An Integrated Image Clarity Method for Coal Mine Safety Monitoring

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Abstract

According to the poor image quality of the monitoring system in coal mine monitoring, an integrated image clarity method was presented which using adaptive multi-level noise reduction median filter based on the direction in the spatial domain to denoise the image first, then using multi-wavelet transform to enhance the low-light image in the transform domain. This integrated approach combines the benefits of spatial domain and transform domain noise reduction and enhancement. It can reduce the impulse noise effectively, while retaining good image detail features of the coal mine images. Experiments show that the method can greatly improve the clarity of the image of coal mine so can improve the readability of the image, and this is of great significance for the coal mine safety monitoring.

Keywords: *Coal mine, Median filter, Multi-wavelet transform, Image denoise, Image enhancement.*

1. INTRODUCTION

In these years, the coal mine safety monitoring system such as the coal industry television has been used widely to guide the mine safety production and command with intuitive, convenient and reliable means during the development of coal mine science. The video safety monitoring system not only monitors the mine production directly on the ground to detect the risks underground and take preventive measures, but also provides the first-hand information for the ex post analysis of the accidents.

For the harsh environment of the coal mine, such as the poor lighting, low illumination and serious dust, the quality of images captured by the monitoring system has been degraded. The correlation between pixels structure and content has been destroyed and this makes the further image analysis and finding the danger in the mine much more difficult. So it is very necessary to preprocess the images captured by the system for denoising or enhancement and to increase the clarity of the monitoring images. This article designs an integrated algorithm based on directional adaptive median filter and wavelet transform according to the illumination under complex noise environment in the coal mine.

2. COAL MINE IMAGE NOISES

Image noise usually means the visible error information produced by CCD/CMOS or digital signal system. Visible noise in digital images is often affected by temperature effects and the ISO sensitivity: the higher the two values are, the worse the effect is. For the mine harsh conditions, the CCD images obtained through D/A converter, transmission lines will produce noise pollution. There are variable types of noise collected in the monitoring images, but the most common and most serious impact on image quality in general are impulse noise and Gaussian noise. So how to reduce the effects of these two kinds of noise is the key to improve the monitoring image quality.

3. THE INTEGRATED IMAGE CLARITY METHOD

3.1 Median Filtering Principle

Non-liner filtering has a wide range of applications in image processing. It has good characteristics on the noise rejection and image edge maintaining. Median filter is a nonlinear filtering operation and belongs to the spatial denoising methods. Its output is related to the distribution of input noise density. The squared difference of output noise is inversely proportional to the square of density function of the input noise. For the rejection of random noise, median filtering is not so good as the mean filter. But in terms of pulse interference, in particular of the pulse width less than half the length of filter window and far away from the narrow pulse, the median filter is very effective. Since there is lots of impulse noise in the coal mine environment, median filtering noise can be used in the preliminary process of the images.

Median filter uses a sliding window containing odd points to sort the neighborhood pixels in terms of pixel gray level and the middle value is the output pixel. Its mathematics description is as following.

If S is the neighborhood set of pixel (x_0, y_0) (including (x_0, y_0)), $(x, y) \in S$, $f(x, y)$ means the gray value of point (x, y) , $|S|$ means the number of elements in set S , $Sort$ means to sort the elements in order. Then for smoothing can be expressed as:

$$f^{'}(x_0, y_0) = \left[\underset{(x,y)\in S}{Sortf}\ (x, y) \right]_{\frac{|S|+1}{2}} \tag{1}$$

3.2 Adaptive Multi-level median filtering based on the direction

As median filter is characterized by simple and fast operation, especially for unipolar or bipolar pulse noise, it is very effective. Adaptive multi-level median filter is an improved algorithm based on the traditional median filter. It sets several strip sub-windows in the rectangular window so to protect the edge information in more directions than the traditional median filter while preserving the characteristics of median filter which can suppress impulse noise effectively.

The adaptive multi-level median filter based on direction is as follows (5*5, for example).

