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Intelligent Image Recognition Research on Status of Power Transmission Lines

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Abstract: For the requirements of smart grid construction to remote monitoring on transmission lines status, find an intelligent identification method based on digital image processing and artificial neural networks identification: using gray scale transformation, histogram modification, compressed sensing de-noising, edge detection algorithm and other methods all together to deal with remote images of transmission lines, and make the characteristics more outstanding. Breaking up the images into some regions, and extracting the distribution of edge features of transmission line components as characteristic values, can extract characteristics, and this method have good adaptability. At last, construct a three-layer BP artificial neural network to training and recognizing on typical transmission line status. The results of status recognition aiming at insulator strings and transmission lines show that, this method has good recognition effect and important promotional value.

Keywords: Power transmission line, Status recognition, Digital image processing, Compressed sensing, Artificial neural networks.

1. Introduction

With the advance of smart grid lines link building process, various types of transmission line condition monitoring technique, such as wire breeze vibration, icing, dancing, weather, wire temperature image/video monitoring, have been more and more widely applied. The remote monitoring technology of line image/video has its intuitive, comprehensive monitoring features, the running and monitoring maintenance units consider that it is one of the most effective ways. By application of this technology, the line special areas can not only be monitored effectively and directly such as the external damage-prone areas, the remote and difficult to reach areas, the line defect-prone areas, but it can play a supporting observation role for most lines running phenomena such as icing, dancing, tower tilt etc. [1-4].

In the field application line image/video surveillance system, it is subject to the wild-powered environment, which works often take the interval to send pictures/video mode and to maximize power savings. Once the scene occurs abnormal circumstances, such as more limited cranes, tower material stolen, line dancing, etc., it is difficult to be identified. Even using a special tool, a lot of money is invested heavily on-site power to achieve uninterrupted operation of the device around the clock, line supervisors site staff can not stare at the screen in 24 hours a day, and can not observe the situation at any time [5-7]. And with the gradual

increase in one area line video equipment, video equipment is returned for each video or pictures it can only turn to switch on the display, it is difficult to control the situation timely and comprehensively. Through artificial observation, judgment image/video method, the running needs of the actual production can be not meet, and image/video system is required to automatically analyze and the abnormal situation is judged, and the sound and light alarm gives is given in SMS and other appropriate manner, operating personnel is alerted to take timely measures, and major accidents are avoided. There are some recent research results of image processing and discriminant analysis for a specific abnormality of some particular line device (such as insulator cracks, icing, etc.), feature extraction methods can not be applied to other state occasions, it is still difficult to promote.

Based on the above analysis, in this article, digital image processing techniques will be applied to extract the transmission line status feature, they are combined with the BP neural network to achieve the intelligent identification on line status, and it has achieved good results.

2. Get Image Information of Transmission Line

In the transmission line remote monitoring, equipment to obtain image information is mainly spherical HD camera, as is shown in Fig. 1. By the wireless public network mode, image is accessed from the field of transmission lines, as shown in Fig. 2, high-speed ball is mounted on a tower, the control bus commands is sent to wireless image/video server, according to the provisions of the orientation, the site information is sent to the image/video server by the original image collection. After compressed coding, the image information is sent into the public network backend server through CDMA/GPRS/3G public network, and through the internal and external network isolation device, image is ferried to the power network image database server. The remote image capture on the line may also take WiFi wireless [8] and fiber communication, as is shown in Fig. 2, the image is accessed to the secure access platform in electricity network [9, 10].

Remote video danger point surveillance is Fig. 3. At present, China transmission line condition monitoring systems at all levels are enabled and established gradually, live images can be released through a unified platform, these greatly enhances the ability of remote access in field wiring running, the safe operation of the line is ensured. However, there are the large number of field image measuring points, they are accessed to monitoring system at levels, even showing a rapid cycle also requires quite a long time, it can not make timely identification and response to many unusual events or device problems, therefore, we need to make monitoring image analysis and processing and feature extraction, and completion status of automatic identification becomes further to enhance the operating safety and security of transmission for the line, and to improve production management capabilities is an urgent need [11].

