Research on Belt Longitudinal Tear Technology Based on Visual Inspection

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Keywords: Belt conveyors, longitudinal tear, machine vision.

Abstract: In order to quickly and accurately detect the longitudinal tear of the belt when the belt conveyor is working, this paper proposes a machine vision detection method that uses line laser to assist the belt surface tearing. The "one" word line laser projects a linear laser stripe onto the underside of the belt, uses a CCD camera to capture the image, and through a series of processing to determine whether longitudinal tearing occurs, and if so, locates the crack. First, the acquired image is pre-processed, the required features are enhanced, the interference is suppressed, and the laser stripe region is extracted, thereby improving the detection efficiency. Then, the image is fitted, rotated, and projected to determine the location of the suspect area. Finally, the threshold method is used to determine whether the suspicious area has a longitudinal tear. The experimental results show that the method is fast and accurate and can meet the requirements of belt inspection.

1. Introduction

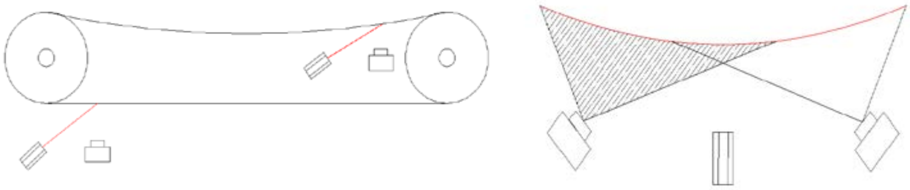
Belt conveyors are the main equipment for transporting coal, ore, etc. Due to the fast running speed and long distance of the conveyor, once a tearing accident occurs, it must be detected and stopped in time. If it is not effectively solved, it will cause damage to the belt of tens of meters or even hundreds of meters, which will lead to major safety accidents such as production stoppage, equipment damage and casualties[1]. For belt tear detection, domestic and foreign experts have tried a variety of methods, such as roller abnormal force detection method, ultrasonic method, electromagnetic detection method and X-ray method, but they are not ideal [2].

With the development and maturity of machine vision technology, as well as non-contact, real-time and active control, it has a wider range of applications. By analyzing the tear characteristics of the belt, it is known that there is a significant difference between the surface of the torn belt and the surface characteristics of the intact belt, which is easy to realize by using image feature analysis. Therefore, visual technique can be used to complete the longitudinal tear detection.

2. Design of laser-based longitudinal tearing machine vision inspection system

This paper uses machine vision technology to extract the tear features in the image through an image acquisition device (CCD camera) mounted under the belt to complete the tearing accident on the belt surface as shown in Fig. 1(a).

This design wants to use two cameras to image the left and right sides of the belt, so that the acquired data is more comprehensive and wider, and the method is also suitable for the belt with a larger width. The line laser emitter and the CCD camera are mounted under the belt conveyor, and the line laser emitter is at an angle to the direction of movement of the belt conveyor, and the CCD camera is perpendicular to the lower surface of the belt conveyor as shown in Fig. 1(b) .



(a) Detection device diagram (b)Image acquisition system

Fig. 1 The conveyor belt image acquisition system based on machine vision.

3. Pre-processing

3.1. Image filtering

Due to the complex environment, dust and darkness of the system, the original pictures collected by the CCD camera often contain a lot of interference information, so we need to perform image preprocessing. Preprocessing can not only improve the quality of the image, but also make the image easier to be recognized by the computer, which facilitates the analysis and extraction of subsequent tear features. Due to the method used in this paper, only the state of the laser line in the longitudinal tear image collected by the CCD is concerned, and the stripe state of the laser line is used to judge whether the belt is longitudinally torn [3]. We need to preprocess the original image (Fig. 2) to make the laser line in the image more significant and improve the detection efficiency.

As a nonlinear filter, median filtering is widely used. For many types of random noise, median filtering has good denoising ability, and at the same size, it has very little edge blur compared to the mean filter. In particular, median filtering has a very good effect on reducing salt and pepper noise. The noise with higher frequency in the research process is salt and pepper noise and Gaussian noise. Therefore, this topic uses median filtering to remove noise during the research process.

3.2. Image enhancement

The purpose of image enhancement is to highlight the required feature information, suppress other irrelevant information, improve the visual effect of the image, prepare for subsequent feature extraction, improve detection efficiency, and satisfy the detection performance of the system. The surface image of the conveyor belt collected by the CCD camera is black, and the laser line is a thin line with high brightness in the gray image. The detection system is interested in the morphological changes of the laser line in the image, so it is necessary to enhance the laser line of the portion of interest while weakening the conveyor belt itself of the uninteresting portion. From this analysis, we use the piecewise linear gradation transformation to enhance the laser line, and weaken the surface of the conveyor belt itself, which is more conducive to the extraction of the features of the torn image.

