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Rock image enhancement algorithm based on multi-scale and multi-direction analysis

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ABSTRACT

This paper proposes an improved image enhancement algorithm for rock image based on multi-scale and multi-direction analysis. This algorithm firstly decomposes the original rock image by wavelet transform. Then it designs the Gabor filter bank to filter and de-noise the low-frequency component figure that extracts from original rock image. At last, it reconstructs the image and regains the enhanced rock image. The experiment results show the edges and details of the rock image is enhanced obviously by using this image enhancement algorithm. It is helpful to further study and interpretation for seismic data.

KEYWORDS

Rock image; Image enhancement; Wavelet transform; Gabor filter bank; Peak Signal to Noise Ratio.

INTRODUCTION

Tectonic interpretation of the Seismic data is the important part of the seismic exploration. Seismic data which has in-phase axis continuous and good lateral resolution is more conducive to structural interpretation and automatic interpretation of computer software. Rock image occupies an important position in the seismic data. Seismic data will be influenced inevitably by various factors in the process of collecting, it causes to decrease PSNR (peak signal to noise ratio) of rock image. Therefore, it occupies an important position in seismic data processing for how to get rid of noise in seismic signal.

So far, there have been existed several seismic data denoising algorithm and mostly for tunnel seismic data denosing, but the information of structure or sequence in seismic data has not been taken into account [1]. Traditional image enhancement algorithm has enhanced the image noise when enhanced image contrast, so image denosing is showed particularly important before enhanced the image. The reference [2] was denoised speckle noise of SAR image in combined with improved weighted median filter and enhanced Lee filter, removed speckle noise of SAR image effectively while keeping the edge information of the image. The reference [3] proposed a new wavelet transform denoising method for the uniform noise of the image and the denosing effect is good. The reference [4] combined with improved Teager energy operator and Gabor function for fingerprint image enhancement, the denoising and edge enhancement effect are good for low quality fingerprint image. The reference [5] used the Curvelet transform for image denoising after the wavelet transform for image. The reference [6] improved the hard threshold and soft threshold of the traditional wavelet analysis, constructed a new threshold function and the denoising effect is good for voice signal.

The above denoising algorithm only applies to specific image [7-10], and the image denoising effect is not significant when they used to processing the rock images which has obvious directivity. Gabor filter has the characteristic of frequency and direction selection, it removed noise at the same time keep the continuity of seismic event on the maximum limit and not reduce the resolution of seismic data. Therefore, in order to have a better enhance effect for rock image, this paper proposes a rock image enhancement algorithm that fused the wavelet transform and Gabor filter on the basis of the existing image enhancement algorithm. Finally, it gets the rock image of which edges and details are more prominent and the overall contrast of rock image is enhanced.

WAVELET TRANSFORM AND GAVOR FILTER

In the field of application, especially in the signal processing, image processing, speech processing, as well as many nonlinear science, wavelet transform is considered to be another effective method of time-frequency analysis after Fourier analysis. It is a new kind of frequency conversion technology which developed in recent 20 years used for signal analysis and signal processing. It can be used to represent time-frequency characteristics of signal [11] and is more suitable for image enhancement processing which consider directivity of image [12]. For this reason, it can effectively to enhance rock image when wavelet transform is applied to rock image processing and in favor of the further processing and research for seismic data. The original image can be decomposed into low frequency components figure and high frequency component figure after wavelet transform. In general, the main information of images corresponding to the low frequency part, the edge and noise of images corresponding to high frequency part. So, it can achieve the effect of enhancing images through enhancement processing to low frequency component and attenuation processing to high frequency component.

