Power Line Image Segmentation and Extra Matter Recognition based on Improved Otsu Algorithm

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***Abstract*- Extra matters are easy to lead to power lines inter phase short circuit which not only endanger the pedestrians and cars, but also seriously affect normal operation of the power system. Firstly, an improved Otsu algorithm based on morphological approach is proposed. Then a new filtering method according to power lines characteristic is presented to remove tiny noise. Finally, accuracy power line recognition is realized by Hough transform, and the extra matter on power line can be identified by comparing the number of tested power lines and the number of local maxima in Hough transfer accumulator. The result shows that this method can effectively recognize the extra matter on power lines, providing reliability for the power system.**

***Keywords*- extra matter; image segmentation; transmission line; Hough transform**

I. INTRODUCTION[1]

In recent years, some grid-threatening events caused by kites or balloons have occurred, many of them lead to tripping accidents. Kites or balloons twining round transmission lines make the ultimate discharge distance shortened, and endanger the safety of pedestrians and vehicles under the transmission lines. So finding the extra matters such as kites or balloons in time is very significant.

The traditional method of line-tracking is artificial. With the increasing complexity of high-voltage network and long-distance transmission lines, it is becoming more and more difficult to rely on artificial line-tracking. In order to reduce the intensity of the work and improve the efficiency, a new line-tracking method using aircraft loading visible light imaging equipment has arisen recently [1]. The new method brings the problem of how to find the fault images out of the total aerial images. At present, the research on transmission line fault recognition based on aerial images is rarely involved. Zhang et al [2-6] have done a fair amount of work, studying the extraction and detection of straight lines in image, which provide the basis of transmission lines recognition.

Figure 1 shows samples of extra matter image.

(a) (b)

Fig. 1. Samples of extra matter images

This paper provides a new image segmentation method based on Otsu algorithm, and extracts transmission line features by Hough transform. Classifier is designed to check extra matter images following the minimum risk classification decision.

II. AERIAL IMAGE SEGMENTATION

RGB is the default color model of transmission line aerial images. Because of consisting of three component images, images represented in the RGB model have huge information which bring Huge complex calculations [7]. Therefore, before the segmentation of aerial image, gray transformation is used to reduce dimensions, seeing formula (1) below.

$$GRAY(x,y)=0.299R(x,y)+ \\ 0.587G(x,y)+0.114B(x,y) \tag{1}$$

Where, $GRAY(x, y)$ is the gray level after gray transformation; $R(x, y)$, $G(x, y)$ and $B(x, y)$ are red, green and blue components respectively.

Usually, the background of transmission lines in aerial images is a varied topography, which brings great difficulty and calculation for target detection and recognition.

A. TRADITIONAL OTSU ALGORITHM

Image segmentation is one of the most difficult works in image processing, and at present there is no general method. Otsu is an adaptive threshold segmentation algorithm. It is one of the most simple and efficient single threshold segmentation methods. Otsu can divide an image into object and background respectively without any priori-knowledge [8].

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Assume that an image has M rows and N columns, and has N_1 target pixels and N_2 background respectively. Then the percentage of target pixels in image is

$$\omega_1 = \frac{N_1}{M \times N} \quad (2)$$

and the percentage of background pixels in image is

$$\omega_2 = \frac{N_2}{M \times N} \quad (3)$$

Let μ_1 is mean gray value of target area and μ_2 is mean gray value of background area, then the mean gray value of image is

$$\mu = \mu_1\omega_1 + \mu_2\omega_2 \quad (4)$$

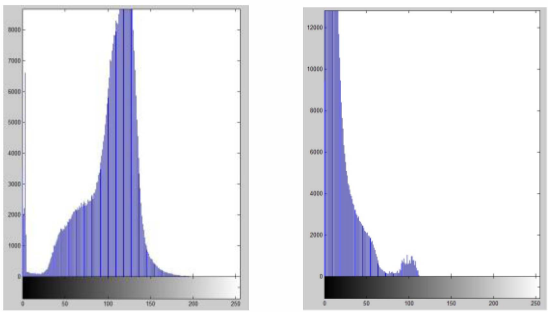
Then the variance of target and background can be expressed as

$$g = \omega_1(\mu - \mu_1)^2 + \omega_2(\mu - \mu_2)^2 \quad (5)$$

According formulas (2)-(5), the maximum threshold T is accomplished by traversing the whole image, which makes the image divided into two parts of target and background.

B. Improved Otsu Algorithm Based on Morphology

To illustrate the extra detection procedure, consider Fig.1, which shows an image of transmission line twined by a kite. Because of the complexity of aerial image, the threshold T_1 of Fig.1(b) estimated using traditional Otsu algorithm is 0.3401, and its gray level histogram has no clear valley as shown in Fig.2(a). Fig.2(b) shows the result of segmentation with the threshold T_1. Note that the segmentation image is not ideal.