3.3. Region of interest (ROI)

The choice of ROI is to extract the red stripe region area and remove the image outside the edge. The red stripe region of interest is cropped to about 700*50 pixels image from the original image of 800*600 pixels, which aims to eliminate the redundancy areas of image so that reduce the amount of data processing and improve the speed of image processing [4].

3.4. Image segmentation

Threshold segmentation is a simple and effective image segmentation method. The method divides the gray level of an image into several parts with one or several thresholds, and regards pixels belonging to the same part as the same area. OTUS is also called: the largest inter-class method. This algorithm is the method of automatically determining the threshold value to maximize the variance between classes. It is based on the principle of decision analysis or least squares method. It is a convenient and feasible threshold selection method.

First, a gray threshold T in the gray level range of the image is determined, and then the gray value of each pixel in the image is compared with this threshold T into two categories. The process can obtain the output image gray scale.

$$B(x,y)=\begin{cases}0 & F(x,y)<T\\ 255 & F(x,y)\geq T\end{cases} \tag{1}$$

Find the average gray of the image

$$u_T = w_0 u_0 + w_1 u_1 \tag{2}$$

In the equation (2), w_0 and w_1 are the image ratios of the feature portion and the background portion, respectively. u_0 and u_1 are the average gray scales of the feature portion and the background portion, respectively.

T is traversed from the minimum gray value to the maximum gray value, and when

$$\delta^2 = w_0(u_0 - u_T)^2 + w_1(u_1 - u_T)^2 \tag{3}$$

Is the maximum, T is the optimal threshold for the segmentation [5].The image after segmentation is shown in Fig. 3.

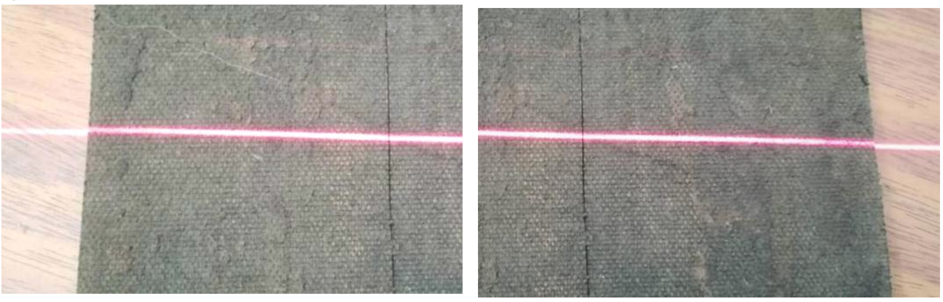


Fig. 2 Original image

Fig. 3 Image segmentation

4. Image Processing

4.1. Straight line fitting and rotation

The most basic and most commonly used curve fitting is straight line fitting. Let the function relationship between x and y be solved by the linear equation

$$y = a_0 + a_1 x \tag{4}$$

There are two unknown parameters in the formula, a_0 for the intercept and a_1 for the slope. For the m sets of data (x_i,y_i)obtained by equal precision measurement, i = 1, 2, ..., m,x_i values are considered to be accurate, and all errors are only associated with y_i .

The observation data is fitted to a straight line by the least squares method below. Require the smallest sum of squares of residuals, that is

$$\sum_{i=0}^{m}[y_i-(a_0+a_1x_i)]^2$$

Should have

$$\frac{\partial}{\partial a_0}\sum_{i=0}^{m}[y_i-(a_0+a_1x_i)]^2 = -2\sum_{i=0}^{m}[y_i-a_0-a_1x_i]=0 \tag{5}$$

$$\frac{\partial}{\partial a_1}\sum_{i=0}^{m}[y_i-(a_0+a_1x_i)]^2=-2\sum_{i=0}^{m}[y_i-a_0-a_1x_i]=0 \tag{6}$$

Get

$$\begin{cases} a_0=\dfrac{(\sum x_i^{\ 2})(\sum y_i)-(\sum x_i)(\sum x_iy_i)}{m(\sum x_i^{\ 2})-(\sum x_i)^2} \\ a_1=\dfrac{m(\sum x_iy_i)-(\sum x_i)(\sum y_i)}{m(\sum x_i^{\ 2})-(\sum x_i)^2} \end{cases} \tag{7}$$

We already know the slope a_1 of the fitted line, find the tilt angle α of the line by the inverse tangent function, and then rotate the image by α degree around its center point. When α is positive, it rotates counterclockwise. When α is negative, it rotates clockwise.

