Unmanned Aerial Patrol Technology Based on Tracking Algorithm of Target Tracking

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Yao Yao(✉)
ZhouKou Normal University, Zhoukou, Henan, China
yaoyao_zknu@126.com

Qing-le Quan
Henan University of Animal Husbandry and Economy, Zhengzhou, Henan, China

Hong-hui Zhang
ZhouKou Normal University, Zhoukou, Henan, China

Qiong Li
Zhoukou, Henan, China

Abstract—In order to study the power patrol technology of unmanned aerial vehicle, the tracking algorithm was applied. The automatic patrolling of power lines was discussed in terms of algorithms. An unmanned aerial vehicle transmission line inspection method based on machine vision was proposed. The image and video of the unmanned aerial vehicle inspection of the power line had a complex background. By Wiener filtering de-noising and probability density functions, the image clarity was improved. According to the existing tracking techniques and algorithms, a Camshaft target tracking algorithm based on lossless Kalman filter was proposed. The method of non-destructive Kalman filter was adopted to predict the region of interest of power line identification. Using the Camshaft algorithm, the prediction of the window was searched and the size of the window was adjusted. Transmission lines were tracked in real time. The results showed that the restoration effect of the algorithm was obvious. The clarity of the image was improved. It prepared for the extraction and tracking of the future transmission lines. Therefore, the proposed method provides a feasible way for the UAV power line inspection technology based on machine vision.

Keywords—UAV, machine vision, power line inspection, lossless Kalman filter

1 Introduction

With the improvement of the national economic level, the demand for industrial and living electricity has surged. The voltage level of the transmission line is also getting higher and higher. In particular, high voltage transmission lines and UHV transmission lines are important lines of power transmission. Electricity is transported from rich areas to economically developed areas. It plays an important role in electric energy transmission. As early as in 2014, the total length of power lines in China had reached 1 million 150 thousand kilometers. It is expected to reach more than 159 million meters by 2020. These power lines are mostly in the underdeveloped areas. The surrounding environment is very complicated. The area covers a wide range and is exposed to the natural environment for a long time. It suffers from the destruction of external force machinery and load, as well as the invasion of branches, ice, snow, storm and flood. These external effects can lead to the aging of transmission lines and transmission equipment. Then, it will have a series of problems. If these problems are not found in time, unimaginable disasters may occur. Therefore, it is necessary to make regular inspection, find out the faults and make the corresponding treatment as soon as possible, so as to ensure the demand for electricity in the industry and the residents' life [1].

There are many disadvantages in the traditional way of patrol line. In places where conditions are bad and the environment is hard, the work efficiency of traditional patrol line is very low. With the deep research of image processing technology in machine vision, UAV technology is applied to power patrol line. The power patrol technology based on unmanned aerial vehicle (UAV) can solve many disadvantages of traditional line inspection. The typical application of UAV technology and machine vision technology in power line inspection is studied. Through the image processing technology, the collected images and videos are processed. The state of the transmission line is extracted, judged, located and tracked. Then, the automation line of the transmission line is realized [2]. The unmanned aerial vehicle (UAV) patrol line has low requirements for the flight environment. It is suitable for many occasions, and its accuracy is very high. Especially in remote areas and complex geographical environment, UAV can determine the location of the fault faster, and deliver the scene's condition in real time, so that the maintenance personnel's walking investigation is avoided. The unmanned aerial vehicle (UAV) can perform the patrol task in the case of electrification. It can be reduced to a very low altitude to take close range of transmission lines and related equipment. This not only improves the accuracy, efficiency and reliability of power transmission line, but also avoids the accident of live work. According to relevant statistics, the unmanned aircraft inspection line efficiency is 41 times the manual inspection line. Now, China is gradually forming a patrolling line mode with unmanned aerial vehicle (UAV) line as the leading line. With the further development of image processing technology, unmanned aerial vehicle (UAV) will be an efficient way of electric power patrol. It will gradually become the development direction of the power line patrol line. The new era of electric power patrol was opened [3].

2 Image processing of aerial power line

At present, most of the domestic high-voltage transmission lines are built in fields, mountains and other places. They are far away from traffic main roads. Unmanned aerial vehicles (UAVs) can shoot high altitude transmission lines. Complex background images will be the primary problem for target recognition and tracking. Because UAV is captured in the air, it is easy to be influenced by the weather conditions such as light intensity and atmospheric turbulence. Thus, the target is blurred. The quality of the resulting video image is not good [4].

The core of target tracking is to find the connection between the key frames of the adjacent images. In particular, the Gauss noise and mixed noise in the mutation, the gradient and the complex background in the lens transformation are processed in the early stage. The detection of lens gradient is mainly based on the combination of the whole moving distance between frames and the feature of the target. The feature is mainly a target model such as the fusion of lines, colors, edges or several features. The mutation of the lens mainly includes the color difference between frames, the shot segmentation of the histogram, and the twice frame difference method. At present, there is no way to apply all kinds of lenses. It can only be analyzed according to the target video, and select the appropriate detection methods and denoising methods, so as to achieve the desired results [5].

