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Edge Detection Algorithm Based on Wavelet De-nosing Applied tothe X-ray Image Enhancement of the Electric Equipment

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Abstract**—**The X-ray technology has been used in non-destructive evaluation in the Power System, in which a visual non-destructive inspection method for the electrical equipment is provided. However, lots of noise is existed in the images that are got from the X-ray digital images equipment. Therefore, the auto defect detection which based on these images will be very difficult to proceed. A theory on X-ray image de-noising algorithm based on wavelet transform is proposed in this paper. Then the edge detection algorithm is used so that the defect can be pushed out. The result of experiment shows that the method which utilized by this paper is very useful for de-noising on the X-ray images.

Keywords**—**de-noising, edge detection, wavelet transform, X-ray

I. Introduction

VARIETY of detection and diagnostic methods has been utilized in Power System, which ensures that the reliability of transmission and distribution equipment, such as Gas Insulate Switchgear (GIS). Detection and diagnosis of X-ray digital imaging technology can be achieved without removing the device or damaging the equipment operating environment, or even in the case of testing the GIS and other power transmission equipment in live, which achieves thepurposes of visualize diagnostic.The use of real-time X-ray imaging system according to the electrical equipment, a series ofimages can be achieved in a variety of capture conditions. In order to make the defects in X-ray images that can automatic analysis, automatic identification, the digital image processing theorywill be used from the picture of image enhancement [1], [2]. As the conditions of X-ray equipment and the site, the X-ray images are captured by the X-ray equipment, which often has lots of digital noise. Although the image discussed by this paper overlaymultiple shots, so that a lot of random noise can be filter out, but there still has a certain degree of random noise in the image. Edge detectionin image processing is an effective way to detect defect inside the equipment. Therefore, anedge detection algorithm based on wavelet de-noising applied to the image enhancement of electrical equipment is proposed in this paper.

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II. The Wavelet Transform

With the development of wavelet method, wavelet transformexpand its field fromthe initial application of pure mathematics to images processing, signal analysis, quantum theory, the computer aided classification and identification. Compared with the Fourier transform, the wavelet transform has better localization propertiesin time domain and frequency domain, and because of the high frequency components using gradually narrow time or frequency domain sampling step, which can be focused to any details in target object. Thus the wavelet transform has known as mathematical microscope.

Let $\psi(t) \in L2(R)$, corresponding Fourier transform $\varphi(\omega)$ satisfy the following conditions.

$$C_{\psi} = \int_{-\infty}^{+\infty} \frac{|\varphi(\omega)|}{\omega} d\omega < \infty \qquad (1)$$

Then, $\psi(t)$is called basic wavelet or mother wavelet, make ψ (t) do stretching transformation and translation transformations to get Eq. as follow.

$$\psi_{a,b}(t) = \frac{1}{\sqrt{|a|}} \psi\left(\frac{t-b}{a}\right) \quad a, b \in R \text{ and } a \neq 0 \qquad (2)$$

The Eq. (2) known as a wavelet series, a is a flexible factor, b is translation factor.

The discrete form is utilized in the parameters a, b in Eq. (2).

$$a = {a_0}^m, b = nb_0{a_0}^m m, n \in Z \quad (3)$$

Then discrete wavelet is got.

$$\psi_{m,n}(x) = |a_0|^{-m/2}\psi({a_0}^{-m}x - nb_0) m, n \in Z \quad (4)$$

The Eq. (4) is known as a one-dimensional discrete wavelet, extension it to two-dimensional case. Let ψ (x)the corresponding wavelet, then get the following three two-dimensional continuous wavelet Eq.:

$$\overset{1}{\psi}(x, y) = \phi(x)\psi(y) \quad (5)$$

$$\overset{2}{\psi}(x, y) = \psi(x)\phi(y) \quad (6)$$

$$\overset{3}{\psi}(x, y) = \psi(x)\psi(y) \quad (7)$$

Thus two-dimensional wavelet function setis obtained as the Eq. (8).