(1) Supposing the current pixel is located in the center of the pixels and its value is $x(i, j)$, Define a set $D = \{D_i, i = 1,2,...8\}$, D_i is the absolute difference value of the current pixel and its 8-point adjacent pixels. Sort the elements of D in ascending order getting the set $d_1 \le d_2 \le ...... d_8$, $d_1 \le d_2 \le ......d_8$.

(2) Make the two smallest elements in set D_{order} as the feature direction in the 3×3 window, and using this direction as the trend of the 5×5 direction.

(3) Supposing the current pixel value is $x(i, j)$, the output $Y(i, j)$ in the 5×5 window in which (i, j) is the center is as follows:

$$Y(i, j) = \begin{cases} MMF\ [x(i, j)] \\ SCMMF\ [x(i, j)] \\ M\,[x(i, j)] \end{cases} \quad (2)$$

$MMF[x(i, j)]$ is the processing result when the current pixel is an isolate pixel or the direction of related line feature is horizontal or vertical. $SCMMF[x(i, j)]$ is the processing result after the improved multi-level median filter when the related line feature has an angle in $(0, \pi / 2)$. In other cases that it's difficult to determine the direction of feature line, $M[x(i, j)]$ is used to express the pixel value filtered.

In the formula,

$$M[x(i, j)] = med[m_1, m_2, m_3, m_4, x(i, j)] \quad (3)$$

This directional adaptive multi-level median filtering denoise method can adapt to the direction of the image edge better comparing with the traditional median filter and it can keep a better compromise between the denoising and edge protection. Therefore, if the method is applied to underground monitoring for denoising complex environment, not only the effect of impulse noise can be reduced more obviously, but also the part of the Gaussian noise can be reduced.

3.3 Image enhancement with multi-wavelet transform

Wavelet transform has many features such as low entropy, multi-resolution, decorrelation and flexible radical selection, which can do the local analysis both in the time and frequency domain at the same time, and extract the local singular characteristics of the signal flexible. At present, denoising and enhancement based on wavelet has become an important way in image processing field.

First, the image after median filtering is denoised with multi-wavelet; this can reduce the most Gaussian noise. Then the image will be enhanced with the multi-wavelet to increase the contrast of the image. For enhancement, the image is transformed with multi-wavelet first, and then the image is decomposed into several parts with different size, position and orientation. Then the coefficients of some different position and orientation are changed according to the need, so that some components which we are interested in are enlarged while unnecessary component reduced. Finally, the enhancement image was reconstructed with multi-level wavelet. The wavelet enhancement process is shown in Figure1.

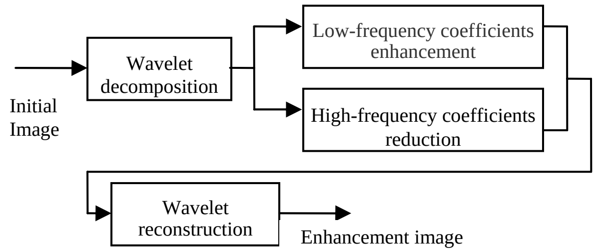
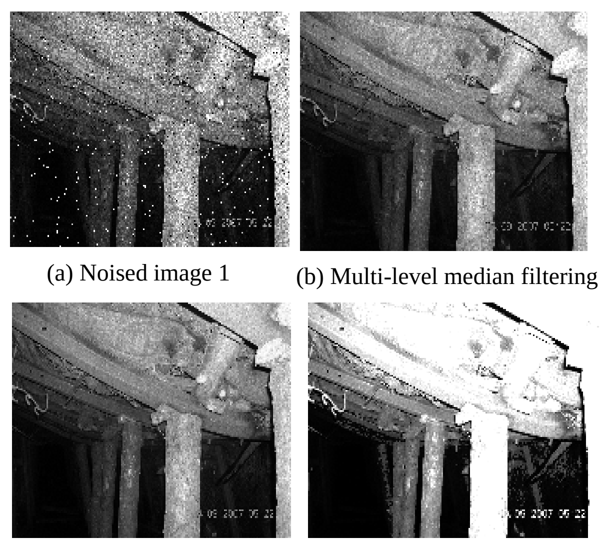


