Separation Of Gangue From Coal Based On Histogram Thresholding

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ABSTRACT: Coal gangue is residual abandoned coal, produced after the pre-processing steps of mining. It is an amalgam of several unwanted substances. It is important to separate coal gangue from lump coal before fed to thermal power plants. In this paper, investigation on the fundamental characteristics of coal images and gangue images with digital image processing technology is proposed. The system determines the image feature of coal and gangue, particularly their gray scale values by using traditional threshold segmentation. By analyzing the characteristics of the image, the system identifies the gangue. The outcome indicated that the comparison of coal images and gangue images could successfully achieve the real-time automatic separation of gangue.

Keywords *:* Coal gangues; Edge detection; Separation;

1 INTRODUCTION

Coal is the most important and abundant fossil fuel in India. It accounts for 55% of the country's energy need. The country's industrial heritage was built upon indigenous coal. Commercial primary energy consumption in India has grown by about 700% in the last four decades [11]. In coal mining, waste-rocks from underground or open pit mining are mixed with coal is called coal gangue. Compared with coal, it is dark grayscale rock which is harder and with lower carbon content. It's necessary to separate gangue from lump coal during the production of coal mine. At present, the sorting of coal and gangue is mainly manual or mechanical sorting. However, the manual way is a great labor demanding and low efficient; meanwhile, it affects the health of workers. Digital image processing technology is a new method that has been developed rapidly in recent years. In the paper, based on digital image processing technology, coal and gangue images were distinguished. The proposed technology reduced the labor intensity and the associated environment pollution and it may increase coal production efficiency and intelligent level of the gangue sorting.

2 TRADITIONAL COAL CLEANING METHODS

The traditional coal cleaning methods are broadly classified as the wet and dry processes. The dry process doesn't involve the use of water, whereas in the wet process, the water is the main medium for washing and jigging [12].

TABLE 1: COMPARISON OF COAL CLEANING METHODS

Sl. no	Methods	Advantages	Disadvantages	Costs
1	Jigs	Large capacity Inexpensive world-wide usage	Lower separation than dense-medium	Inexpensive
2	Dense-medium separators	Good separation	Small capacities	Expensive
3	Hydro cyclones	Simple structure	Water consumption	Inexpensive
4	Concentration	Inexpensive Good pyrite separation	Small capacities	Inexpensive
5	Froth flotation	Good results on fines	Complex Poor pyrite separation	Expensive
6	Dry cleaning	No water required	Used for metallurgical coals size<0.5mm	Lower than wet processes

All the above methods have some disadvantages such as serious environment pollution, expensive equipment's, time consuming and so on. Xian-min Ma [2007] proposed a revised algorithm based on wavelet transform to suppress the speckles in the gangue images, to enhance edges, because the coal gangue images are always contaminated with speckles of coal dust [1]. Xiao-ru Song and Feng-jun Wang [2007] proposed a coal gangue on-line automatic separation system based on the improved BP algorithm and advanced risc machines (ARM) [2]. Xian-min Ma and Jie Zang [2008] proposed a novel image process method of separating gangues from coal with wavelet analysis. Under the different frequency ranges, a series of image processing approaches were exerted on coal gangue images with wavelet transform. The image edges were detected by fast multi-scale edge detection and images were segmented by self-adaptive threshold [3]. Xian-min Ma and Che Liang [2009] proposed a

novel application of rough set theory in the coal gangue image process. The coal gangue image processing operations such as the denoising, enhancement, sharpening and edge detection were performed by using the rough set theory [4]. Wenhui Li, Ying Wang, Bo Fu and Yifeng Lin [2010] proposed automatic separation of coal and coal gangue based on computer vision and intended a coal and coal gangue separation system framework. Grayscale histogram, fractal dimension and energy value were extracted as ore features [5]. Haonan Liang, Huidong Cheng, Tianran Ma, Zengwei Pang and Yin Zhong [2010] proposed a self-organizing competitive neural network algorithm and support vector machine (SVM) algorithm based on the difference of the gray scale and texture in the images of coal and gangue [6]. Renbao Wang and Zhe Liang [2011] proposed a system to investigate the fundamental characteristics of coal images and gangue images on the basis of digital image processing technology. To improve operation speed, the high performance microcontroller (DSP) was used as the core processor of system [7]. Chen Zhang and Chenglian Zhang [2012] proposed a method of separating gangue from coal based on density by calculating volume and weight of the ores [8]. Qian Mu and Ji-xian Dong [2013] proposed a high-speed image processing of embedded systems based on FPGA and DSP collaboration used in coal detection technology. The system used a modular design, including a real-time image acquisition module, DSP image processing module and peripheral interface module. The system determined the image feature of coal and gangue, particularly their gray scale values and the center of gravity. By analysis of the characteristics of the image, the system identified the gangue [9].