$$\left\{ \overset{1}{\psi}_{j,m,n}(x) \right\} = \left\{ 2^j \psi\left(x - 2^j m, y - 2^j n\right) \right\} \ j \geq 0, l = 1,2,3 \quad (8)$$

Assuming the signal function f(x,y)∈L2(R2),based on the Eq. (8)canget two-dimensional discrete wavelet transform below.

$$DWT(j, k_1, k_2) = 2^j \sum_{l_2} \sum_{l_1} f(l_1, l_2)\, \psi(2^j l_1 - k_1, 2^j l_2 - k_2) \quad (9)$$

Corresponding reconstruction Eq.that is two-dimensional inverse wavelet transform is.

$$f(x, y) = < f(x, y), \phi_{j,k_1,k_2} > \widetilde{\phi}_{j,k_1,k_2} = < f(x, y), \widetilde{\phi}_{j,k_1,k_2} > \phi_{j,k_1,k_2} \quad (10)$$

Where j indicates the wavelet scale, k_1, $k_2$is the horizontal direction and vertical direction of the shift amount in the function, respectively.

III. Wavelet De-noising and Image Enhancement

Image noise model generally is as follows.

$$s(i) = f(i) + \sigma \cdot e(i) i = 0,1,2, \ldots, n - 1 \quad (11)$$

In Eq. (11), $s(i)$ is the noisy image, $f(i)$ is the desired image, σ is the noise variance, $e(i)$ is the image noise. The image de-noising is restored the original image from the noisy image $s(i)$ and to maintain the $f(i)$ characteristics.

The basic idea of image de-noising based on wavelet transform shown in Fig. 1.

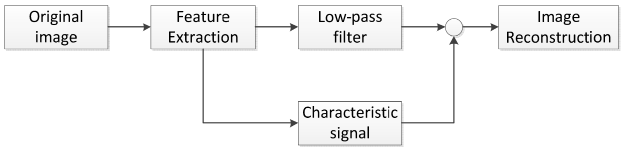


Fig. 1 Block diagram of wavelet de-noising

Aftera pre-treatment,the original image with noise pass in the wavelet converter will decomposed the image to a variety of scales,remove the wavelet coefficients which belongs to noise in each scale, preserve and enhance the wavelet coefficients of image itself, then restore the image by inverse wavelet transform.In this paper,wavelet de-noising will be decomposedinto two scales, wavelet decomposition shown in Fig. 2.

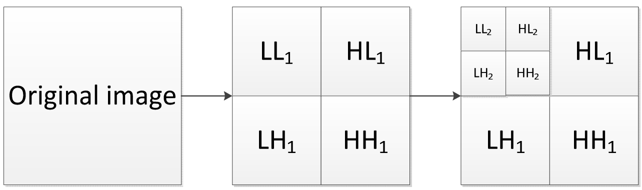


Fig. 2 wavelet decomposition

As Fig. 2 shows above, L for low frequency, H for high frequency, and the subscripts 1 and 2, respectively, for one or two scales. After decomposition of transformation, image low-frequency component LL retains the original image overview information, and the rest of the high frequency components LH, HL, HH contain the edge, contour and other details of the image.After the two wavelet decomposition, the high-frequency components ofimage need to filter the noise by threshold. Threshold selection is directly related to the quality of image de-noising effect. A correct, good threshold can both retain more image information, and reduce the high frequency noise. This paper comparing several existing theories[1]-[3], consider the advantages and disadvantages of each threshold theory and the feature of X-ray radiographic image, using the local threshold technique and combine the hard-threshold function and soft threshold functionto filter the noise in X-ray radiographic images.

