The Application of Digital Image Processing in the Monitoring of the Coking inside the Boilers of Thermal Power Plants

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Abstract: ***The prospective aspects of the application of digital image processing in the field of monitoring the coking process inside the boilers in thermal power plants are discussed. Timely monitoring the dynamics of the coking is an important issue to the safety of thermal power plants. Digital image processing is an effective technique to fulfill this monitoring. Edge detection and wavelet transform serve as accurate tools to investigate the ash images captured by the high-speed camera to inspect the coking. Edge detection finally presents the boundary contour of the coking zone. The advantage of wavelet transform over Fourier transform is that the former obtains not only the information on the frequency but also the information on time.***

Keywords: digital image processing; coking; safety; edge detection; wavelet transform

1. Introduction

Boiler, acting as a steam generator, is an important device in thermal power plants. The role of the boiler is to use the energy of the fuel (such as coal and natural gas) to give heat to water that finally becomes high pressured steam. The coking on the surfaces of the tubes inside the boilers is inevitable in thermal power plants. During the process of coking, the ash agglomerate and the thickness of the ash increases gradually. This eventually results in the decrease of the evaporation rate of the boiler and the increase of the temperature inside the boiler. Moreover, the thermal efficiency of the boiler is decreased, and the pipe walls are inclined to be broken due to the coking. So timely inspection on the coking and qualitatively assessing the change of the situation of the ash accumulated is crucially important to the safety of the boiler [1-5]. Nowadays, with the development of artificial intelligence and the power of computers, digital image processing [6-15] has been widely employed in engineering to do classification, pattern recognition, diagnosis, and etc. Research on edge detection [6-8] and wavelet transform [9-15] are very active to offer effective solutions to in a variety of engineering fields. The two methods can also be used in enhancing the performance of the safety monitoring systems in thermal power plants.

2. Edge Detection

Figure 1: Original image of the coked tubes

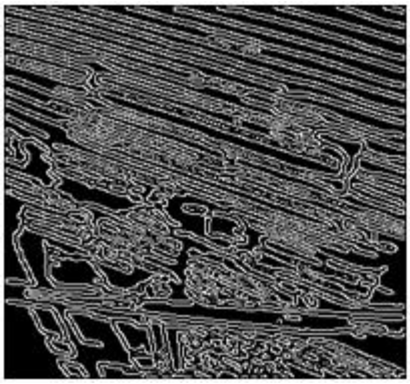

Figure 2: The result of the edge detection

A digital image can be viewed as a function with two variables x and y that are the coordinates in the X and Y directions respectively. Note that x and y are integers because a digital image is a discrete signal. For a point (x, y) in the image, there is a corresponding value $f(x, y)$ that represents the pixel value. The gradient the pixel is defined as:

$$\nabla f = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix} \quad (1)$$

And the absolute value of the gradient is defined as:

$$g = [G_x^2 + G_y^2]^{1/2} = [(\frac{\partial f}{\partial x})^2 + (\frac{\partial f}{\partial y})^2]^{1/2} \quad (2)$$

Generally, for an algorithm of edge detection [15], the first step is to remove some noise in the image by filters (the commonly used filter is Gaussian filter), the second step is to obtain the gradients of the pixels' intensities, the third step is to use gradient thresholding to get rid of spurious response to edge detection, and the fourth step is to suppress all the other edges that are disconnected to strong edges.

Fig.1 shows the coked tubes image captured by a high-speed camera in Wangqu Power Station in the city of Changzhi which is in Shanxi province, China. In fig.2, the result of the edge detection on the image of fig.1 is presented. The boundary contour of the tubes is detected, but the ash on the tubes and the edges of the tubes are not distinguishable. Canny edge detector [15] is used to achieve the result shown in fig.2.

3. Wavelet Transform

In a wavelet transform, the signal is decomposed into a set of base functions including contractions, expansions, and translations of a mother function. This allows us to capture both the temporal and spectral characters of the signal. Wavelet transformations only allow changes in time extension, instead of shape. The continuous wavelet is defined as:

$$C\left(a,b;f(t),\varphi(t)\right) = \int_{-\infty}^{\infty} f(t)\frac{1}{a}\varphi^*\left(\frac{t-b}{a}\right)dt \quad (3)$$

where $\frac{1}{a}$ represents the scaling, and $\frac{t-b}{a}$ represents the change of the frequency.

Commonly used wavelets include Haar, Daubechies, Symlets, Coiflets, and Biorthogonal [15]. Haar wavelet is the simplest. Daubechies wavelets are a family of orthogonal wavelets and the corresponding transform is discrete and intended to maximize the number of vanishing moments. Symlet wavelets are a modified version of Daubechies wavelets with increased symmetry. Coiflets belong to discrete wavelets. As to a Biorthogonal wavelet transform, it is not necessarily orthogonal, but it is invertible.

Choosing which kind of wavelet depends on the specific nature of the problems. As to the application of wavelet in digital image processing, it belongs to a multi resolution analysis in which the signal is approximated at progressively coarser scales, and it is also needed that the differences between approximations at consecutive scales are stored.

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