3 PROPOSED METHOD

The grey-scale and texture are main basis for manpower to separate gangue from coal. In appearances, coal surface color was black and gangue surface color was grey-white. Therefore, the wave lengths of coal and gangues caused by light reflection were different. So the grey-scale distribution functions of the coal and the gangue were different and their curve peak values were too different. According to this principle, the coal and gangue can be differentiated by image processing. The proposed system is shown in Figure 1.

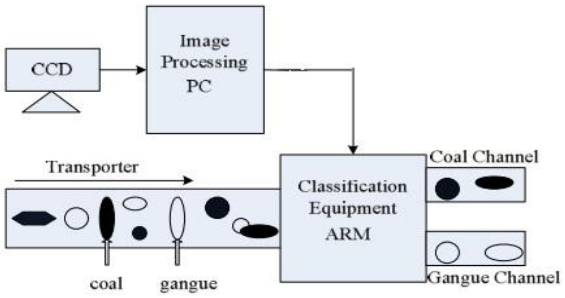


Figure 1: The gangue separation system

The separation system was composed of 5 parts: reading video sequences, frame image pre-processing, candidate region location, feature extraction and recognition [7].

A. Video sequence

The camera is fixed above the entrance of coal mine on conveyor belt. The coal and gangue images were pictured by CCD. It was displayed on the PC and the image was classified by the classification equipment.

B. Image pre-processing

The main purpose of pre-processing part was to extract ROI (Region of Interest) image for further recognition. Firstly, video frames were smoothed by Median Filter. After noises were eliminated, the system detected motion regions in image.

C. Region location

From image processing to image analysis, image segmentation is a key step. Detection and extraction of edge features determine the effect of image recognition and processing. Image edge reflects its grayscale discontinuities and can outline target object. By extracting the edges of coal image and gangue image, their position in the images can be assured and be separated from the background for further feature extraction and image recognition.

D. Feature extraction

Image segmentation was made to extract the contours of coal and gangue edge that was mapped to the original grayscale images. Then, the ranges of coal or gangue image were obtained. By analyzing the grayscale histograms of coal and gangue images, their grayscale distribution curves were generated. By comparing them, it was observed that grayscale of coal was lower than that of gangue. The mean and variance of the grayscale probability distribution for coal and gangue were different. Therefore, coal and gangue could be distinguished by analyzing their mean and variance. If a M ×N image grayscale is f (i , j), i= 1,2,...M; j=1,2,...N, its mean(μ) and variance(σ^2) can be represented as follows:

$$\mu = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N} f(i,j) \quad (1)$$

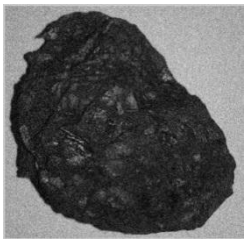
$$\sigma^2 = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}[f(i,j)-\mu]^2 \quad (2)$$

E. Image recognition

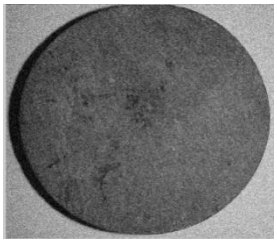
According to the Equation (1) & (2), the mean and variance of grayscale probability distribution of coal and gangue sample images were calculated and used as standard values. When in identifying the images, coal or gangue could be judged through comparing processing results of the actual coal and gangue images with standard values.

4 IMAGE PROCESSING RESULTS AND ANALYSIS

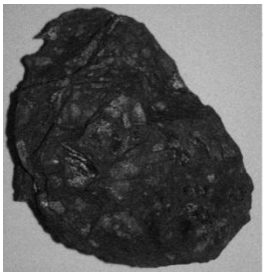
The experiment was performed on samples of coal and gangue. The median filter was used for smoothing grayscale image, removing the isolated noise points and it ensured the edges of the coal and gangue. The results obtained after using median filter is shown in Figure 2.