4.2. Projection positioning

First, the horizontal projection is used to find the approximate area where the laser line is located, and then the vertical projection is used to search for suspicious areas where longitudinal cracks of the belt [6].

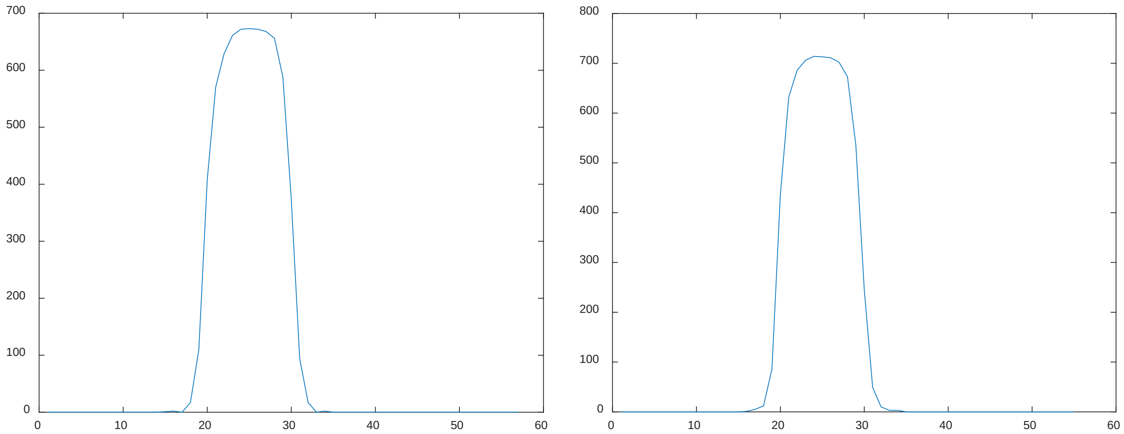


Fig. 4 Horizontal projection

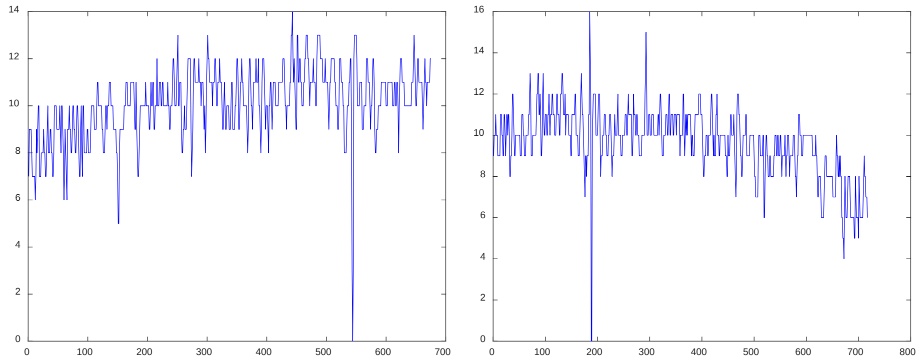


Fig. 5 Vertical projection

It can be seen from Fig. 4 that after horizontal projection, a projection peak appears around 20 to 30 lines, that is, the position of the laser stripe is about 20 to 30 lines. After that, the vertical projection is as shown in Fig. 5. It can be clearly seen that the left figure shows the suspicious area of the longitudinal tear of the belt in about 540 columns, and the right figure is about 190 columns.

5. Experimental result

When we find the suspicious area where the belt is longitudinally torn, the area is judged by the number of white pixels, and whether the longitudinal tear actually occurs. Set a threshold, when the final value is greater than the threshold, the belt is not longitudinally torn, that is, this picture is positive; when the final value is less than the threshold, the belt is torn, that is, this picture is negative. The final experimental results are as follows:

As can be seen from the Fig. 11, the belt tears occur in both pictures, and the distance from the crack to the left or right edge of the belt can be known. Together with the width of the belt we know, it can be determined that the cracks in the two figures are the same crack.

6. Conclusion

This paper proposes a detection method that uses line laser to assist in the longitudinal tearing of the belt surface. The image acquired by the CCD camera is pre-processed to enhance the required features, eliminate interference and extract the region of interest, reduce unnecessary redundancy calculation, and improve detection efficiency. The position of the suspect area is then determined by straight line fitting, rotation, and projection. Finally, the threshold method is used to determine whether the suspicious area has a longitudinal tear.

Experiments show that the method can detect the longitudinal tearing of the belt well and can determine the distance from the longitudinal tearing position to the edge of the belt, which has a good application prospect.

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