3 De-noising preprocessing of video frames

There are many kinds of noise caused by various factors. By Fourier spectrum analysis, it can be divided into Gauss noise, gamma noise, impulse noise and mixed noise. Most of the video is the Gauss noise and mixed noise caused by strong or too weak light, electronic components and complex background. These two kinds of noise are processed directly. Although filtering de-noising can make it smooth, the image will lose a part of the details. Therefore, the de-noising selection is improper. It can not only get bad results, but also make the image quality performance poor. The contrast of the image is weakened, and the image becomes blurred. Therefore, it is very important to choose a suitable and effective video frame de-noising method. It minimized the impact of the details. In order to filter the interference better, the image is processed by means of mean filter, median filter and Wiener filter respectively. By comparing the algorithm, the corresponding noise reduction method is selected [6].

3.1 Mean filtering

The basic idea of mean filtering is that the output pixels are the mean values in the neighborhood of the relative pixel. The process is to set up a template for the image to be processed, and the template is the image set of the neighborhood with the target pixel as the center point and the 8 pixels around it. Then, the mean of all the pixels in the filter template is taken, and the mean is replaced by the pixels to be processed. The comparison of the 3*3 template after filtering is shown in Figure 1. The comparison of the 5*5 template after filtering is shown in Figure 2. The comparison of the 3*3 template filtering is shown in Figure 3. The comparison of the 5*5 template filtering is shown in Figure 4.