Fig. 1. Transmission lines danger point remote video monitoring system HD camera.

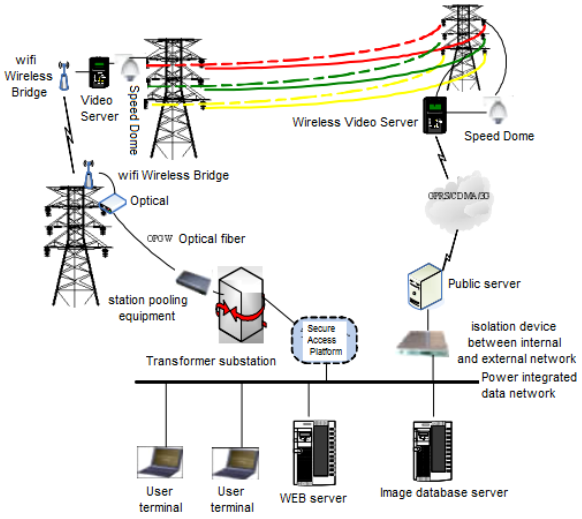

Fig. 2. Get image information of transmission line.

Fig. 3. Remote video danger point surveillance.

3. Processing the Monitoring Image

Because transmission lines are often complex in the harsh natural environment, there are the performance factors of the camera itself, and noise which is introduced in the acquisition, these impact on the characteristics extraction of the body line, it must be pretreated to enhance the contrast of the image, to reduce noise and to enhance image features. As is shown in Fig. 4, the following image of insulator string is processed to illustrate the flow of image processing, which is used in the study.

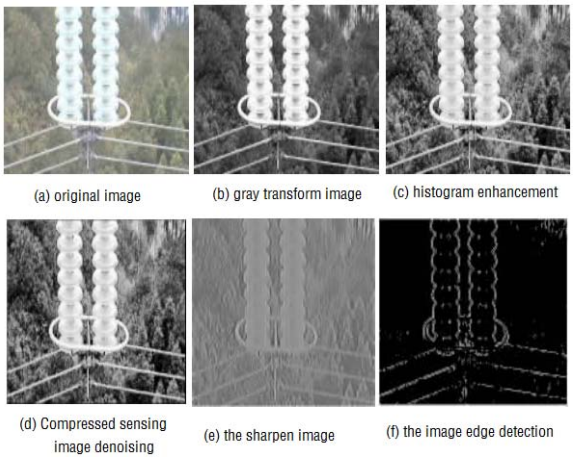

Fig. 4. Insulator string image processing.

1) Gray-scale transformation.

In gray-scale transformation, color images, which are captured by camera, and are converted to grayscale images, image display is improved, image dynamic range is expand, and the image contrast is enhanced, the image is made clearer, there is more obvious characteristics, treatment results are shown in Fig. 4 (b).

2) Histogram Correction.

By adjustment on the image histogram, the entire range of gray gradation is mapped to [0255], the image contrast is enhanced, correction results are shown in Fig. 4 (c).

3) Compressed sensing denoising.

When the signal and noise are unknown, the problem boils down to find the sparse solution with constrained quadratic programming (BSQP) problem.

$$\min \ \frac{1}{2}\| Ax-y \|_2^2 +\lambda \| x \|_1 , \qquad (1)$$

The restoration of noisy signals (1) is generalized [12]:

$$\begin{aligned} &\min_{x\in R^n} \quad \phi(x)=f(x)+\lambda c(x) \\ &f:R^n \to R, c:R^n \to R \end{aligned} \qquad (2)$$

where $f(x)=\frac{1}{2}\| Ax-y \|_2^2, c(x)=\| x \|_1$.