Gabor filter is a Gauss window windowed Fourier transform filter, Daugman firstly extended one-dimensional Gabor to two-dimensional in 1980 [13]. Dimensional Gabor function is only able to reach the lower bound of the uncertainty principle function. Uncertainty principle means that it is impossible to get any accuracy both in time domain and frequency domain. If the frequency resolution increased, the temporal resolution will be decrease. In other words, Gabor function can achieve high resolution both in time domain and frequency domain. Its expression as follows:

$$h(x,y,\theta,f)=\exp\left(-\frac{1}{2}\left(\frac{x_\theta^{\ 2}}{\delta_x^{\ 2}}+\frac{y_\theta^{\ 2}}{\delta_y^{\ 2}}\right)\right)\exp\left(\frac{2\pi x}{wavelength}\right) \quad \mathbf{(1)}$$

It can be seen by formula (1), actually, D Gabor filter is the product of two functions in the time domain. One is the Gaussian function. The other is the Complex exponential function. The “frequency domain convolution theorem” shows that the two functions multiply in the time domain is equal to their Fourier transform convolve in the frequency domain. Fourier transform of the Gaussian function is still a Gaussian function. Fourier transform of Complex exponential function is the impulse function. Because any function convolves with impulse function is equal to the function. So the convolution result is still a Gaussian function. That is to say, Gabor filter in the frequency domain is also a form of Gaussian function.

Gabor filters has self-similar, all of the Gabor filters can be generated through expansion and rotation from a mother wavelet. The representation of frequency and direction of Gabor filters is closed to the human visual system, and is often used to represent and describe the texture. D Gabor filters can be seen as a microscope that has the direction-sensitive and scale-sensitive. In practical applications, Gabor filter can extract related features of different scales and different directions in frequency domain. Gabor filter can generate a variety of filter templates by adjusting the parameters [14]. So it can be widely used in denoising processing for different images.

IMPROVED IMAGE ENHANCEMENT ALGORITHM

The traditional denoising algorithm is easy to blurred image details when removing noise. So it is important to find an algorithm that can balance remove noise and preserve the details. The improved algorithm firstly decomposed rock image by wavelet, extracted the high frequency component figure and low frequency component figure. Then the high frequency component coefficient is reseted, and the low frequency component figure was filtered and denoised by Gabor filter group. Finally it obtained the enhanced rock image after reconstructed image. As shown in figure 1:

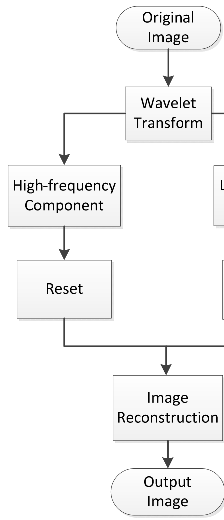


Figure 1 : Image enhancement fused wavelet transform and Gabor filter group

Wavelet transform

In this paper, it selects the Single-layer two-dimensional wavelet transform to decompose the original image. Tensor product method is the most simple and common method to construct a multi-dimensional wavelet. One-dimensional multi-resolution analysis can be easily extended to two-dimensional multi-resolution analysis through this method.

For two-dimensional image $f(x,y)\in L^2(R^2)$, it can define the discrete wavelet transform as follow:

$$\left(A_J^d f, \left(D_j^1 f\right)_{1\le j\le J}, \left(D_j^2 f\right)_{1\le j\le J}, \left(D_j^3 f\right)_{1\le j\le J} \right) \quad (2)$$

Among it,

$$A_J^d f = \left(\left\langle f(\mathrm{x},\mathrm{y}), \phi_{j,m,n} \right\rangle\right)_{m,n\in Z}$$

$$D_j^1 f = \left(\left\langle f(\mathrm{x},\mathrm{y}), \varphi_{j,m,n}^1 \right\rangle\right)_{m,n\in Z}$$

$$D_j^2 f = \left(\left\langle f(\mathrm{x},\mathrm{y}), \varphi_{j,m,n}^2 \right\rangle\right)_{m,n\in Z}$$

$$D_j^3 f = \left(\left\langle f(\mathrm{x},\mathrm{y}), \varphi_{j,m,n}^3 \right\rangle\right)_{m,n\in Z}$$

Expression (2) constitutes the two-dimensional orthogonal decomposition of signal. D_j^1f represents the wavelet coefficients in vertical direction. D_j^2f represents the wavelet coefficients in horizontal direction. D_j^3f represents the wavelet coefficients in diagonal direction.