Use Eq.(12) to express hard threshold function is as follow.

$$W' = \begin{cases} W & |W| \geq \delta \\ 0 & |W| \leq \delta \end{cases} \quad (12)$$

Use Eq.(13) to express soft threshold function.

$$W' = \begin{cases} sign(W)(|W| - \delta) & |W| \geq \delta \\ 0 & |W| \leq \delta \end{cases} \quad (13)$$

IV. Edge Detection Algorithm Based on Wavelet De-nosing Applied to TheX-ray ImageEnhancement of theElectric Equipment

In the process of field test and collection, taking into account of site conditionsand restrictions on the X-ray imaging equipment,the image will always contain a variety of noise. If these imageshave been analyzed directly, it will difficult to the analysis, which is caused by noise. Edge detection algorithm based on wavelet de-nosing applied to the X-ray image enhancement of the electric equipment isproposed in this paper to reduce noise and highlight the defect, make theX-ray image enhancement.In this paper, the edge detection algorithm based on wavelet de-noising flow chart is shown below.

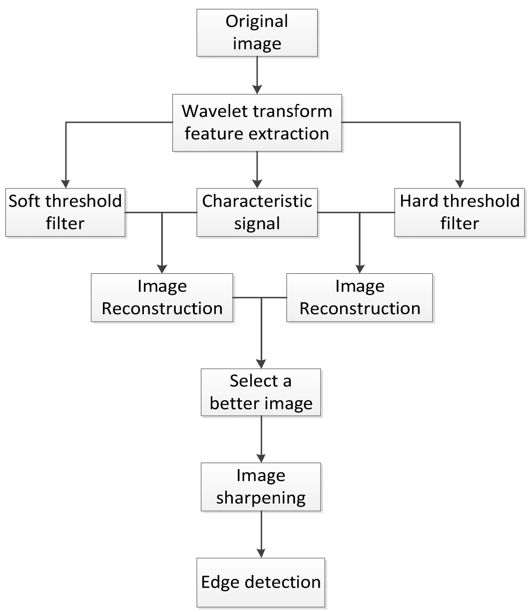


Fig. 3 The flow chart of edge detection based on wavelet de-noising

A. X-ray Digital Imaging

In this paper, the X-ray images arethe conductive rodin GIS tank not fully closing conditions.

The conductive rod in GIS tank closing conditions shown in Fig. 4.

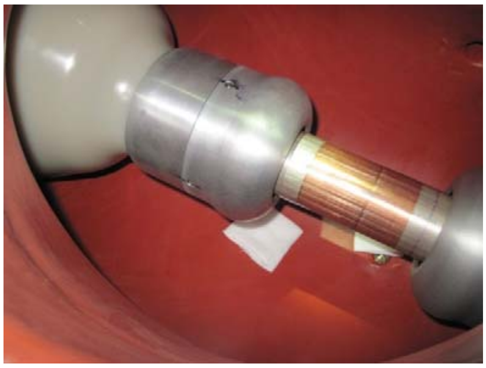


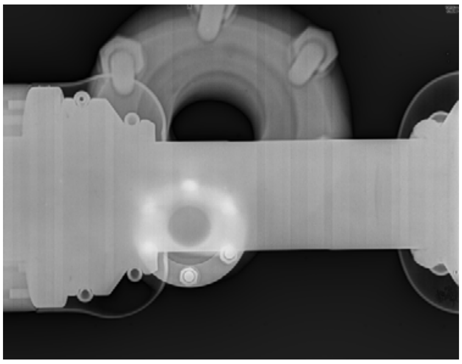
Fig. 3 The conductive rod in GIS tank

In Fig. 4, the middle of the conductive rod is moving contact, the left is the static contact, and the condition in this paper is the moving contactis not completely closed with static contact.

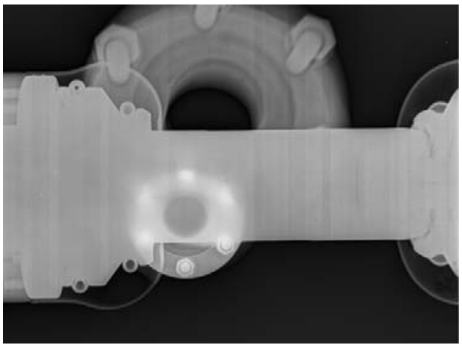
The layout ofX-ray machine and theimaging plate in site shown in Fig. 5.