Solution (2) is converted to the iterative (3), $\{x^t, t=0,1,2,\cdots\}, \alpha_t > 0, \nabla f$ is gradient.

$$\begin{aligned} x^{t+1} \in \arg\min_z \quad & \frac{1}{2}\| z-u^t \|_2^2 +\frac{\lambda}{\alpha_t} c(z), u^t \\ & = x^t - \frac{1}{\alpha_t}\nabla f(x^t) \end{aligned} \qquad (3)$$

If $c(x)=\sum_{i=1}^{n} c_i(x_i)$ is separable, then (3) optimization into:

$$\begin{aligned} x_i^{t+1} \in \arg\min_z \quad & \frac{1}{2}(z-u_i^t)^2 +\frac{\lambda}{\alpha_t} c_i(z) \\ & ,i=1,2,\cdots,n \end{aligned} \qquad (4)$$

$$\begin{aligned} \arg\min_z \quad & \frac{1}{2}(z-u_i^t)^2 +\frac{\lambda}{\alpha_t} c_i(z) \\ & = soft(u_i^t, \frac{\lambda}{\alpha_t}) \end{aligned} \qquad (5)$$

Which soft threshold shrink operations are:

$$soft(u,a)=sign(u)\max\{|u|-a,0\} \qquad (6)$$

Denoising results are shown in Fig. 4(d).

4) Image sharpening.

The purpose of the transmission line image sharpening is to highlight the edges of the image information, to strengthen the image outline feature, and to facilitate the feature extraction and recognition. Laplacian method is applied to the blur image, which is caused because the light is diffuse, the treatment result is shown in Fig. 4(e).

5) Edge Detection.

Prewitt is applied to the image of edge detection transmission lines, it lays the foundation for a feature extraction. The treatment result is shown in Fig. 4(f).

Prewitt operator is a first-order differential operator, and it is used to edge detection, the pixels up and down, left and right neighbor point gray scale difference is used, reaching extreme points are the edge detection pints at the edge, part of the pseudo-edge is removed, there is a smoothing effect to noise. The principle is to use the both direction templates in the image space, the image is convoluted with neighborhood to complete edge detection. In these two direction templates, horizontal edge is detected, another is vertical edge detection (Fig. 5).

Definition of a digital image f (x, y), Prewitt operator as follows:

$$\begin{aligned} G(i) &= |[f(i-1,j-1)+f(i-1,j)+ \\ &\quad f(i-1\neg j+1)]-[f(i+1,j-1)+ \\ &\quad f(i+1\neg j)+f(i+1\neg j+1)]| \\ G(j) &= |[f(i-1,j+1)+f(i,j+1)+ \\ &\quad f(i+1\neg j+1)]-[f(i-1,j-1)+ \\ &\quad f(i,j-1)+f(i+1\neg j-1)]| \end{aligned} \quad (7)$$

Then P(i,j)=max [G(i),G(j)] or P(i,j)=G(i)+G(j).

Classic Prewitt operator is that: where the new grayscale value is greater than or equal to the pixel threshold, they are edge points. This selects the appropriate threshold value T, if P (i, j) ≥ T, then the (i, j) is an edge point, P (i, j) is an edge image [13, 14].

1	1	1	-1	0	1
0	0	0	-1	0	1
-1	-1	-1	-1	0	1

Fig. 5. Prewitt operator.

4. Feature Extraction

In the image conventional feature amount extraction of power line, the state features are only extracted for the image particular measuring point, which leads to that the feature amount extraction method is not promoted.

For example, the insulator strings feature extraction methods can not be used for wire feature extraction, even the mounting position and viewing angle are different, the insulator strings feature extraction method in the specific measurement points is difficult to apply to the images of other insulator strings. If the more common feature extraction method can not be found, the method is more difficult to promote and to replace the manual observation discrimination.

After taking into account the state change of the measuring point, the distribution of the image will be different, therefore, on the basis of the edge extraction, the image is divided into n rows × n columns (n> = 2), the percentage distribution of the edge feature pixels were calculated, thereby a dimension vector is obtained with n^2 elements, and it is used as a feature amount. The method is simple, and it is able to adapt to various situations, and normalization is easy, it is conducive to artificial neural network convergence. This article takes the example n = 6.

5. Intelligent Recognition Based on Artificial Neural Network

Artificial Neural Network (ANN) [15-19] is a nonlinear system, it consists of a number of neurons which are interconnected in different ways, the certain fundamental characteristics of the human brain or natural neural network are abstracted and simulated, there are capabilities with high degree of parallelism and high-speed information processing. This nonlinear mapping and learning ability is well suited for image pattern recognition.

