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# An effective Filter Algorithm Approach to Steel Strip Surface Image

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***Abstract*—Due to the complexity of surface texture, the images obtained from the existing online detection system cannot show the strip surface defects exactly, which becomes one of the important problems to be solved for the detection of surface defects of cold-rolled strip. An innovative wavelet-based image filtering algorithm by virtue of anisotropic diffusion is therefore proposed. It decomposes the original image into the low and high-frequency components by wavelet transform, then the high-frequency components are regularized by wavelet diffusion coefficients and, finally, the filtered image is reconstructed by inverse wavelet transform. To achieve a satisfactory filtering result, the wavelet-based anisotropic diffusion is often performed iteratively. Experimental results indicated that this new algorithm could not only filter off the unnecessary texture background unnecessary texture background but also preserve the valuable information in detail effectively. With more favorable combinability in filtering, this algorithm will lay a solid foundation for the subsequent image processing, e.g. image edge detection, image auto-segment, etc.**

***Index Terms*—anisotropic diffusion, defect detection, image filtering, image processing, wavelet transform**

## I. INTRODUCTION

The application of steel strip surface defects online detection system can provide high reliability for defects detecting and quality improving of cold-rolled strip products. However, one of the critical problems in the detection system is that image defects cannot be detected correctly due to complexity of the background texture, which seriously affects the following edge extraction, image segmentation and other processing. Therefore, before the image sequential processing, it is essential to filter the images with unnecessary background texture so as to improve the image quality, get clear edge information and improve the detection precision.

There are plenty of image processing methods such as Gaussian filtering, Median filtering [1] etc. The main principle is to filter out the high frequency components of the image. The edge of the image tends to be blurred when the noise is filtered because some edge information of the image is also distributed in the high frequency zone. In recent years, the filtering algorithm using anisotropic diffusion based on partial differential equations causes great attention [2-5]. This new method describes the filtering process with a diffusion equation that varies with time. By adjusting the diffusion coefficient, the contradiction between blurred edge and noise filtering is resolved. However, it is not accurate enough to separate high and low frequency components.

For solving the problem, this paper introduces two-dimensional wavelet and proposes an innovative filtering algorithm, that is, wavelet-based image filtering algorithm by virtue of anisotropic diffusion. Wavelet transform is partial transform of space (time) and frequency so that it can accurately separate the high and low frequency components [6-9] of the signals, which can make up for the deficiency of nonlinear anisotropic diffusion. The algorithm mechanism proposed in this paper includes three steps, wavelet decomposition, anisotropic diffusion coefficient regularization and wavelet reconstruction. The experiment results show that by using this new algorithm proposed image noises and background texture can be filtered effectively, meanwhile, the image edge information can be preserved well.

The remainder of this paper is organized as follows. Section 2 introduces the analysis of nonlinear anisotropic diffusion image filtering algorithm. Section 3 presents the proposed steel strip surface defective image filter algorithm which integrates nonlinear diffusion and wavelet transformation techniques. Experiments results are shown in Section 4, and conclusions are given in Section 5.

## II. ANALYSIS OF NONLINEAR ANISOTROPIC DIFFUSION IMAGE FILTERING

The nonlinear anisotropic diffusion filtering based on partial differential equation (PDE) model was first put forward by Perona and Malik together [2]. The nonlinear anisotropic diffusion of Perona-Malik equation is expressed as follows:

$$\frac{\partial}{\partial t} f_t(x,y) = div\left(C_t\left(x,y\right)\cdot\nabla f_t(x,y)\right) \quad (1)$$

where, ft(x, y) is the gray value of image pixel at time (scale) t, div is the divergence operator, $\nabla$ is the gradient operator, t is iteration step in the program, Ct(x, y) is the diffusion coefficient, which is a nonnegative monotone decline function about the image gradient |$\nabla$ ft(x, y)|. To avoid the edge-smearing during the diffusion, the coefficient Ct should be constructed to encourage homogenous-region smoothing and to inhibit the smoothing across the boundaries.