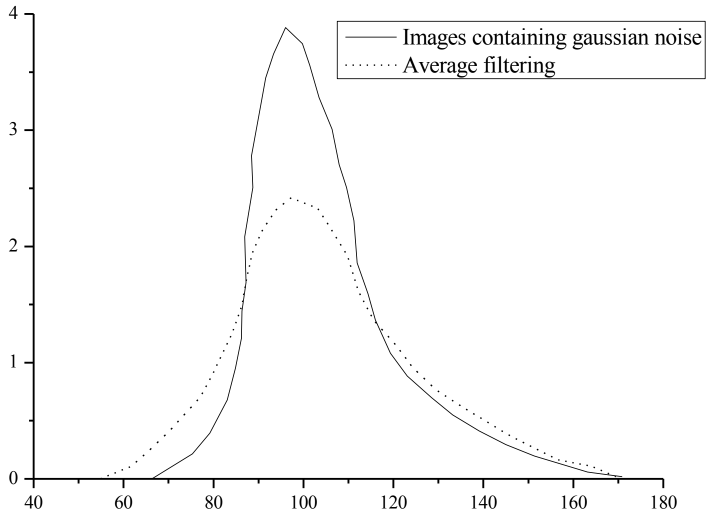

Fig. 1. The comparison of the 3*3 template after filtering

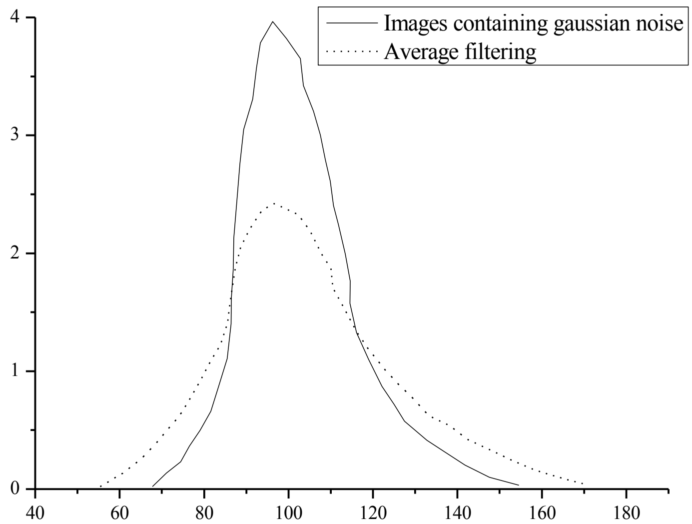

Fig. 2. The comparison of the 5*5 template after filtering

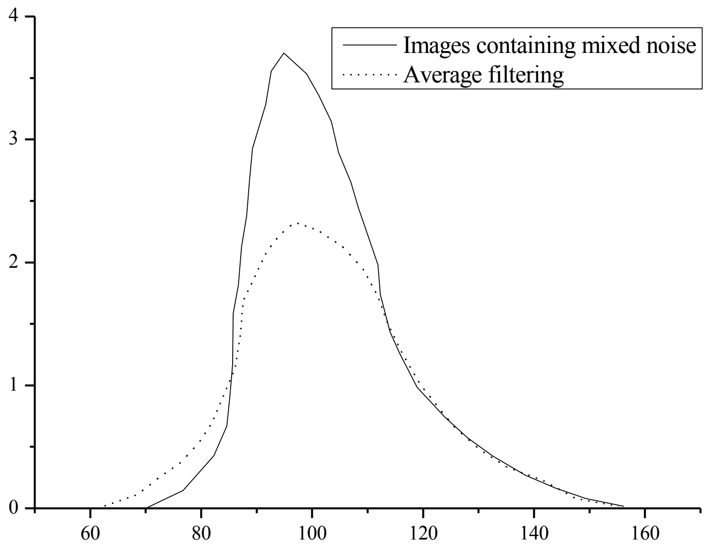

Fig. 3. The comparison of the 3*3 template filtering

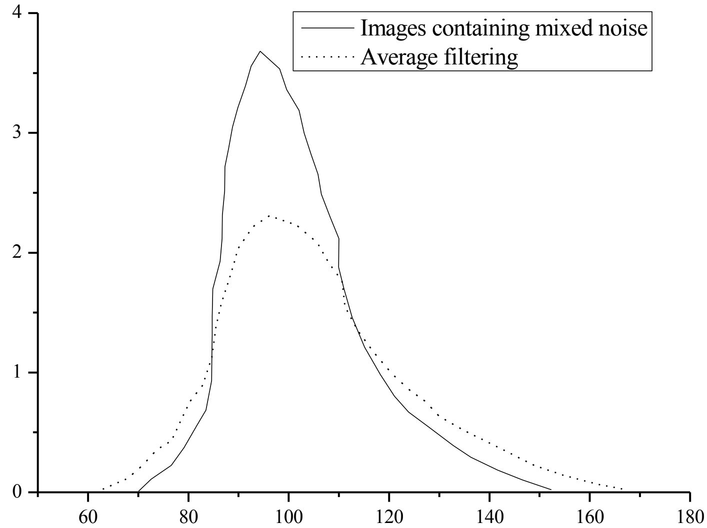

Fig. 4. The comparison of the 5*5 template filtering

It can be seen that the template with 5*5 is the best, especially for Gauss noise. However, the image becomes blurred, which affects the further processing of the image. The filtering effect of mean filtering on Gauss noise and mixed noise is limited. It is not suitable for processing the image de-noising of aerial video.

3.2 Median filtering

The median filter output pixel value is the median of the corresponding pixel neighborhood, which belongs to the domain calculation method. The neighbourhood models usually have square, circular, and cross shaped. It is usually used to protect the edge of the image. The general steps of median filtering are as follows:

The entire image is applied to the selected size of the template from the upper left corner;

The gray value of the traversing pixels is stored to form a pixel sequence;

Pixel values are ordered in order from large to small;

The values of the pixels in the middle position are stored;

The pixel values that are stored in the last step are assigned to the pixels in the required position of the selected template. Then, the module is converted to the next corresponding pixel. This step is repeated until the entire image is traversed.

The median filter is expressed in the formula (1).

$$d(x,y) = Mid\{p(x-m, y-n),(m,n \in W)\} \tag{1}$$

The contrast effects of video frame images with Gauss noise and mixed noise are compared with the processed images, as shown in Figure 5 to Figure 8.