Figure 1: Enhancement process of wavelet

The main information of the decomposed image (i.e. the image contours) is characterized by low frequency part while the details of the image is characterized by high frequency. Therefore, the decomposed low frequency coefficients are weighted while high frequency coefficients are weakened. After such wavelet transform treatment, an enhanced image can be achieved. In the low contrast environment such as coal mine, if the quality of initial denoised image is not so good, the wavelet transform will be used to enhance it, which can improve the image quality greatly.

4. EXPERIMENTS ANALYSIS

To verify the integrated algorithm, two images from different coal mine have been used. In order to highlight the noise in the original image, some salt and pepper noise(0.02) and Gaussian noise have been added as shown in Figure 2 (a) and Figure 3 (a). The processing tool is Matlab2007, the processed comparison image effects are shown in Figure 2 and Figure 3 respectively.

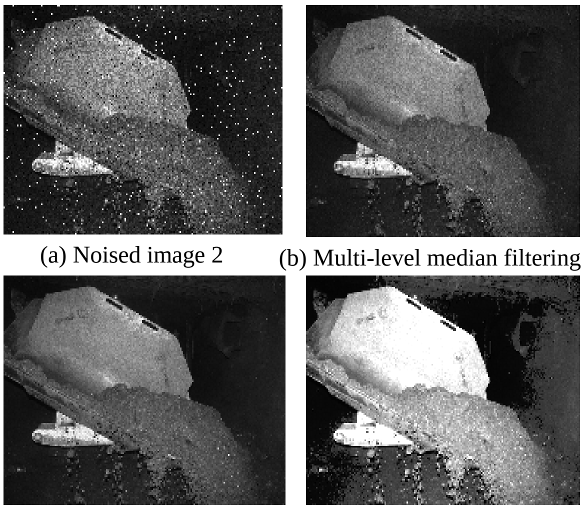


(a) Noised image 1 (b) Multi-level median filtering

(c)Wavelet denoising (d)Wavelet enhancement

Figure 2 : Image1 process effects

The noise images has been filtered lots of salt and pepper noise by the directional multi-level median filtering, and the image quality has been improved greatly as shown in Figure2 (b) and Figure3 (b). Since the Gaussian noise cannot be reduced effectively by median filter algorithm, the multi-wavelet denoising has been used to do further denoising, the results are shown in Figure2 (c) and Figure3 (c). From these two parts, we can see the images are clearer than the former. This can also be proved by the increasing of objective parameters Peak Signal to Noise Ratio (PSNR) as shown in Table 1.



(a) Noised image 2 (b) Multi-level median filtering

(c) Wavelet denoising (d) Wavelet enhancement

Figure 3: Image 2 process effects

After processing above, sometimes the background is still dark, so the multi-wavelet transform is used to enhance the images. Figure2 (d) and Figure3 (d) show the images enhanced by multi-wavelet transform. Due to the characteristics of wavelet transform, image quality has improved while the image details are preserved.

Table 1: Image quality objective parameters

***PSNR* (*dB*)**	***(a) Noised image***	***(b) multi-level median filtering***	***(c) Wavelet denoising image***
Image 1	*17.9014*	*26.013*	*27.6952*
Image 2	*19.1431*	*28.8422*	*29.9378*

5. CONCLUSIONS

Safety monitoring in the coal mine is an important safeguard to achieve safety production. But the special complex environment of the underground leads to poor image quality thus increasing the difficulty of monitoring for supervisors. This also restricts the application of the intelligent monitoring technology in the coal mine monitoring. An integrated image processing method is presented based on the combination of directional multi-level median filter denoising and wavelet transformation which can improve the readability of the coal mine image effectively. And this is of great significance for the safety monitoring in the coal mine.

6. ACKNOWLEDGEMENTS

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