Design Gabor filter

Rock image has good frequency characteristic and direction. So it needs to choose filtering algorithm suit the texture feature of rock image. Because of the Gabor filter has obvious direction selectivity and frequency selectivity characteristics, and to achieve the optimal joint resolution both in airspace and frequency domain. For this reason, the Gabor filter group will have better enhancement effect than other image enhancement algorithm when it used to rock image enhancement. In this paper, the Gabor function was changed for the digital filter, and then chose the real part of Gabor filter operator. So it makes the real part of the Gabor function as the template, makes the frequency of approximate sine wave of the ridge valley as the frequency of the filter, makes the direction of the local area as the direction of filter, to establish the filter we need. The designed filter was more real close to the characteristics of rock image.

Definition 1: Suppose wavelength as the size of the structured filter, θ as the direction of the filter, Gabor filter can be divided into odd filter and even filter, and defined respectively as follows:

$$h_{odd}(x,y,\theta,f)=\exp\left(-\frac{1}{2}\left(\frac{{x_\theta}^2}{{\delta_x}^2}+\frac{{y_\theta}^2}{{\delta_y}^2}\right)\right)\sin\left(\frac{2\pi x}{wavelength}\right) \quad \textbf{(3)}$$

$$h_{even}(x,y,\theta,f)=\exp\left(-\frac{1}{2}\left(\frac{{x_\theta}^2}{{\delta_x}^2}+\frac{{y_\theta}^2}{{\delta_y}^2}\right)\right)\cos\left(\frac{2\pi x}{wavelength}\right) \quad \textbf{(4)}$$

Among them, x_θ and y_θ for:

$$x_\theta = x\cos\theta + y\sin\theta \quad \textbf{(5)}$$

$$y_\theta = -x\cos\theta + y\sin\theta \quad \textbf{(6)}$$

Definition 2: Suppose *u, v* express the scale and direction respectively, *Wg* express the filter window size, *G(i,j)* express the original low frequency images, *G'(i,j)* express the low-frequency images after filtering, extract the real part of the Gabor filter for filtering, defined as follows:

$$G'(i,j)=\sum_{u=-\frac{W_g}{2}}^{\frac{W_g}{2}}\sum_{v=-\frac{W_g}{2}}^{\frac{W_g}{2}} h_{even}(u,v,o(i,j),f(i,j)G(i,j)) \quad \textbf{(7)}$$

Improved algorithm process

The improved image enhancement algorithm uses the Gabor filter group to filtering and denoising for low frequency component image that extracted from the result after wavelet transform, and finally achieves the enhanced obviously rock image. The improved image enhancement algorithm is more suitable for rock image enhancement than others. Specific algorithm steps are as follows:

Step1: Original rock images is decomposed by single-layer D discrete space wavelet transform, and extracts low frequency component figure and high frequency component figure.

Step2: Reset the wavelet coefficients of high frequency component figure.

Step3: Construct the Gabor odd filter and Gabor even filter by formula (3) - (6).

Step4: Extract real part of the filter, and filtering the low frequency component figure by using formula (7), obtain the low frequency component figure after denosing.

Step5: Reconstruct the high frequency component figure after wavelet coefficients reset in Step2 and low frequency component figure after filtering and denosing in Step3, achieves the enhanced rock image that edges and details are enhanced obviously.

In Step1, it just needs once wavelet decomposition because it just filtering and denoising the low frequency component figures. And it is conducive to improve the overall operation rate. In Step3, after repeated experiments, it shows that the filtering effect of 5 scales, 8 directions filter group is the best. So it selects 5 scales, 8 direction to construct filter group that containing 40 filters. The direction change of filter group is implemented by formula (5) and (6).