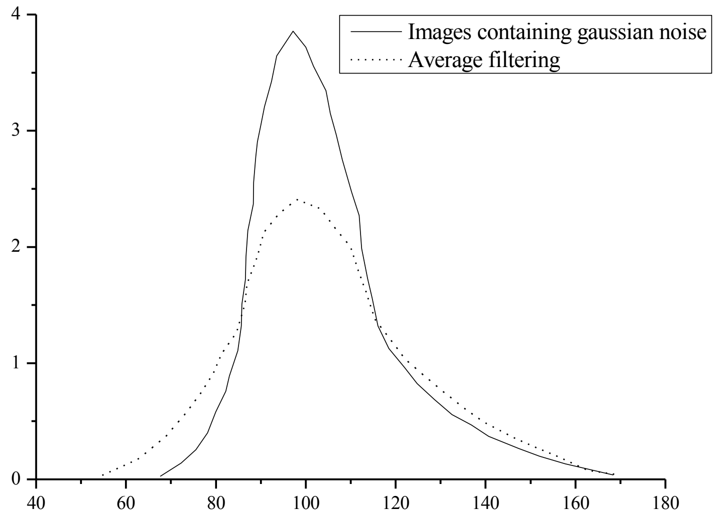

Fig. 5. Comparison of 3*3 template filtering

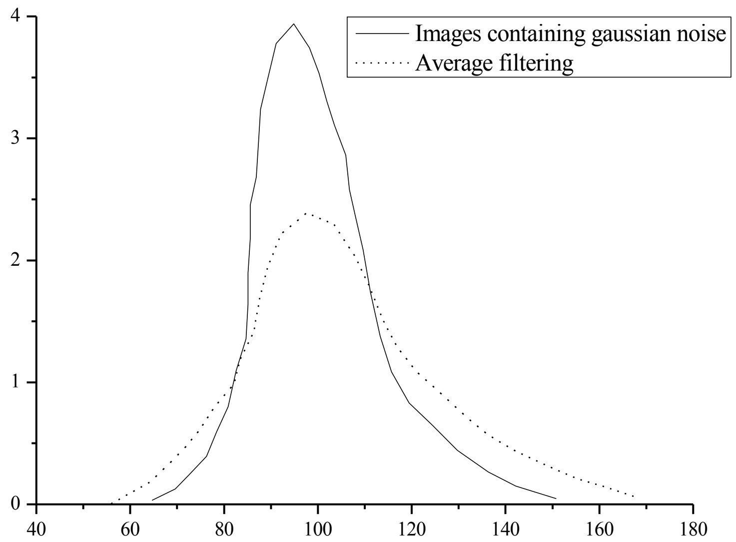

Fig. 6. Comparison of 5*5 template filtering

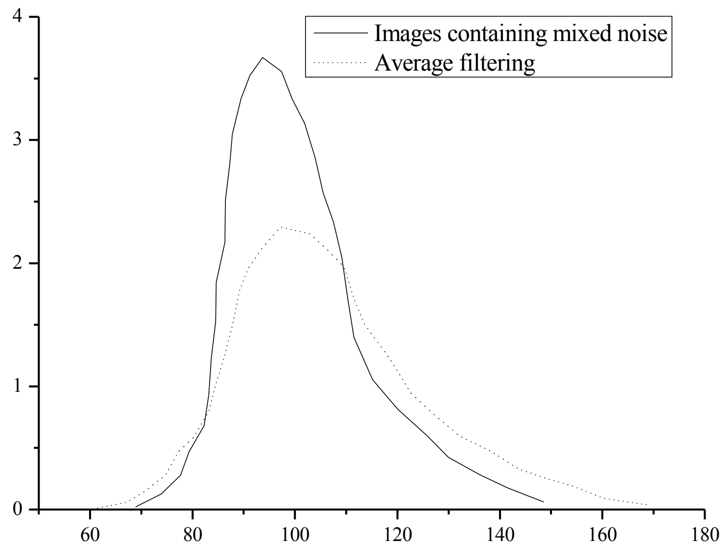

Fig. 7. Comparison of 3*3 template filtering

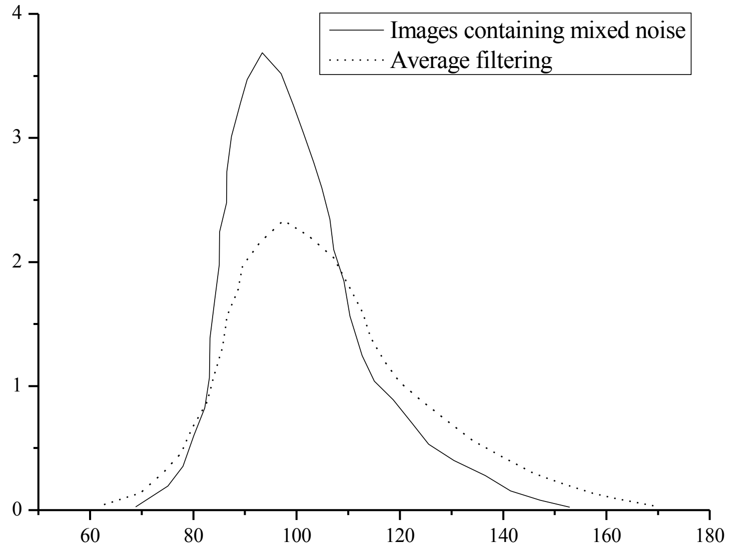

Fig. 8. Comparison of 5*5 template filtering

Gauss noise and mixed noise are added to the selected images respectively. The results after the median filter are obtained. The treatment effect of median filter is not ideal. However, if only Gauss noise is handled only, the effect of median filter is ideal, but the effect of mixed noise is poor.