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The different diffusion coefficients [2, 4, 10] were proposed by a lot of scholars. Taking the efficiency and stability of the algorithm into consideration, the diffusion coefficient c used in this paper is as follows:

$$C(s) = \frac{1}{1 + k \cdot s^2} \tag{2}$$

where, k is an edge magnitude threshold parameter. Generally, a smaller value of k produces a smoother result in a homogenous region than a larger one. In this sense, k acts as a threshold for the diffusion process. The diffusion coefficient c used in the anisotropic diffusion equation is different according to different directions. And due to using monotone decline function in different directions as diffusion coefficient of the image, the smoothing effects will be different in different areas.

After the Perona-Malik model was proposed, anisotropic diffusion technology, as an effective image-processing tool, is widely applied in image interpretation, image segmentation, image enhancement and edge extraction [3-5]. However, with the further study of this technology, it is found by plenty of experiments that some problems still exist in Perona-Malik model. For ideal Perona-Malik model, at the position with image edge features (gray value changes sharply), the diffusion speed is supposed to be decreased so as to preserve the image edge information. At the position without obvious features (gray value changes slightly), the diffusion speed is supposed to be increased to filter the noises in this area. But in actual application, at image edge with obvious features the diffusion speed cannot decrease quickly, which causes the image edge features are filtered. At the position without obvious features the diffusion speed cannot increase quickly, which make the noise smoothing effects not good enough. Therefore, by improving Perona-Malik model, many scholars tried to establish such a filter that can effectively protects image edge information and some progress have been made.

Through the analysis of the essence of Perona-Malik model and interrelationship of the algorithms, this paper introduced two dimensional wavelet transformation technologies and combined it with Perona-Malik model to get an innovative texture image filtering algorithm.

First, we make further derivation of Perona-Malik model in 2D. Form "(1)", we can get:

$$\frac{\partial}{\partial t} f_t(x,y) = \frac{\partial}{\partial x}\left( C_t(x,y) \frac{\partial f_t(x,y)}{\partial x} \right) + \frac{\partial}{\partial y}\left( C_t(x,y) \frac{\partial f_t(x,y)}{\partial y} \right) \tag{3}$$

According to the definition of derivative and conduct Fourier transformation, from "(3)"we get:

$$\begin{aligned} \hat{f}_{t+1}(u,v) = {} & (1-u^2-v^2)\, \hat{f}_t(u,v) - \\ & (ju)\left( \frac{1}{2p}\, \hat{p}_t(u,v) * \left( ju\, \hat{f}_t(u,v) \right) \right) - \\ & (jv)\left( \frac{1}{2p}\, \hat{p}_t(u,v) * \left( jv\, \hat{f}_t(u,v) \right) \right) \end{aligned} \tag{4}$$

Supposing A1(x, y) and A2(x, y) is the function of coordinate (x, y), its Fourier transformation are separately $\hat{A}_1(u,v)$ and $\hat{A}_2(u,v)$. Letting $\hat{A}_1(u,v) \cdot \hat{A}_2(u,v) = 1 - u^2 - v^2$. In addition, letting $\hat{B}(u,v) = ju$, $\hat{D}(u,v) = -ju$, $\hat{E}(u,v) = jv$, $\hat{F}(u,v) = -jv$, $\hat{G}(u,v) = (1/2p)\hat{p}_t(u,v)$, and substituting into "(4)", we get:

$$\begin{aligned} \hat{f}_{t+1}(u,v) = {} & \hat{A}_2(u,v) \cdot \hat{A}_1(u,v) \cdot \hat{f}_t(u,v) + \\ & \hat{D}(u,v) \cdot \left( \hat{G}(u,v) * \left( \hat{B}(u,v) \cdot \hat{f}_t(u,v) \right) \right) + \\ & \hat{F}(u,v) \cdot \left( \hat{G}(u,v) * \left( \hat{E}(u,v) \cdot \hat{f}_t(u,v) \right) \right) \end{aligned} \tag{5}$$

