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Researching on filtering processing algorithm for conveyor belt surface images

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ABSTRACT

The research analyzes the role conveyor belt played in the modern production and the significance of image processing on the conveyor belts surface, and by applying machine visual detecting system to obtain the images of conveyor belts surface and studying them with filtering processing algorithm it mainly researches the smooth spatial filtering algorithm and frequency domain filtering algorithm, of which the former studies the mean filter and the median filter while the latter studies the ideal low-pass filter and the ideal high-pass filter. Meanwhile, it applies these two algorithms to process conveyor belts surface images, which reflects the noise of images on the conveyor belts surface can be lowered while the quality of images be improved and the object to be identified can be separated from the background images to identify the fault. This research in this paper will widely be applied to detecting conveyor belts surface images.

KEYWORDS

Conveyor belts surface images; Smooth spatial filter; Frequency domain filter.

INTRODUCTION

The conveyor belt is a key part of belt-shaped transmission machine for traction and carrying, widely used in such spheres of engineering as mine, port, chemical engineering, metallurgy, electric power and cement. It is one of the main transporting machine in modern production and its working condition directly determines enterprise's productivity and ensures safety in production.

The main faults on conveyor belts surface include deviation, tearing, crack and damage. The main reasons that devoted to these faults are from the aged conveyor belt owing to its long-term use under harsh environment, increased load, bad lap joint and vulcanization, scratching from such foreign objects and obstacles as scrap iron and coal gangue, inappropriate installation and adjustment (the skew carrying idlers, improper driven roller installation, uneven roller sticky material and wear and improper adjustment of conveyor's tension device) and uneven load caused by blanking malposition of reprinted point.

THE ACQUISITION OF CONVEYOR BELT SURFACE'S IMAGES

This research applies machine visual detecting system to obtain conveyor belts surface images. The detecting system is built on the theory of diffuse reflection principle of light and the process is similar to human being using the diffuse reflection to reflect images of objects in the eye.Light outputted from the source shines on the surface of conveyor belt to form diffuse reflection, the intensity of which is determined by the surface characteristic, and the surface images information is formed by absorbing the light signal that taken by camera and reflected from conveyor belt surface. Then these images are transmitted to the computer. In this paper the conveyor belt it detected is used for mine and its parameters are as follows, the largest width is 2.0m and the maximum running speed is 6m/s. The detecting accuracy requires that the image resolution is no less than 1.0×1.0m in width direction and movement direction.

The Components of Machine Visual Detecting System

Its main components involve image acquisition and transmission, image processing and fault identification as shown in Figure 1. The image acquisition and transmission module is responsible for real-time acquisition and long-distance transmission of conveyor's running image and image processing module for realizing rapid processing of image while fault identification module for detecting the surface faults and once happened reporting to police.

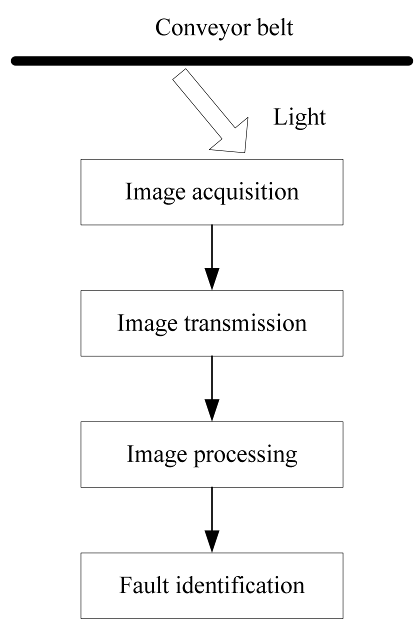

Figure 1 : The Machine Visual Detecting System Block Diagram of Conveyor Belt

The Hardware Composition of Machine Visual Detecting System

The camera that system applied is linear CCD with model as MVC2048DLM-CL19, pixel as 2048, the highest line frequency as 19kHz and two lens as 10mm SIGMA and 20mm Nikon, which meet system's requirements.

The light source is linear light with the width of 1m. For such wide conveyor belts, the linear light they needed will be long enough. So multiple linear light source can be jointed together to lower the cost.

Based on selected camera, lens and linear light source, using a desktop (2.4GHz Pentium4 CPU and 1280MB Memory) equipped with gigabit network card to construct an experimental platform for conveyor visual detecting system,

shown in Picture 2. The width is 1m, the thickness 12mm, total length 10m, specifications as ST1000 and the highest running speed is 6m/s with stepless speed regulation.
The experimental platform is as shown in Figure 2.

Figure 2 : Experimental Platform for Machine Visual Detecting System

Conveyor Belt Surface's Original Image

The conveyor belt surface's original image it acquired by using machine visual detecting system is as Figure 3.