3.3 Wiener filtering

Wiener filtering is a linear filter, which is used to extract the image processing method that is contaminated by Gauss noise. It is aimed at the unknown condition of the captured images and the interference noise. An estimated value $\hat{f}$ of an image f, which is not disturbed by noise, is obtained. The mean square deviation of F and $\hat{f}$ is minimized. That is:

$$e^2 = E\left\{\left(f - \hat{f}\right)^2\right\} \tag{2}$$

In the formula, $E\left\{\left(f - \hat{f}\right)^2\right\}$ is the expectation of the difference. Even if the e2 is a minimum value, the steps of the filtering method are as follows:

Each pixel is estimated in its neighborhood (N * M) for the respective mean value μ and variance σ^2.

$$\mu = \frac{1}{\mathrm{NM}} \sum_{s,t \in S_{xy}}^{\mathrm{n}} f(s,t) \tag{3}$$

$$\sigma^2 = \frac{1}{NM} \sum_{s,t \in S_{xy}}^{n} f(s,t)^2 - \mu^2 \tag{4}$$

In the formula, Sxy is a neighborhood window, which is centered on the pxy. The window is N*M.

Using the formula (5), the gray value of pxy is obtained.

$$\hat{f}(x,y) = \mu + \frac{\sigma^2 - v^2}{\sigma^2}\left(f(x,y) - u\right) \tag{5}$$

In the formula, v2 is a noise variance. If it is unknown, it can be replaced by the mean of the variance of all the neighborhood of the pixels.

$\hat{f}(x,y)$ is used to replace the original gray value $f(x,y)$ of the pixel p.