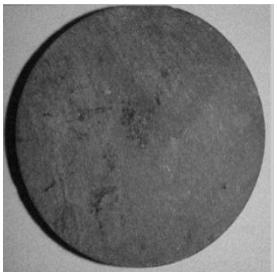
(a) Coal original image



(b) Gangue original image



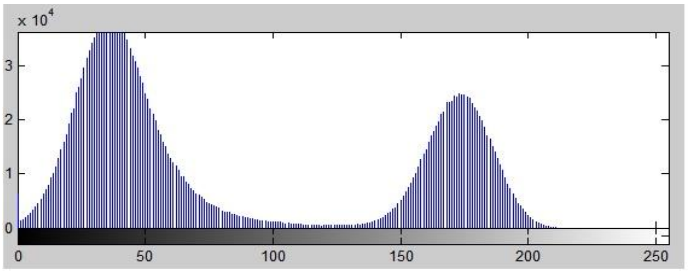
(c) Coal image



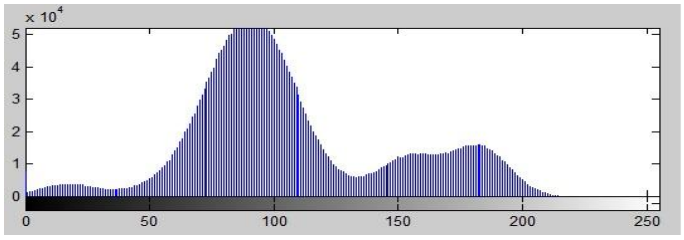
(d) Gangue image

Figure 2: Results of median filter

Their histograms of the images were plotted in Figure 3. Comparing them, it was observed that the grayscale value of the coal image was smaller as compared to gangue image. It was observed that the gray scale distribution curve of coal was towards left side of the graph indicating its color as black and the gray scale distribution curve of gangue was in the middle of the graph indicating its color as gray-white.



(a) Coal grayscale histogram



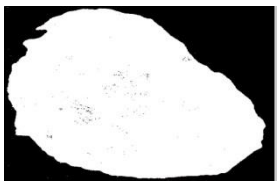
(b) Gangue grayscale histogram

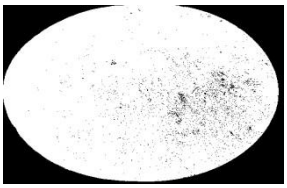
Figure 3: Grayscale histogram

The basic idea of threshold algorithm is to segment the objects from the background image according to their gray value differences. Then threshold t was selected, and each pixel was converted as followed:

$$S(i,j) = \begin{cases} 1, r(i,j) > t \\ 0, \ r(i,j) < t \end{cases} \quad (3)$$

The s(i,j) in the formula indicates the pixel in corresponding location after the conversion[10]. The threshold value t for this experiment was 120.The coal and gangue image segmentation based on threshold were shown in Figure 4





(a) Coal image after threshold segmentation (b) gangue image after threshold segmentation

Figure 4: Threshold segmentation

Mean and variance of the images were calculated and then compared to the standard sample based on which coal and gangue could be separated.

TABLE 2: COAL-GANGUE SAMPLE

Image	Mean	Variance
Coal	40.37	189.65
Gangue	85.85	199.70

According to the Table 2, the mean and variance of coal were 40.37 and 189.65respectively. The mean and variance of gangues were 85.85 and 199.70 respectively. Comparing them, the mean and variance value of the coal was smaller than the gangue. Results proved that the separation of coal and gangue can be done by mean and variance values.

5 Conclusion

In this article, a digital image processing technique was proposed to separate gangue from coal. The median filter was used to reduce noises of gangue images. The histogram images of the coal and gangue explored the grayscale value distribution. Based up on the grayscale value distribution a threshold value was selected for segmenting the coal and gangue from the background. Gangue image was detected based on features extracted from histogram thresholding. Test results demonstrated the performance on coal and coal gangue recognition with real-time processing speed.

6 References

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