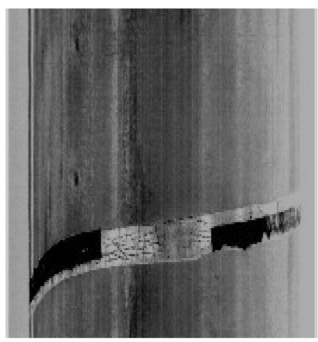

Figure 3: Conveyor Belt Surface's Original Image

The purpose of processing the original image is to lower noise and improve image quality, and on the other hand is to separate the objects to be identified from the background image to identify faults. Here it applies smooth spatial filtering algorithm and frequency domain filtering algorithm to process conveyor belt surface's images.

SMOOTH SPATIAL FILTERING

The smooth spatial filter introduces template to work domain operation on images in the image space, the value of processing image pixel being obtained from calculating the pixel value in the domain of input pixel. To lower the noise, applying linear and nonlinear filter to delete the details of image, usually the mean filter and the median filter.

Mean Filter

Mean filter (also be called linear filter) mainly uses neighborhood averaging, which is a local spatial domain processing algorithm. Setting an image f (x,y) as an array of N×N and the processed image as g(x,y), to determine the gray level of each pixel by calculating the average value of several pixels' gray level contained in (x,y) domain, that is, the processed image can be calculated by the following formula.

$$g(x, y) = \frac{1}{M} \sum_{(i, j) \in S} f(i, j) \quad (1)$$

In the formula, $x, y = 0, l, 2, \ldots, N-1$, S is assemblage of domain around (x, y) and M is the total amount of coordinates in S. The difference of neighborhood domain radius determines the different effects achieved by using neighborhood averaging, the larger the radius the higher the blurring degree. In addition, image neighborhood averaging algorithm is simple and has rapid calculated speed while the mean filter itself has inherent defect, that is, it can not perfectly protect the image detail and will destroy the detail when used to delete noise, which will make images become blurring and the function of deleting noise cannot perform well.

Median Filter

Median filter, a nonlinear filter, doesn't need the statistical characteristic of image in actual precalculation process but needs to sequence all pixels in neighborhood domain according to their gray level and chooses the median as the gray value of window's central pixel. The median filter is widely used in image processing domain, for to some noises it is able to eliminate noises well and causes less blurring than the same size linear filter produced. It performs excellently in the presence of unipolar or bipolar noise.

Median filter has a good effect on eliminating noises and restraining pulse interference and protecting edges from blurring, playing special role in the phase analysis and processing method of measuring optical stripe image. In image processing, it can be used to protect edge information and be regarded as classic method of eliminating noises.

Supposed one-dimensional sequence as g_1, g_2, …, g_m and the length of window as n (n is odd number), then applying median filtering processing to process this sequence. Thus from the input sequence first continuously selecting n numbers g_{i-u}, …, g_{i-1}, g_i, g_{i+1}, …, g_{i+u}, of which $g_i$is the value of window's central point, u=(n-1)/2,then sequence these values,the median number as output and the formula is as follows.

$$y_i = med\{g_{i-u}, \cdots, g_i, \cdots, g_{i+u}\},\ i \in Z\ ,u = \frac{n-1}{2} \tag{2}$$

The mathematical formula of two-dimensional median filter is:

$$y_{ij} = \underset{M}{med}\{g_{ij}\} \tag{3}$$

And M refers to sliding windows, usually being set as 2×2, 3×3 and $\{g_{ij}\}$ the data sequence in two-dimensional median filter.

The process of median filter is shown in Figure 4.

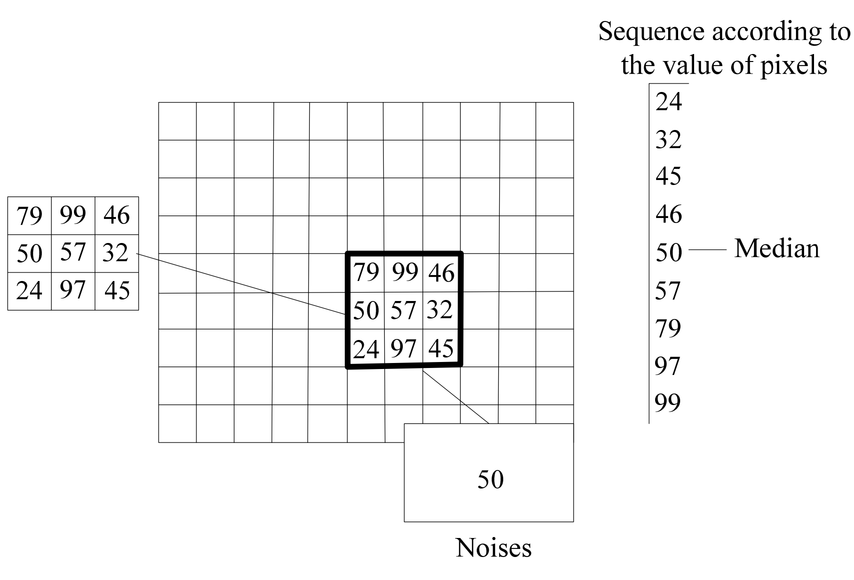

Figure 4 : Diagram of 3×3 Neighborhood Domain Median Filter

Images of Smooth Spatial Filtering Processing

The images acquired from applying smooth spatial filtering processing algorithm to process are shown in the following Figure 5.