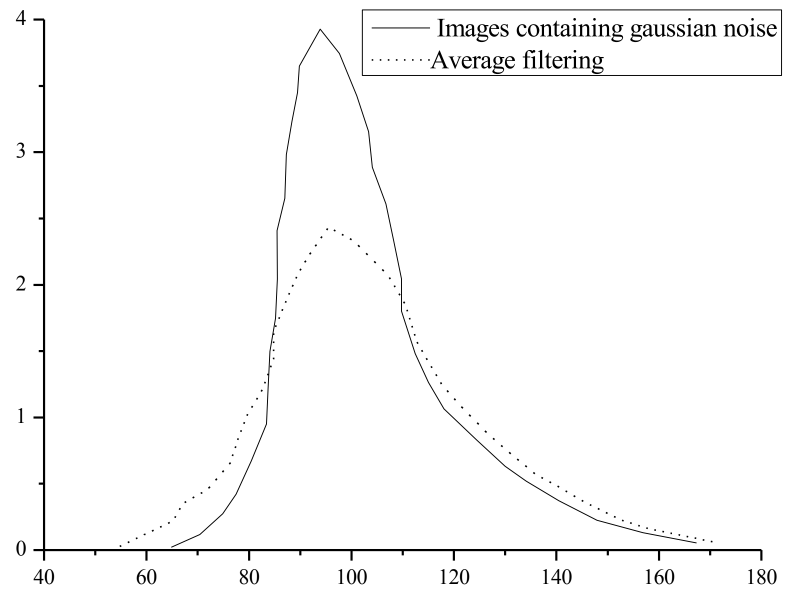

Fig. 9. Comparison of 3*3 template filtering

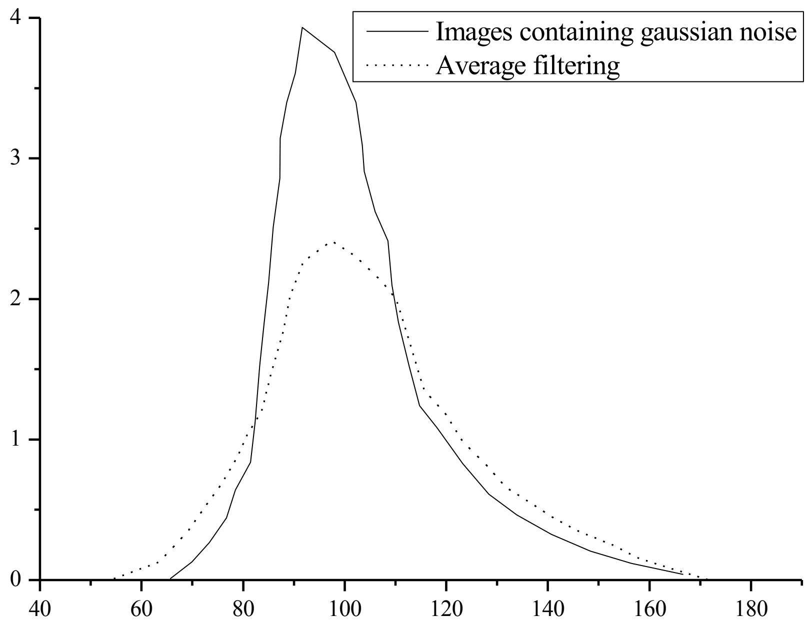

Fig. 10. Comparison of 5*5 template filtering

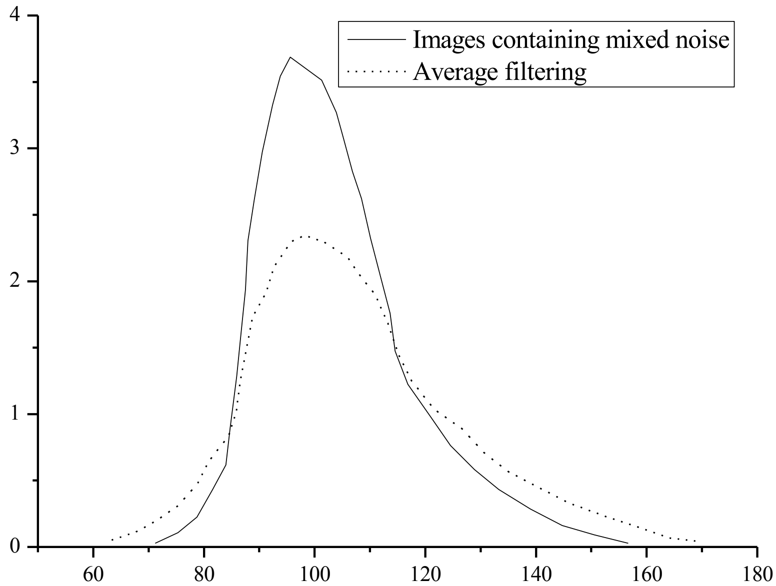

Fig. 11. Comparison of 3*3 template filtering

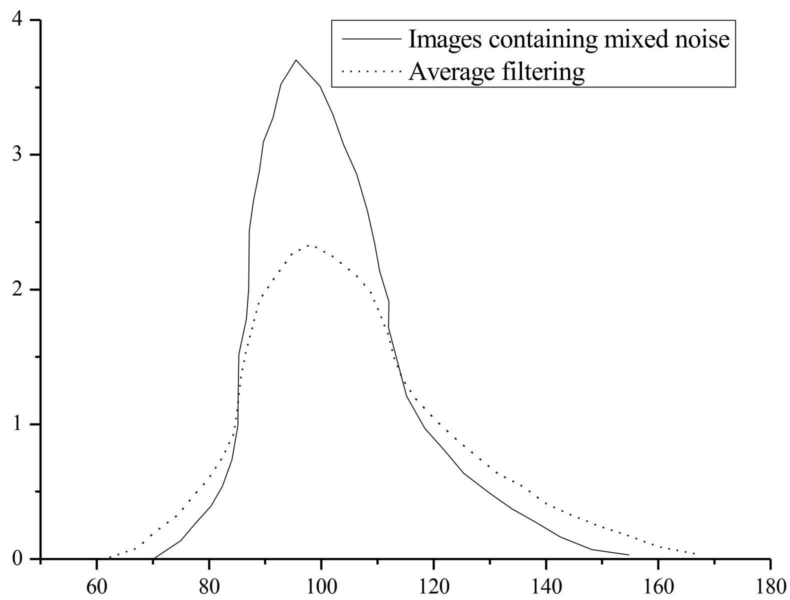

Fig. 12. Comparison of 5*5 template filtering

The degree of Wiener filtering is also influenced by the size of the template. The final size of the template will be selected through the experiment. Figure 9 to Figure 12 shows the contrast of Wiener filtering to the experimental results of a video frame image that adds Gauss noise and mixed noise.

Wiener filtering has an ideal effect on the processing of mixed noise. While filtering out the excess noise, the details of the image are preserved as much as possible. It makes the necessary preparation for the processing of the subsequent images.

4 Defuzzification processing of video frames

The power lines are in a complex background. Because of noise and mechanical vibration, the images taken by unmanned aerial vehicles are often deformed and blurred. The effect of the image is not good. The deblurring of images is the reverse process of image degradation. Through the approach, important details of original image are recovered as much as possible. It is also called image restoration. The key of image restoration is to establish a suitable image degradation model. According to the model, the corresponding algorithm is selected for recovery processing. The inspection speed and specific direction of the UAV in this paper are not known. The correlation between the image distortion and the original image in the image is also uncertain.

The image and video of the UAV inspection of transmission lines has a complex background. As a result of mechanical shock, the swing of the lens and other factors, the image at high altitude will be blurred. The Radon transform is used to estimate the direction and the fuzzy length of motion blur. Because the correlation between noise and power spectrum and the correlation between noise and original image is uncertain, the restoration algorithm of maximum pain deblurring based on probability density statistics is proposed. This algorithm requires less prior knowledge. Compared with the traditional Wiener filtering method, the original restoration effect is obvious. The sharpness of the image has been greatly improved. It is prepared for the extraction and tracking of the future transmission lines.