(a)Histogram of aerial image (b)Histogram of the morphology conversion result

Fig. 2. Result contrast after the morphology conversion

In order to solve the foregoing problem, an improved Otsu algorithm based on mathematical morphology is proposed in this paper. Morphology offers a unified and powerful approach to numerous images processing problem [7, 9]. The language of mathematic morphology is set theory. Sets represent objects in an image. Dilation and erosion are fundamental to morphological processing. The structuring element S moving on the given image F has three possible statuses as follows.

a. $S[f] \subseteq F$;

b. $S[f] \not\subset F$;

c. $(S[f] \cap F) \cup (S[f] \cap \bar{F})$;

Then the erode operator is

$$F \Theta S = \{ f \,|\, S[f] \subseteq F \}$$

And the dilation operator is

$$F \oplus S = \{ f \,|\, S[f] \cap F \neq \Phi \}$$

Erode algorithm can eliminate the borders of an object, while dilation operation can make the background points which are around the object joined into the object [8].

In this paper, double cascading morphological structure processing method is proposed. Two morphologic structures with different size are cascaded to change grey value distribution of the transmission line image, which can improve the result of Otsu segmentation. First, take erode operation with circular structure with 20 pixels diameter. Second, take dilation operation with square structure with 25 pixels side length. At last, subtracted with original result, the gray peak of original image is gotten, as shown in Fig.2(b).

III. Aerial Image Filtering Based on Geometric Features of Transmission Lines

The background grey value of Aerial image and its distribution is random. After image segmentation, there still exists noise in the background, which has the similar grey value with transmission line. So we need further processing to filter the noise.

Traditional filtering methods can't achieve local filtering. Aimed at the problem, this paper proposed a filtering method using the linear geometric features of transmission line. Linear features of transmission lines in the image are as follows:

(1) Morphological dilation can avoid discontinuity of power line. Therefore, relative to the scattered noises in image, a power line can be seen as a rectangle, which has certain regularity in its aspect ratio.

(2) The area proportion of the transmission line in the image is larger than the area proportion of random noise.

Mathematical expression of the method is as follows:

$$D(i)_{goal} = \{D(i) \,|\, R(i) \cap P(i)\}$$

where,

$$R(i) = \{D(i) \,|\, (\frac{D(i)_x}{D(i)_y} > \beta \cup \frac{D(i)_x}{D(i)_y} < \frac{1}{\beta}\}$$

$$P(i) = \{D(i) \,|\, D(i)_P > \lambda\}$$

After segmentation, tag and number the parts which are connectionless in 4 field, let the part *i* be *D*(*i*), and its geometric ratio of length and width satisfies feature(1). That is, the ratio of horizontal maximum width and vertical maximum width is greater thanβ when the minimum angle of transmission line and horizontal line is less than 45°, and less than $1/\beta$ when the minimum angle of transmission line and horizontal line is greater than 45°. *P*(*i*) indicates that *D* (*i*) satisfies feature(1), that is, the pixel number in *D* (*i*) is greater than λ. Through a large number of experiments we got β=11 and λ=1000. Only the area which satisfies the two features is the transmission line area, and excludes the others.

Using the proposed method, the result is shown in Fig.3, the transmission line area is completely and accurately abstracted.

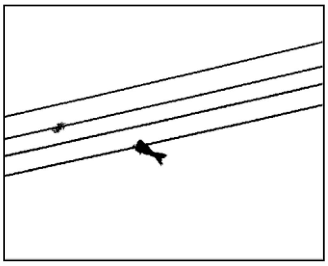


Fig. 3. Aerial image filter result based on the feature of transmission line

The result is the binary image, which contain too little information. Combining the original gray image and the position of target pixels in the binary image, we got simple background aerial gray image *G*(*x*, *y*) as the processing object for further recognition.

IV. AERIAL IMAGES EXTRA MATTERS IDENTIFICATION

The premise of accurate identification to extra matters in aerial images is the recognition and accurate positioning of power lines, the power lines in the images can be thought of as a set of paraller lines throughout the images [3].This paper obtains the edge of power lines based on the gradient method, detect the power lines by using of the theory of Hough transform, and judge that whether there are extra matters.

A. THEORY OF HOUGH TRANSFORM

Hough transform is linear description method, transform the lines in Cartesian coordinate space to the points in polar coordinate space, and divides the polar coordinate space into accumulator units [5-6]. In Cartesian coordinate space, the straight lines in images can be represented as standard type [7]:

$$\rho = x\cos\theta + y\sin\theta$$

In this formula, ρ is the normal range from line to original point, θ is the included angle between the normal and x-axis. Straight line becomes a point(ρ,θ) in polar coordinate space after Hough transform, every sine curve in polar coordinate space means a set of lines those through the specific point(x, y). Divides the ρ and θ into many small pieces, and every ρ piece and every θ piece make a small unit($\Delta\rho$,$\Delta\theta$), set an Accum corresponding to every small unit, after the transformation of all the pixel's coordinates(*x*, *y*) in Cartesian coordinate space, the unit whose each small unit cumulative fall is more can be thought of the position of the line in Cartesian coordinate space.

