive to the subsequent detection of power lines. Here, a second-order Gaussian differential operator is used to form a directional energy function and a ridge energy function for detecting ridge points [4].

The designed adaptive filter adjusts the filter parameter \( W \) to make the observation signal \( \hat{s}(n) \) based on the past observation samples most approximate the original signal \( s(n) \) in a certain sense. At this time, on the one hand, the recovery error:

\[
\eta(n) = s(n) - W^T X(n)
\]

On the other hand, \( W^T X(n) \) can be regarded as the prediction of \( x(n) \). Therefore, the prediction error can be defined:

\[
e(n) = x(n) - W^T X(n)
\]

The purpose of designing the adaptive filter is naturally to minimize the recovery error \( \eta(n) \). But because the real signal \( s(n) \) is unknown, \( \eta(n) \) is unobservable or incalculable. On the contrary, the prediction error \( e(n) \) is observable, and its relationship with the recovery error is:

\[
e(n) = \eta(n) + n(n)
\]
The noise sequence $\eta(n)$ is independent, so the minimization of the unobservable recovery error $\eta(n)$ is equivalent to the minimization of the observable prediction error $e(n)$. Specifically, consider the following formula to minimize.

$$
\varepsilon(n, W) = \sum_{i=1}^{n} \lambda^{n-i} |e(i)|^2
$$

(4)

In the formula, $\lambda$ is the forgetting factor, usually $0 \leq \lambda \leq 1$. By

$$
\frac{\partial \varepsilon(n, W)}{\partial W} = \frac{\partial}{\partial W} \sum_{i=1}^{n} \lambda^{n-i} \left[ x(i) - W^T X(i) \right] = -2 \sum_{i=1}^{n} \lambda^{n-i} \left[ x(i) - W^T X(i) \right] X(i) = 0
$$

(5)

The equivalent relationship can be obtained:

$$
\sum_{i=1}^{n} \lambda^{n-i} X(i) X^T(i) W = \sum_{i=1}^{n} \lambda^{n-i} x(i) X(i)
$$

(6)

make:

$$
R(n) = \sum_{i=1}^{n} \lambda^{n-i} X(i) X^T(i)
$$

(7)

$$
U(n) = \sum_{i=1}^{n} \lambda^{n-i} x(i) X(i)
$$

(8)

Then formula (24) can be abbreviated as:

$$
R(n) W(n) = U(n)
$$

(9)

Assuming that $R(n)$ is non-singular, then:

$$
W(n) = R^{-1}(n) U(n)
$$

(10)

This is the formula for the filter parameters of the filter. The reason for this is $W(n)$ because $W$ changes with time.

The construction of a linear support area is a key step in power line detection. The traditional method mainly sorts the gradient of pixels, selects the pixels from the high gradient in order and selects the pixels as the initial point of the region, and adds the pixels in the neighbourhood whose gradient angle is within the maximum tolerance error from point to line support area, the angle and endpoint coordinates of the line support area are finally output. The traditional linear support area construction method is difficult to adapt to the detection of power lines in a complex background, and it is prone to misdetection and breakage. Therefore, this paper combines the image features of the power line to improve the construction method of the support area and improve the accuracy of target straight line detection.

Firstly, the characteristics of the power line in the forward image of the drone are analysed to obtain the following characteristics: 1) The power line is approximately a linear object, and the power line in the image can be regarded as a slightly curved straight line; 2) The power line has a certain range of tilt angle, and approximately parallel and similar in length, throughout the entire image.

The ridge point detection results are shown in Figure 3. Figure 2 (a) is the original aerial image, and Figure 2 (b) and (c) are the ridge points and ridge energy maps obtained after filtering through the directional adjustable filter. It can be seen from Figure 2 that after filtering, the background in the image is suppressed, the power lines are enhanced, the noise and thin lines are filtered out, and the power lines are not reduced to a single pixel width, which can avoid the power lines after filtering breaking, reducing the position accuracy of power line detection, this is the obvious difference between the directional filter and other types of filters [5].
3. Power simulation calculation results

3.1. Realization of power overhead line pattern recognition

3.1.1 Detect the wire shape in the picture. To detect the shape of the wire in the picture, a single background is needed, mainly with the sky as the background. Each wire is shown in a straight line as much as possible in the picture, and as many wires as possible are required to enter the view. Implementation process: grayscale image processing; use the edge detection algorithm of Canny for edge detection; use the straight line detection algorithm to detect the part of the edge that belongs to the straight line, retain the first 12 responses with the highest straight line response, and each response must be higher than the peak value 0.35 times response (core algorithm); record rho and theta of each straight line in polar coordinates; fine-tuning of angles, forcibly set two straight lines with angle difference less than 10° to parallel state; two straight lines with parallel angles If the rho difference is less than 50, merge the two branches; record all the straight lines that meet the conditions after the merge; calculate the distance between the straight lines, if the distance between the two straight lines is less than the present threshold, merge the two straight lines again, and finally record All the remaining straight lines; if the straight line angle is between (-10°, 10°), it is considered to be the two sides of the pole, if the remaining straight line is less than 1000, it is deleted, and the rest is the detected wire or pole The obvious part of the bar; determine the electric current according to the slope of the detected straight line and the number of straight lines with corresponding slopes.