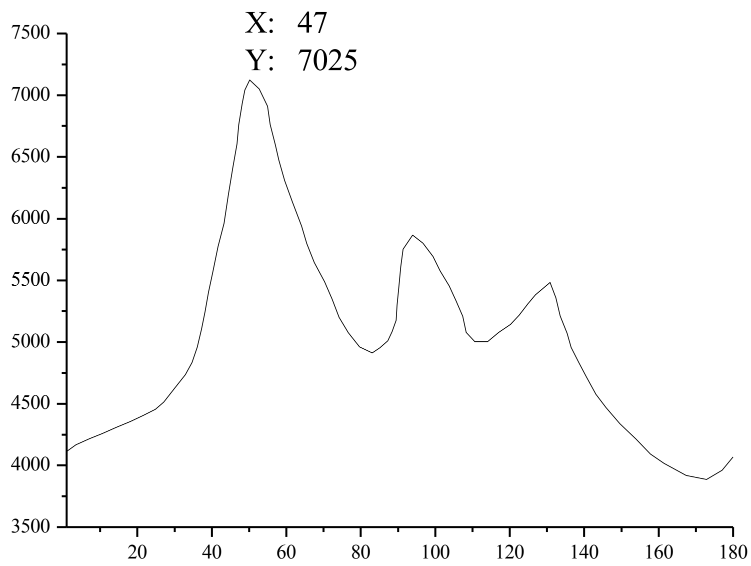

Fig. 13. Radon projection angles

5 Extraction, recognition and tracking of power lines under complex background

5.1 Image segmentation

Image segmentation is to divide the image into several non-overlapping and intersecting regions according to the established rules. In a picture, people often focus on a small number of features that are different from those of the surrounding image, such as texture, grayscale and color. The differences between these features are relatively small. The matrix of image segmentation is to extract the target according to these features. Image segmentation plays an important role in image recognition. Image segmentation has a great influence on the processing of later stage. In the process of image segmentation, the expression of the target and the extraction of features are expressed by the mathematical expression transformed from the original image. This processing method also provides convenience for further processing of subsequent images.

The traditional Canny algorithm by using the finite difference divide gradient amplitude area is in the neighborhood of 2*2. Therefore, the direction of the gradient operator is only 4, which makes the noise more sensitive to the false edge or leak detection. In order to reduce the degree of positioning accuracy and the degree of noise suppression, the 8 neighborhood algorithm of 3*3 is proposed. The gradient and gradient direction in the direction of x, y, 45°, and 135° are calculated.

When taking ∞, the point (i, j) is calculated as:

$$M(x,y) = \max\left(\left|f_x\right|,\left|f_y\right|,\left|f_{45^\circ}\right|,\left|f_{135^\circ}\right|\right) \tag{6}$$

$$\alpha(x,y) = \arctan\left(\frac{f_y}{f_x}\right) \tag{7}$$

This method takes into account the 45° and 135° of the pixel. Although the amount of computation is increased, the edge positioning accuracy is improved.

5.2 The implementation of the improved phase marshalling and Hough transform

The advantages and disadvantages of the improved phase marshalling method and Hough transform are analyzed. The phase grouping method is suitable for the extraction of low contrast linear primitives, but it is easily disturbed by noise, and most of the extracted line primitives are discontinuous. Although the Hought transform has a large amount of operation, its stability is very good. The two points vote Hought transform inherits the advantages of the stability of Hought. The amount of operation is small [7].

The specific steps are as follows:

The filtering and restoration of complex background images of aerial transmission lines: Wiener filtering algorithm is used for background filtering and linear enhancement. Complex background noise is filtered out. The complete target information is saved.

Gradient calculation: an improved Sobel operator is used to determine the gradient direction of the image.

Phase grouping and calculation of linear support areas: a group of edge points which are similar and adjacent to the phase information of the edge points are arranged. The area of this group is compared with the threshold value T. The value above T is stored in the corresponding accumulator.

Linear edge detection and global voting: first, the global accumulator A is initialized. Then, the corresponding marshalling area of the accumulator is transformed by two points of vote. The line parameters ρ and θ corresponding to the marshalling area are calculated, and the accumulator A is superimposed.

Find out the global peak: the local peak of the global accumulator A is carried out by unit storage detection. According to the data stored in this unit, the corresponding linear parameters are found.

The points corresponding to ρ and θ in the global parameter space are searched.

5.3 Automatic tracking of electric power lines

The basic idea of the tracking algorithm is as follows. According to the power line in the current image key frame, the key ton of the next frame in the image window is searched and predicted. It provides direction speed and other control information for UAV flight [8].