Fig. 5 X-ray machine and the imaging plate

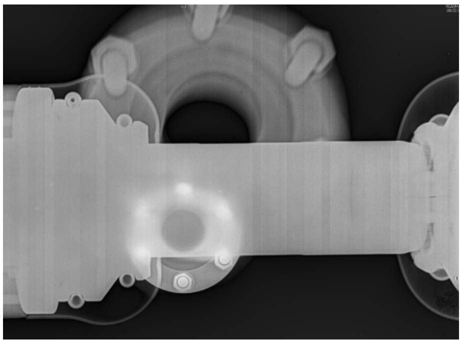
Adjust the emission parameters of X-ray machine and the receive parameters of imaging plate, obtained as follows three original X-ray digital image:



(a) Completely closing



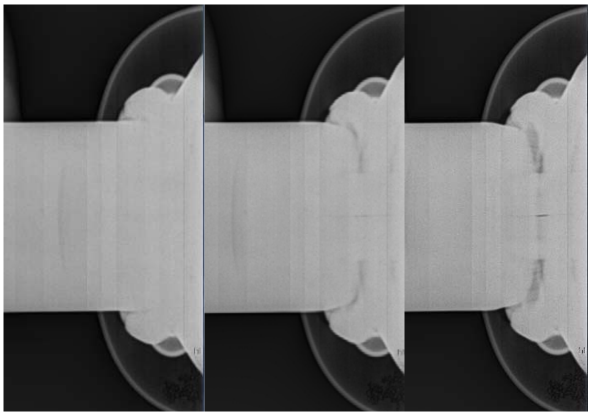
(b) Not fully closing position-1



(c) Not fully closing position-2

Fig. 6 Original X-ray digital image

In Fig. 6, as shown it is very clear that the moving contact is completely closing with the static contact in Fig. 6 (a). But in (b) and (c) of theFig. 6, it is not fully closing. The location of not fully closing condition is highlighted with the red rectangles.And it is obviously that in position-2, the gap between moving contact and static contact is two times larger than position-1.Depending on the requirements of testing location, pickthe local closing position as a detection position, enlargement as follows:



(a) Completely closing(b) position-1(c) position-2

Fig.7 local closing position

B. The Algorithm of Wavelet De-nosing

As Fig. 3 shows, use the following steps to process the image inFig. 6, the effect shown in Fig. 8.

(1) Select the appropriate wavelet function[6], such asHaar, Daubechies, sym, Biorthogonal and so on, consider the result oftest this paper determine to select sym8 wavelet function;

(2) Using Eq. (9) as the basic Eq. and sym8 as wavelet function to make the 2-layer wavelet decomposition of the original imageand get a group of wavelet coefficients;

(3) Selecting the threshold according to the image, combing with the Eq. (12) and Eq. (13) and utilizingcorresponding soft or hard threshold to set the step (2) to set the wavelet coefficients which is less than the threshold to absolute zero,then obtain new wavelet coefficients;

(4) Using the Eq. (10) and Step (3) reconstruction the wavelet coefficients to get the image;

(5) Select the best imagefrom step (4);

(6) Sharpeningthe selected imagein step (5).