EXPERIMENTAL RESULTS AND ANALYSIS

Experimental process

The traditional image enhancement algorithms often brought some serious negative effects when they used to enhance image. For example, smooth filtering was blurred the original edges and details of image when it gets rid of the noise. But, wavelet transform have the characteristic that can extract signals in multi-scale and multiple perspectives, and it can apart from the noise and signal obviously in different scales. It is more suitable for rock image processing. This article selects a set of rock images. It firstly decomposes the original rock images by two-dimensional wavelet. Then it gets the low frequency component figure (cA) and high frequency component figure of the original rock image. The main information of original image is contained in low frequency component figure. The edge and noise information from original image is contained in high frequency component figure.

In this paper, it filters and denoise the low frequency component figure by using Gabor filter group. The selection of the Gabor filter parameters is crucial in designing Gabor filter group. Gabor filter parameters are obtained by experimental method. Experimental method is based on the parameters under certain constraints, through compares concrete experiment performance, it finally determine the parameters [15].

The realization of the Gabor filter group can be divided into odd filter and even filter. Among them, the odd filter on behalf of the real part, even filter on behalf of the imaginary part. The real filter is used to smooth image, the imaginary part filter is used for edge detection. Because this article is the study of image enhancement algorithm, so it extracts the real filtering of Gabor filter to de-noising the low-frequency component figure. It makes the low frequency component figure convolve with real part of the designed filter group, and gets the Gabor filtering results with different scales and different direction. Then it deals with the results by weighted average method. Then it structures the low frequency component figure after denoising. Finally it reconstructed image to achieve the enhanced rock image.

Results analysis

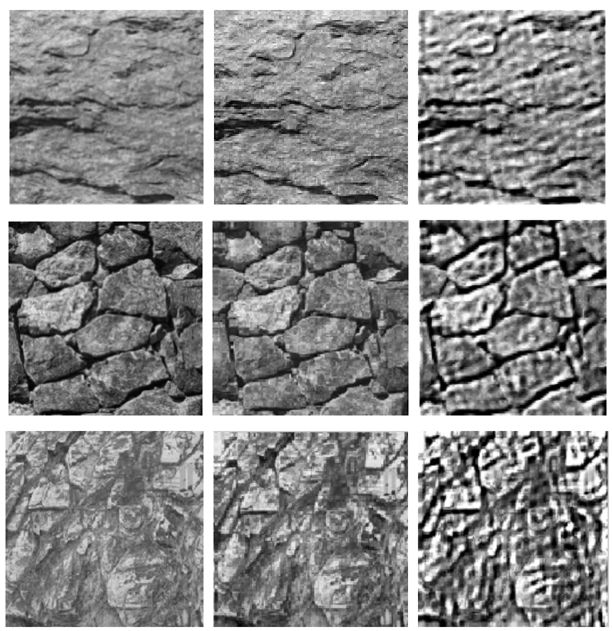
The methods to evaluate the effect of image enhancement are divided into subjective evaluation and objective evaluation. It can be seen from figure 2 that the results of image (figure2 (c)) enhancement using this algorithm is better visual effect than using wavelet transform (figure2 (b)). The edges and details of original images are obviously enhanced by using this algorithm. Therefore, it has better enhancement effect for rock image by using this algorithm than traditional image enhancement algorithms.

In addition, this article selects MSE (Mean square Error) and PSNR (Peak Signal to Noise Ratio) as the main objective evaluation standard.

$$MSE = \frac{1}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} \left[G'(i,j) - G(i,j) \right]^2 \quad \textbf{(7)}$$

$$PSNR = 10 \times \log \left(\frac{255^2}{MSE} \right) \quad \textbf{(8)}$$

In the above formula, M and N is the image size. G(i,j) represents original image. G'(i,j) represents processed image. The smaller MSE and greater PSNR, the difference between enhanced images and original image is greater. It can show that the greater degree of image is enhanced to a certain extent. Table 1 lists the MSE and PSNR of different enhancement algorithm for the first group rock images in figure 2. It can be seen in table 1 that MSE is the minimum and PSNR is the largest of processed image by the image enhancement algorithm in this paper. It shows that the effect is more obvious for the rock image enhancement by using this algorithm.