Finally, by inverse Fourier transformation of "(5)", we get:

$$\begin{aligned} f_{t+1}(x,y) = {} & \left[ \left( f_t(x,y) * A_1 \right) \right] * A_2 + \\ & \left[ p_t(x,y) \cdot \left( f_t(x,y) * B \right) \right] * D + \\ & \left[ p_t(x,y) \cdot \left( f_t(x,y) * E \right) \right] * F \end{aligned} \tag{6}$$

Equation (6) indicates that the image ft is firstly decomposed with the low-pass filter A1 and the high-pass filters B and E, then regularized the high frequency coefficient with pt, after that reconstructed with the corresponding low-pass filter A2 and high-pass filters D and F. Finally, we get the filtered image ft+1. At time t, the structure diagram of the processing of nonlinear anisotropic diffusion filtering model on the images can be shown in Figure 1.

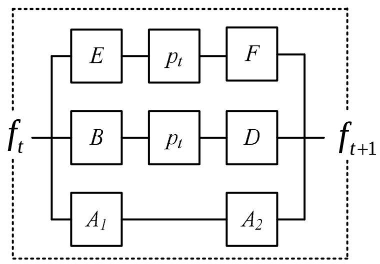



Fig.1 Scheme of anisotropic diffusion at time t

## III. THE PROPOSED IMAGE FILTERING ALGORITHM

From the analysis above it can be known that the high-pass filters *B (x, y)* and *E (x, y)*, which are obtained from the decomposition by anisotropic diffusion filtering, are linear and sensible to the image noises. Such a method often cannot achieve a precise separation of signal and noise. Therefore, anisotropic diffusion filtering cannot separate high frequency components and low frequency components of the image accurately and difficult to filter out the noises and texture background. In order to precisely locate the imagine outlines, an innovative wavelet-based image filtering algorithm of steel strip surface defective image by virtue of anisotropic diffusion is proposed in this paper, which makes the filtering mechanism possess a better anti-noise ability. The new filter algorithm not only inherits the advantages of wavelet as multi-scale analysis and separating the noise and signals effectively, but also inherits the features of anisotropic diffusion filtering as protecting image edge information and iterative filtering. Consequently, this new algorithm can effectively separate the high frequency components and low frequency components of the image and keep detail information of the image while filter out the noises and texture background.

To achieve this goal, we improve the Perona-Malik model and decompose the image by wavelet transformation. Firstly, decompose the steel strip surface defective image *f (x, y)* by wavelet transformation and get the low frequency coefficient $w_{i,j}^{LL}$ and the high frequency coefficients $w_{i,j}^{HL}$, $w_{i,j}^{LH}$ and $w_{i,j}^{HH}$. Then regularize the high frequency coefficients $w_{i,j}^{d}$ (whre d = HL, LH, HH) with pt(x, y), that is, $\tilde{w}_{i,j}^{d} = p_t(x,y)w_{i,j}^{d}$. Finally, reconstruct with wavelet coefficient processed and get the filtered steel strip surface defective image $\tilde{f}(x,y)$ . To achieve a satisfactory filtering result, the proposed filter algorithm is often performed iteratively. Take a two-level decomposition filtering of the wavelet-based image filtering algorithm by virtue of anisotropic diffusion as an example, the structure diagram is shown in Fig. 2.