Due to the little change of position of UAV in adjacent key frames, only a small displacement can be considered as the object of study when it's flight control, that is, the region of interest. By setting the region of interest, the amount of information processing is reduced. It only needs to pay attention to the power line within the scope of the field of vision. The tracking is more real-time. There are few areas of interest in the area of interest in UAVs. The ROI method for road tracking in unmanned vehicles is mainly used for reference. Calman filter, particle filter, digital filter and so on are commonly used in the tracking algorithm. They have their own advantages and disadvantages in terms of smoothness, filtering speed and predictive performance. The speed of Calman filter is fast and the prediction ability is good. The performance of particle filter is good and the ability of prediction is good. The prediction ability of digital filtering is weak, but the smoothing ability is strong. It has nothing to do with the model. Based on Calman's principle, there are mainly Calman filters, extended Calman filters and lossless Calman filters. Because UKF is suitable for linear and nonlinear processing, and the speed is fast, it is widely used. Therefore, the method of lossless Calman filter is used to predict the RIO area of the power line recognition, and then the tracking of the power line of the key frame is completed [9].

Calman put forward the theory of Calman filtering. By fusing the state space of the signal and noise, the estimated value of the next meal is updated by using the estimation in the previous critical time and the current key estimation. The filtering algorithm can be used in many fields, such as signal communication, aviation navigation, social and economic and so on. The characteristics of Calman filter:

The iterative operation is used to obtain the minimum variance, and the efficiency is high. The object of processing is a random signal. The discrete difference algorithm has the advantages of small calculation and good real-time performance. It is not sensitive to the white noise and measurement noise in the system, which cannot be considered. In the time domain, it is still applicable to the estimation of multidimensional random processes. The state and accuracy of the estimation are given.

The lossless Calman filter is derived from the Calman filter. However, it is more widely used than the Calman filter. It is mainly applied to the image target tracking of nonlinear target and non-Gauss noise. Compared with the traditional nonlinear filtering algorithm, it has the advantages of high accuracy, good stability and sensitive reaction. It still follows the idea of Kalman filtering without doing complicated Jacobian matrix calculations similar to those in extended Kalman filters. The kernel of the algorithm is also a lossless transformation. The nonlinear problems of the mean and the covariance are dealt with through the systematic statistics of the random variables of the nonlinear transformation, and then the posterior probability density of the approximation state is obtained.

The Camshift algorithm is derived from the Mean-shift algorithm. Therefore, it is also called a continuous adaptive Mean-shift algorithm. According to the color information of the target object in the key frame of the video image, the object is tracked. The image key frames are converted from the RGB space to the HSV space. Then, based on the components in the HSV, the color probability model is determined. The key frame of the image is strong in outdoor light, while the RGB space is greatly influenced by light. The V component in the HSV space has nothing to do with the light. The effects of light can be ignored. The basic idea of the Camshift algorithm is as follows. The Mean-shift operation is performed on the critical image of the image. The initial next frame algorithm search window value is a frame window search and location [10].

The advantages of the Camshift algorithm are as follows. The accuracy and stability are good. Real time tracking can be implemented. The color model is established, and the target can still be tracked well and the efficiency is high. According to the distance of the target in the field of vision, the window is automatically adjusted to realize the semi-automatic. The Camshift algorithm can be easily decomposed into reverse projection, Mean-shift and Camshift operations. The concrete steps are as follows. The location of the region is searched. The size and location data of the window are initialized. The search window color is calculated. The distribution of the color probability is solved. Mean-shift is used to find the new location of the window and the size of the window. The result is initialized for the next frame.

6 Conclusion

The power line inspection of unmanned aerial vehicle (UAV) based on machine vision is studied. The image processing method of aerial power line is analyzed. The images taken by the patrol line have Gauss noise and mixed noise. The known image is added to Gauss noise and mixed noise. Then, mean filtering, median filtering and Wiener filtering are used for filtering preprocessing. The effect of the image processing was observed before and after the contrast. The image and video captured by the UAV transmission line has a complex background. Because of the factors such as mechanical shock and the swing of the lens, the images taken at high altitude are blurred. Using the Raddon transform, the direction and the fuzzy length of motion blur are estimated. The correlation between the power spectrum of the noise signal of the image and the original image is uncertain. Based on the probability density statistics, the restoration algorithm of maximum entropy defuzzification is proposed. According to the existing tracking techniques and algorithms, a tracking algorithm of Camshaft tracking based on UKF is proposed. The lossless Calman filter method is used to predict the area of interest in the transmission line recognition. Camshaft prediction algorithm is used to search for the window. The transmission line is tracked.

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8 Authors

Yao Yao is with the College of Physics and Telecommunication Engineering, ZhouKou Normal University, Zhoukou, Henan 466001, China (e-mail: yaoyao_zknu@126.com).

Qing-le Quan is with the School of Information and Electronic Engineerin, Henan University of Animal Husbandry and Economy, Zhengzhou, Henan 450044, China.

Hong-hui Zhang is with the College of Physics and Telecommunication Engineering, ZhouKou Normal University, Zhoukou, Henan 466001, China.

Qiong Li is with Zhoukou Academy of Agricultural Sciences, Zhoukou, Henan 466001, China.

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