(a) Original image (b) WT (c) Gabor filter

Figure 2 : Enhance effect comparison

Table 1 : It compares evaluation parameters of image enhancement algorithm

	Enhancement algorithm		
Evaluation parameters	**Original image**	**Wavelet transform**	**Algorithm in this paper**
MSE	190.530	183.741	100.638
PSNR	15.418	17.283	26.425

CONCLUSIONS

In this paper, the traditional wavelet transform image enhancement algorithm has been improved. It makes full use of the direction of rock images. Gabor filter group is applied to low frequency component figure after wavelet transform. It is targeted on the rock image enhancement. Using Gabor filter group to filter low frequency component figure after wavelet transform, it is not only reduced the calculated amount and improved the operating rate, but also more accurate filtering result because it only filters the low frequency component figure. Compared with other image enhancement algorithms, the edges and details of rock image are enhanced obviously by using this algorithm. Meanwhile, overall contrast of original image has been enhanced obviously. It has higher efficient and better enhance effect for image enhancement. It has a certain promoting role for further interpretation of seismic data.

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REFERENCES

[1] LUO Huanzhang; Method and application of orientation filtering and noising cancelling, Petroleum Geology and Recovery Efficiency, 6, 50-52 (2010).

[2] HAN Mingxing, ZHENG Yongguo; Research on SAR image speckle noise filtering methods, Computer Applications and Software, 29(8), 257-258 (2012).

[3] Yan R, Shao L, Liu Y; Nonlocal hierachical dictionary learning using wavelets for image denoising, (2013).

[4] WANG Lei, ZHENG Jianwei, WANG Wanliang; Fingerprint image enhancement based on wavelet transform and Teager energy operator, Computer Applications and Software, 27(8), 59-61 (2010).

[5] WANG Biao, LI Jianwen, WANG Zhongfei; Threshold de-noising method based on wavelet analysis, Computer Engineering and Design, 32(3), 1099-1102 (2011).

[6] Yi, Q., Weng, Y., & He, J. (2014, May); Image denoise based on Curvelet transform, In Electronics, Computer and Applications, IEEE Workshop on, 412-414 (2014).

[7] LU Yuqing, LI Haiyan, FEI Qinshui, et al.; Noise and speckle reduction of ultrasonic images using an improved Rayleigh-trimmed bilateral filtering algorithm, Computer Engineering and Design, 35(1), 228-232 (2014).

[8] YANG Xianfeng, FAN Yong, PENG Bo, et al.; Fast denoising algorithm based on regions for image corrupted by Gaussian noise, Computer Engineering and Design, 35(4) (2014).

[9] QIAO Ziliang, DU Huimi; NL_MEANS algorithm based on K-means clustering for ultrasound image denoising, Computer Engineering & Design, 35(3), 939-942 (2014).

[10] Guo Q, Dong F, Sun S, et al.; Image denoising algorithm based on contourlet transform for optical coherence tomography heart tube image, Image Processing, IET, 7(5), 442-450 (2013).

[11] Garg V, Raheja N; Image Denoising Using Curvelet Transform Using Log Gabor Filter, International Journal of Advanced Research in Computer Engineering & Technology (IJARCET), 1(4), 671-679 (2012).

[12] Bhatnagar G, Wu Q M J, Raman B; A new fractional random wavelet transform for fingerprint security, Systems, Man and Cybernetics, Part A: Systems and Humans, IEEE Transactions on, 42(1), 262-275 (2012).

[13] Sihalath, K., Choomchuay, S., Wada, S., & Hamamoto, K.; Fingerprint Image Enhancement with Second Derivative Gaussian Filter and Directional Wavelet Transform, In Computer Engineering and Applications, International Conference on IEEE, (2), 112-116 (2010, March).

[14] Xiaoqing L, Xiaojun W; Detection algorithm for infrared small and weak targets based on wavelet transform and Gabor filter, Infrared and Laser Engineering, 9, 045 (2011).

[15] ZHAO Yingnan, YANG Jingyu, MENG Xianquan; A practical design for parameters of Gabor filters, Computer Engineering, 32(19), 173-175 (2006).