BP (Back-Propagation) network model is relatively mature, there are the most widely applications in artificial neural network models. A typical three-layer BP network has the ability to implement any complex nonlinear mapping, it is network with self-learning capability and good generalization, and it s suitable for promotion in the actual production applications. Therefore, we choose three-layer BP network in pattern recognition of power transmission line image. We take into account the basic BP network learning slowly, it is easy to fall into local minimum, and there is a not convergence weakness, by the study, a modified adaptive learning rate is adopted, and BP network is improved. Three-bp neural network structure is shown in Fig. 6.

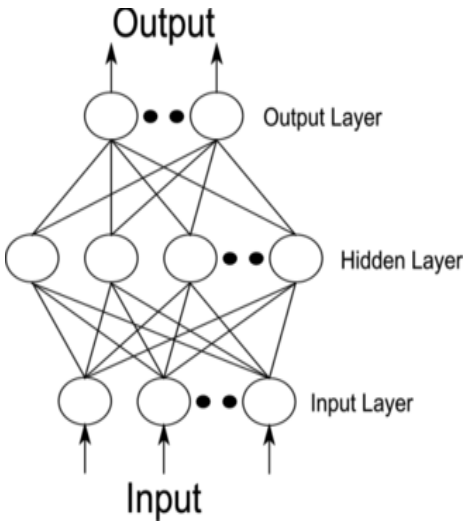

Fig. 6. Three-bp neural network structure.

Network input neurons is 36, it is consistent with the feature quantity extraction program, the test select number of neurons in the hidden layer is 12, the number of neurons of the output layer is 2, a desired three-state output is respectively [1 1], [1 0] and [0 1], the convergence error is 10^{-4}. The insulator string image of three states are select in normal, fog, snow days, there are 3 groups on each image, and then image is processed and feature is extracted, there are the input 3-layer BP network to train. The insulator string image of another three states is selected simultaneously, feature is extracted by two groups of each image, and the states are recognized by neuronal networks. Based on the characteristics of BP network clustering, the output value of output layer neurons is seen as1 when the output is greater than 0.75, when the neuron output value is less than

0.25, it is considered as 0, the actual network output is shown in Table 1.

As can be seen from the recognition result, the output of neuron networks reflect the characteristics of the insulator string under different conditions, the correct recognition results have been received in the images of six groups insulator strings, the recognition rate is 100 %.

To verify the generalization of this method, we take wire images in normal, fog, snow three states, there are 3 groups in each wire image, the image is processed and feature is extracted, 3-layer BP network is input and is trained, while the 2 groups of each wire image are taken to feature extraction in the other three states, and the neuronal networks are recognized by the states, network actual output results are shown in Table 2.

Similarly, the output of the neural network reflects the wire characteristics under different conditions, the correct recognition results have been received in the 6 groups of wire image, the recognition rate is 100 %.

This method is used in the image state recognition of other transmission line devices, good results are obtained in the same, there is important application value.

Table 1. Recognition results of insulator string image status.

Sample Name	Neuron network theory output		Neuron network actual output	
Normal-1	1	1	1.0648	1.6669
Normal-2	1	1	0.9646	0.8819
Fog-1	1	0	1.0472	0.2084
Fog-2	1	0	1.4365	0.1808
Snow-1	0	1	0.0017	1.0030
Snow-2	0	1	0.0007	1.0006

Table 2. Wire image state recognition results.

Sample Name	Neuron network theory output		Neuron network actual output	
Normal-1	1	1	0.9997	1.0002
Normal-2	1	1	1.1310	1.3050
Fog-1	1	0	1.0000	0.0006
Fog-2	1	0	0.8372	0.1900
Snow-1	0	1	0.0000	0.9997
Snow-2	0	1	0.1250	1.1976

6. Conclusions and Outlook

For less than the current power line remote video monitoring system, based on digital image processing, compressed sensing, and artificial neural network technology, this paper presents the state recognition method of the transmission line image, it is able to identify typical line state, the early warning basis is provided for line running, and there is good generalization, the capacity of the transmission line security monitoring is improved, and the level of operation and maintenance is improved.

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