(a)Original image **(b)Image after mean filtering** **(c)Image after median filtering**

Figure 5 : Conveyor Spatial Smooth Filtering Image

From the above images, we know after filtering the conveyor image is enhanced obviously, which is good for the further image processing and fault identification.

FREQUENCY DOMAIN FILTER

In fact, frequency domain filter will restrain the component of some range in the frequency domain space and ensure other components are kept in the same value to change the frequency distribution of output image and strengthen images. The original image $f(x,y)$ transforms to $F(u,v)$ under the guidance of Fourier transformation, then applies the appropriate filter function $H(u,v)$ to adjust the spectral components of $F(u,v)$ and finally obtains the strengthening image $g(x,y)$ by inverse Fourier transformation. According to the difference of frequency transmitting function $H(u,v)$, it can be classified as low-pass filter, high-pass filter and homomorphic filter.

Ideal Low-pass Filter (ILPF)

The working principle of ideal low-pass filter is to keep the low frequency components and eliminate the high frequency components. The edges and noises of images corresponds to the high frequency part of image Fourier transformation, so the low-pass filter in frequency domain can be used to eliminate or weakened the consequence of noises and make the edge profile blur, which is similar to the smooth filtering method of spatial domain filter. Ideal low-pass filter is one of the low-pass filter, its transmitting function is expressed as Formula 4 and frequency response function diagram is shown in Figure 6.

$$H(u,v)=\begin{cases}1 & D(u,v)\le D_0\\ 0 & D(u,v)>D_0\end{cases} \quad (4)$$

$$D(u,v)=\sqrt{u^2+v^2}$$

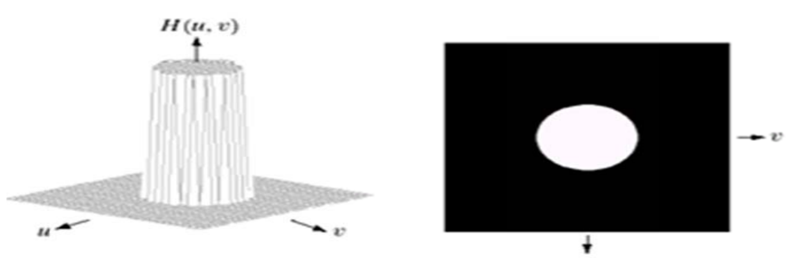

Figure 6 : Frequency Response Function Diagram

Although ideal low-pass filter is defined mathematically, the filter that goes up and down straightly in the cut-off frequency place can be realized in computer simulation but not by the electron device in actual condition. However, in computer simulation the result image processed by ideal low-pass filter is fuzzy and ringing. The common low-pass filter we used includes Butterworth low-pass filter（BLPF） and Gaussian low-pass filter (GLPF).

The image result of conveyor belts surface processed by ideal low-pass filter is shown in Figure 7.

(a) Original image (b)Ideal low-pass filter image

Figure 7 : Conveyor Belts Surface Image Processed by Ideal Low-pass Filter

Observing from Figure 7, we find that the conveyor image processed by ideal low-pass filter is fuzzy and unclear, difficult to do further processing.

Ideal High-pass Filter (IHPF)

From the experimental results of low-pass filter above, we know the high frequency components of Fourier transformation will blur image. For the rapid change in the edge of gray level or other places relates to high frequency, image sharpening can be realized by high-pass filter in frequency domain while the attenuated low frequency part will not disturb the high frequency information of Fourier transformation and its transmitting function can be expressed by the following formula.

Of the formula $H_{hp}(u,v) = 1 - H_{lp}(u,v)$, $H_{lp}(u,v)$ represents the transmitting function of ideal low-pass filter. Compared with low-pass filter, IHPF will set all frequency as 0 in the circle that taking DO as radius without attenuating any frequency that passing out of the circle. And similar with ILPF, IHPF cannot be realized physically but by computer simulation and also has ringing consequence.

$$H(u, v) = \begin{cases} 0 & D(u, v) \le D_0 \\ 1 & D(u, v) > D_0 \end{cases} \quad \textbf{(5)}$$

$$D(u, v) = \sqrt{u^2 + v^2}$$

The image of conveyor belts surface processed by ideal high-pass filter is shown in Figure 8.

(a)Original image (b)Ideal high-pass filter image

Figure 8 : Conveyor Belts Surface Image Processed by Ideal High-pass Filter

CONCLUSION

The research applies machine visual detecting system to acquire the conveyor belts surface images and studies them by filtering processing algorithm, mainly involved smooth spatial filter algorithm and frequency domain filter algorithm, of which the former studies mean filter and median filter while the latter studies ideal low-pass filter and ideal high-pass filter. The experimental result reflects the noise of conveyor belts surface images can be lowered while the quality of images be improved and the object to be identified can be separated from the background images to identify the fault.

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