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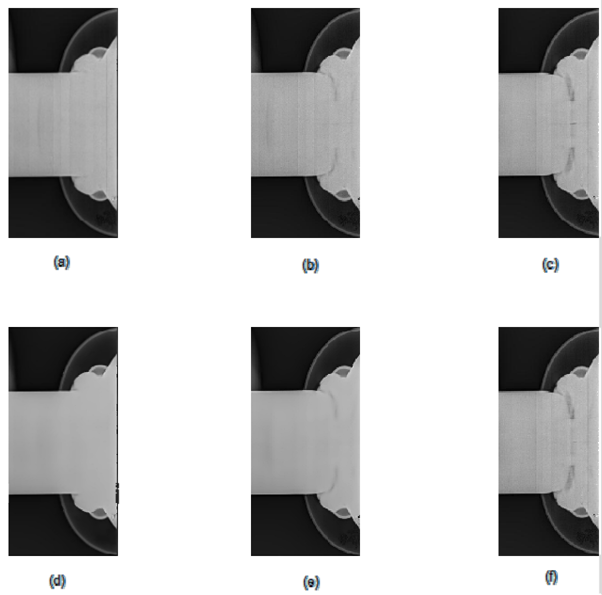

Fig. 8 the comparison chart with wavelet de-noising and sharpening

As Fig. 8 shown,whereFig..8 (a) is completely closing, Fig..8 (b) isnot completely closing position-1, and Fig..8 (c) isnot completely closing position-2. And Fig..8 (a), (b), (c) isthe images before de-noising, Fig..8 (d), (e), (f), respectively corresponding image which areafter the wavelet de-noise. It is obvious that thenoise ofimage after wavelet de-noising which are stripes caused due to the structural problems of imaging plate and random noise have been reduced, the effect of wavelet de-noising is very clear. The following edge detection is used to highlight the defectof GIS in the image before or after the wavelet de-noising.

C. Edge Detection

Edge detection is to construct an edge detection operator by the neighborhood of original image pixels[1]-[2],[4]-[5]. Commonly used edge detection operatorare Roberts operator, Sobel operator, Prewitt operator, Kirsch operator, Laplacian operator, LOG operator, Canny operator, Zero-cross operator and so on.

In this paper, the six operators that exclude the Kirsch operator and Laplacian operator is respectively utilized, before and after wavelet de-noising in images for edge recognition. Using the six operators to recognize the edge ofimagethat are the three conditions before and after wavelet filter shown as Fig. 9 ~ Fig. 11.

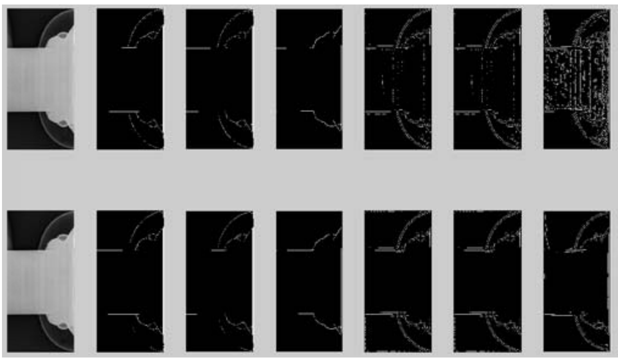

Fig. 9 the edge detection based on before and after wavelet de-noising of completely closing conditions

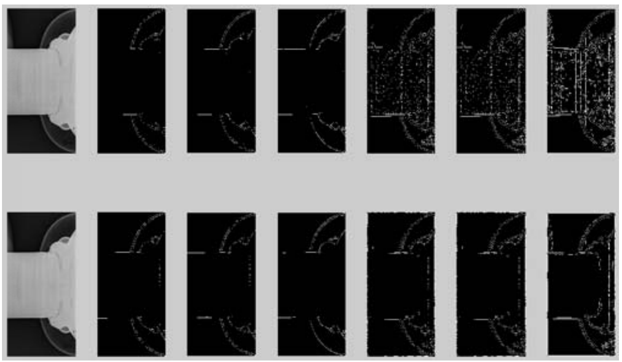

Fig. 10 the edge detection based on before and after wavelet de-noising of not fully closing position1