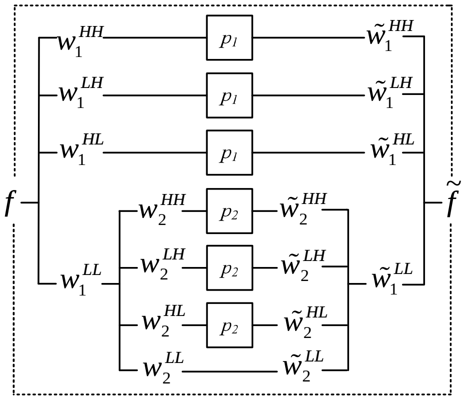
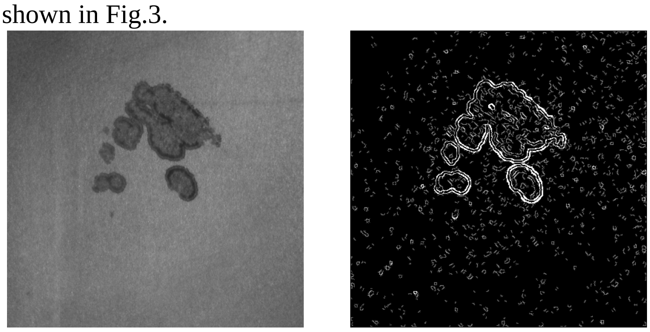


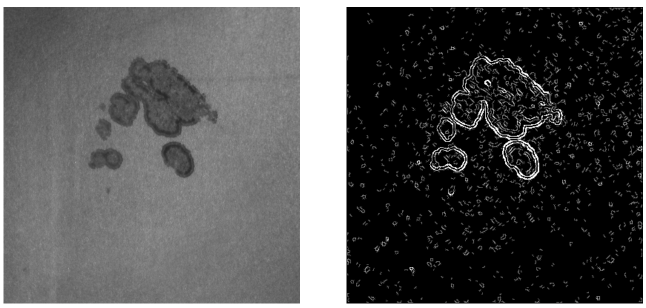

Fig.2 Two-level scheme for the proposed algorithm

## IV. Experimental results and discussion

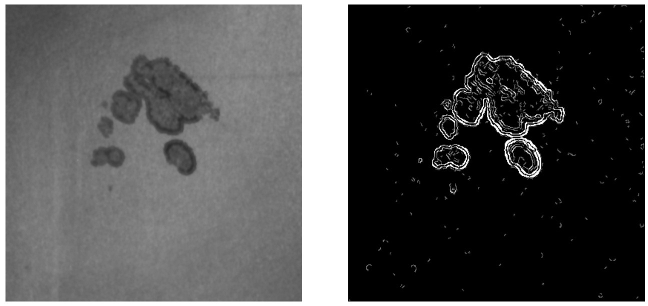
To verify the filtering performance of the new algorithm proposed, we apply it to cold rolled steel strip surface defect images with texture background. First, filter the defective images with new algorithm proposed and anisotropic diffusion filtering algorithm, separately. Then extract edge information of the image through edge detection to estimate the filtering performance. The edge detection results are shown in Fig.3.



(a) Original image



(b) Anisotropic filtering



(c) New algorithm proposed in this paper

Fig. 3 Comparison of different filtering effects on steel strip surface image

Fig. 3 (a) is the original image and its edge detection result. Fig.3 (b) is the image processed by anisotropic diffusion filtering algorithm and its edge detection result. Fig.3 (c) is the image processed by the algorithm proposed and its edge detection result. Comparing these groups of images, it can be found that the images processed by the new algorithm are more easily to detect the edge information and get clear edge outline, which is convenient for the following image segmentation. Thus, no matter the visual effects or edge detection accuracy, the algorithm proposed is superior to nonlinear anisotropic diffusion filter algorithm.

## V. Conclusions

In summary, an innovative wavelet-based image filtering algorithm by virtue of anisotropic diffusion has proposed in this paper. This new algorithm which inherits the advantages of wavelet and anisotropic diffusion filtering can effectively separate the high frequency components and low frequency components of the image and keep detail information while filter out the noises and texture background. Experiment results show that this wavelet-based image filtering algorithm has obvious effects on filtering texture background and keeping defects edge information, which contributes to the following processing such as edge detection etc.

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