In this test, for each type of components such as spacers, equalizing rings and shock hammers, the training samples were 150,000, three types of targets totaled 450,000, the test samples were 50,000, and the three types of targets totaled 150 Zhang. Mark the outer frame of the small power components that appear completely in each picture in the training set without being blocked (the incomplete or blocked power components in the training set pictures are not marked); and for the test set, mark each picture All electrical components present, including incomplete and blocked. During the test, if the overlapping area of the recognized outer frame and the marked outer frame reaches more than 90% of the marked outer frame, it is regarded as a successful recognition. In this experiment, the evaluation indicators are the correct rate and the recall rate, where the correct rate is the ratio of the number of correctly marked outer frames of the target category to the number of all marked outer frames; the recall rate is the number of correctly marked outer frames The ratio of the number to the number of all standard peripheral frames. Since there are only three types of categories identified in this experiment, the correct rate and recall rate of each type of power component identification are counted separately.

3.1.2 Line feature detection. After filtering by the directional filter, the ridge points in the image can be obtained, but the number of power lines and which ridge points belong to which power line are still uncertain, and not all line segments and points are power lines, so those that do not belong to the power line must be eliminated Line segments and points. Among the many straight-line detection
algorithms, the Hough transform is the most widely used algorithm, but the Hough transform is computationally intensive and cannot detect a line segment. It can only detect a straight line containing the line segment, and often cannot find the optimal space. Solution, which makes the Hough transform unsuitable for power line detection. In order to detect power lines, this paper adopts the method based on region growth and connectivity component analysis, grouping the connected ridge points into a connectivity area as a subset of power lines. According to the similarity of Gray levels in the direction of the power line, it can be considered that when the difference between the Gray value of a pixel and the average Gray value of the current power line area is less than the set threshold, the pixel point belongs to the current power line area. The current areas are merged, and the process is repeated until no new points are merged. Each connected area thus obtained is a line segment, and its direction and position can be obtained by calculating its covariance and eigenvalues [6].

3.2. Analysis of experimental results
Input the collected images for processing to obtain Figure 3. There is no single angle straight line number of 1, and there are more than 2 straight lines of different angles for the corner type; there is no single angle straight line number of 1, and only one angle of the straight line is more than 1 type; there is a single The number of angle straight lines is 1, and there are more than 2 straight lines with two angles, which are corner-tension type; there are 1 single angle straight lines, and there are more than 2 straight lines with only one angle, which are straight-tension type.

Figure 3. Simulation results
Faster-RCNN involves some parameters, such as the dropout ratio, the maximum number of iterations, the batch size, and the number of areas reserved before and after nms (non-maximum suppression). These parameters have a greater impact on mAP. According to Table 1, when the ratio of dropout increases from 0.2 to 0.8, mAP is generally in a downward trend, but there is a highest value at 0.6. At present, there is no relevant theory to explain the impact of dropout on mAP, usually based on empirical values [7].

| dropout proportion | The maximum number of iterations | Regional proposal stage batch size | Batch size during inspection | nms. Number of top candidate regions | nms. Number of candidate regions | map   |
|---------------------|---------------------------------|----------------------------------|-------------------------------|-----------------------------------|-------------------------------|-------|
| 0.2                 | 8000                            | 256                              | 128                           | 2000                              | 300                           | 0.827 |
| 0.3                 | 8000                            | 256                              | 128                           | 2000                              | 300                           | 0.811 |
| 0.4                 | 8000                            | 256                              | 128                           | 2000                              | 300                           | 0.817 |
| 0.5                 | 8000                            | 256                              | 128                           | 2000                              | 300                           | 0.791 |
| 0.6                 | 8000                            | 256                              | 128                           | 2000                              | 300                           | 0.829 |
| 0.7                 | 8000                            | 256                              | 128                           | 2000                              | 300                           | 0.781 |
| 0.8                 | 8000                            | 256                              | 128                           | 2000                              | 300                           | 0.775 |
4. Conclusion
Aiming at the characteristics of power lines of aerial images, the image is filtered by an adjustable direction filter and the ridge energy function of the image is calculated to suppress the image background. Then, combined with the Gray characteristics of the power lines, the power lines are segmented and fitted using the region growth algorithm. Experimental results show that the algorithm can well suppress the interference in the background, have a higher detection rate and detection accuracy for power lines, and have better real-time performance than the Edline’s algorithm.

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