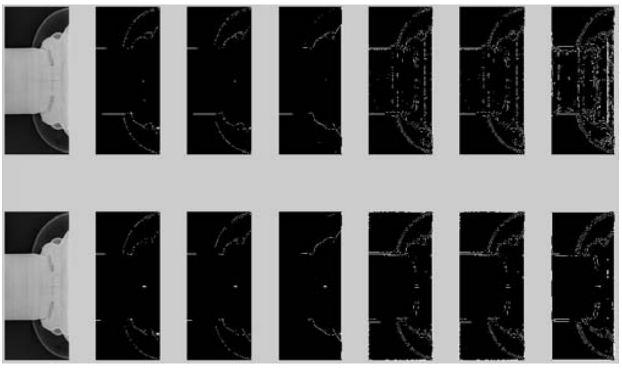

Fig. 11 the edge detection based on before and after wavelet de-noising of not fully closing position2

As shown in Fig. 9 ~ Fig. 11, itisrespectivelythe result of edge detection with different edge detection operator on before and after wavelet de-noising of three kinds of conditions: completely closing, not completely closing position 1, and not completely closing position 2. Each upper half of the image is notprocessed with wavelet de-nosing, the lower half of image is processed with wavelet de-nosing, the image from left to right are original image and the use of Prewitt operator, Sobel operator, Roberts operator, Log operator, Zero-cross operator , Canny operator to detect edge.

D. Experimental Results and Analysis

By observing the images before and after wavelet de-noising in Fig.8, it is easy to see that the original image contains random noise, and some strips noise caused by imaging plate.After wavelet de-noising through the random noise has been significantly reduced, the image becomes fine a lot.

From Fig. 9, Fig. 10 and Fig. 11 can be clearly seen, respectively, the edge detection of the original image and wavelet de-noised image, the resulting image hasa more clear difference. The recognition results before de-noisingis much rough, the relative effect of the de-noised imageis much better. Due to the gap is smallbetween static contact the moving contact in the conditions of not fully closing condition, there is less contrast between foreground and background, it is why the edge detection by these types of more sensitive detection operator such as Log operator, Zero-cross operator, Canny operator can detect this defect which the rod is not entirely closing. Contrast the last three images inFig. 9, Fig. 10 andFig. 11 can find that before the wavelet de-noising there has a lot of noise to interference with the image edge detection, and the image after wavelet de-noising by these types of edge detection operator can clearly see the cracks which the rod is not completely closing.

From the results above, the conclusion can be get that wavelet de-noising algorithm can reduce the noise of the X-ray image of electrical equipment and enhance the detail of X-ray image. And there has less noise in the result of the edge detection by different types of the operators, and the defects in the X-ray image of the equipment make clearly, thus the image enhancement.

V. Conclusion

The noise of the X-ray radiographic images is reduced based on the wavelet which effectively makes the random noise reduce in the result of edge detection, the certain edge detection algorithm is utilized to highlight the defects of the electrical equipment, and the image is also enhanced effectively. Therefore, edge detection algorithm based on wavelet de-nosing for X-ray radiographic image of the GIS equipment is proposed. In this paper, this algorithm has a strong recognition and feasible.

References

[1]. Rafael C. Gonzalez, Richard E. Woods. Digital Image Processing (3rd Edition) [M]. Electronic Industry Press, 2003

[2]. He Liu. Digital image processing and application[M] . Beijing: China electric power press, 2005.

[3]. D L Donoho. De-nosing by soft-thresholding[J] . IEEE Transact ionson Information Theory, 1995, 41(3) : 613- 627.

[4]. Canny John. A Computational Approach to Edge Detection.IEEE Transactions on Pattern Analysis and MachineIntelligence, Vol, PAMI-8,No.6,1986,pp.679-698.

[5]. YANG Xian-Hua, LI Yue-Hua.Study on Edge Detection Algorithm in Image Processing, Development & Innovation of Machinery & Electrical Products, 2(23), 2010 .3

[6]. ZHANG Xiang-fen, XIAO Shu-jun, YE Hong.Study on Choosing Parameters in Denoising Magnetic Resonance Images Based on Wavelet, Ludong University Journal(Natural Science Edition), 2010, 26(4) : 318-321