B. EXTRA MATTERS IDENTIFICATION

a. Gradient directional derivative

In fact, the gray images' gradient directional derivative represent grey value's rate of change in the gradient direction. The ridge line of distance field is just the place where gradient mutation takes place [10]; the boundaries between power lines and background are the places where the gradient mutation of grey value takes place. At first, compute the gradient directional derivative of image *G*(*x*, *y*), the directional derivative obtains maximum value at this time, that is mold of gradient vector [9], shown in the form below:

$$|\nabla L| = \sqrt{\left(\frac{\partial G}{\partial x}\right)^2 + \left(\frac{\partial G}{\partial y}\right)^2}$$

Set the appropriate threshold value of gradient directional derivative and detect the borders of power lines.

b. Accumulator design

Set the accumulator dynamically according to the size of image. For image *G*(*x*, *y*), its size is [M, N], and the size [m, n] of Accum[ρ,θ] is decided by the formula (6), the scope of θ in polar coordinate is fixed in [-π/2,π/2].

$$m = \left\lfloor (N + \sqrt{M^2 + N^2})/2 \right\rfloor \qquad n = 400 \tag{6}$$

c. Feature vector extraction and classification decision

After gray transform, Hough transform is carried out on the pixels whose gradient directional derivatives are greater than T_1. Then put them into the accumulator. Find the local maximum value $N_{LocalMax}[\rho_i, \theta_j]$（$1 \le i \le m, 1 \le j \le n$）through setting up the local maximum value filter, and the number of local maximum is denoted by $N_{PointNum}$.

Search the lines in the original images through $N_{LocalMax}[\rho_i, \theta_j]$. Because the Hough transform doesn't take into account the adjacency of points, this paper assumes that the collinear points in a significant line are T_2 at least. And argues that when the interval points are greater than T_3, the two lines have the same slope and intercept, T_2 and T_3 are experience value based on a large number of experiments. Record the coordinate of lines' endpoints as $N_{SegEnd}[x_{i1}, y_{j1}, x_{i2}, y_{j2}]$, and record the number of lines as N_{SegNum}. The power line would be divided into two lines if there are extra matters in aerial images, so select feature vector I as:

$$I=[N_{PointNum}, N_{SegNum}] \tag{7}$$

In fact, power lines have a certain width, there are two border edges in the boundary between power line and background, and the number of lines detected is the number of lines' edges, so the images those have extra matters should satisfy the formula:

$$N_{PointNum} < (N_{SegNum}/2) \tag{8}$$

Formula (8) means that: when the number of different slope intercept is less than the number of lines, we could think that there are extra matters in power lines; conversely, there aren't extra matters.

V. EXPERIMENTS

In order to test and verify the generality of this proposed method, 150 images concluding 34 extra matter images are used as test samples. Experiments follow the principle of minimum risk [11-12].

Fig.4 shows a group of power lines which are hanging on the farmland, wrapped by a plastic bag. Process Fig.4 by the above method and the result shows in Fig.5, which means this proposed algorithm can recognize extra matters accurately.

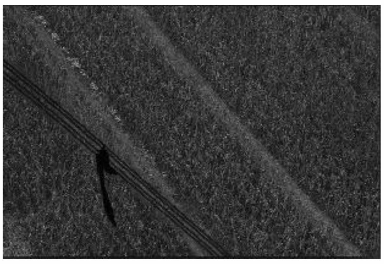


Fig. 4. Validation examples

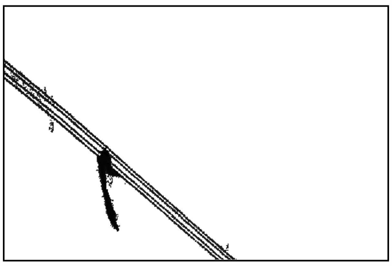


Fig. 5. Result of the algorithm

VI. CONCLUSION

The recognition method proposed in this paper can not only ameliorate the hard working environment of artificial patrolling, and also improve the patrolling efficiency.

The optimized Otsu image segmentation method makes the segmentation effect much better. The traditional filter always processes the whole image, which cannot aim at one certain object, while the filtering method proposed in this paper, utilizing the power line geometry characteristics, can filter the noise in aerial image effectively. Calculating the gradient of transmission line avoids the limit of Hough transform and detects the power line position in images. This paper provides a new method for faults diagnosis of transmission line with high value for engineering application.

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