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The application of improved Roberts operator in crimping detection

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ABSTRACT

In production, if the tow used in cigarette has the edge rolling problem, it will have an effect on the quality of production. Consequently, finding out the rolling tow has become one of the urgent problems and has important significance. According to the feature of crimping tow, gray the G component of RGB image and use Roberts operator to deal with the edge rolling tow from the view of image processing. And combine with binarization, filtering and other methods to simulate and calculate the width of tow exactly to judge whether the tow is crimping. Compared with classical Roberts operator, the improved operator detects more accurately and also meets the need of system. Solidify the algorithm to the system of hardware, the issue has been solved by the system and it can detect the tow online. The result indicates that the operator can detect the crimping tow well, accurately and efficiently.

KEYWORDS

Image processing;
Edge detection;
Roberts operator;
Binarization;
Median filtering.

INTRODUCTION

At the present stage, the research of the tow used in cigarette mainly focus on the original material of tow, and by the way of changing the ingredients and production process of tow to improve quality. Using the method of image process to detect tow's shape can also improve the quality. The research of crimping tow has not an institute feasible scheme, only to borrow the other edge detection algorithm, find the similar of image to achieve the goal of crimp detection. For example, we can get inspiration from Research on an improved Roberts algorithms used in welding line identification[1], High Voltage Transmission Line Infrared image edge detection[2] and so on.

The tow used in cigarette has the similar width about 3.5cm. In industrial production, there is some difference because of existing waving, crimping tow's width is about 2/3 even smaller of standard tow, and this phenomenon belongs to unqualified tow in produce. The tow images discussed in experiment are based on strong light source and white background from tow detection system, so can get the tow image with stable environment. Therefore, we use improved Roberts operator, combine with binarization, and median filter together to detect crimping tow and reach the most effective detection and online detection's aim.

THE THEORY AND COMPARISON OF EDGE DETECTION

The detection of crimping tow is judged to use edge

detection. As we all know, in several field of image process, such as pattern recognition, robot vision, feature extraction, image segmentation, image compression and so on, they act edge detection as basic implement. Normal edge detection algorithms have Roberts algorithm[3-6], Laplacian algorithm[7], Sobel algorithm[8] and Prewitt algorithm[9].

Roberts operator

Roberts edge detection algorithm utilizes the theory which acts the difference of a random pair perpendicular direction as gradient's approximate solution; use the difference between adjacent pixels on the diagonal substitute gradient solver. If $f_x = f(i, j) - f(i + 1, j + 1)$, and $f_y = f(i, j + 1) - f(i + 1, j)$, the convolution and operator of *fx* and *fy* are shown as follow:

$$f_x : \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \quad f_y : \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix} \tag{1}$$

And the use of differential expressed as follow:

$$G(i, j) = |f(i + 1, j + 1) - f(i, j)| + |f(i, j + 1) - f(i + 1, j)| \tag{2}$$

Laplacian operator

Laplacian operator adopts second-order differential operator, and its operation is defined as follow:

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} \tag{3}$$

For digital images, Laplacian operator can be simplified as follow:

$$g(i, j) = 4f(i, j) - f(i + 1, j) - f(i - 1, j) - f(i, j + 1) - f(i, j - 1) \tag{4}$$

Laplacian operator functions can also be achieved by means of a template, common template is:

$$G_x = \begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix} \quad G_y = \begin{bmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{bmatrix} \tag{5}$$

Sobel operator

The operator contains two sets of 3×3 matrix, respectively horizontal and vertical, and then has a plane convolution, which can get the luminance difference approximation of horizontal and vertical. Sobel operator can be shown as follow:

$$S_s = (d_x^2 + d_y^2)^{\frac{1}{2}} \tag{6}$$

Where the templates of d_x, d_y are shown as follow:

$$d_x = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix} \quad d_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \tag{7}$$

Prewitt operator

Prewitt operator is first-order differential operator edge detection, use pixels up and down, left and right neighbor of gray-scale difference to achieve extremum edge detection, remove part of the pseudo-edge, and have a smoothing effect of noise. The principle is that using two directions template and the image neighborhood convolution to accomplish in the image space. These two directions template are horizontal and vertical edge detection. Prewitt operator can be shown as follow:

$$S_p = (d_x^2 + d_y^2)^{\frac{1}{2}} \tag{8}$$

Where the templates of d_x, d_y are shown as follow:

$$d_x = \begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix} \quad \mathrm{d}_y = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} \tag{9}$$

Comparison of algorithm

Combing the theory of the above four kinds operator, detect grayscale images of crimping tow by four kinds of operators respectively, and get the detection results of each operator as figure 1.

Four kinds of edge detection operator have their own strengths and weaknesses. To detect crimping tow, should be based on the characteristics of tow itself, and improve traditional detection operator, so as to achieve a real-time online detection.

CONFIRMATION AND IMPROVEMENT OF EDGE DETECTION ALGORITHM

To detect crimping tow, by full advantage of difference between colors, find up and down edges of tow, confirm the place of crimping tow.

Confirmation of edge detection algorithm

Tow in industrial production runs with 10m/s high speed. In order to meet the speed requirements of the

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detection, algorithm of tow crimping detection and analysis of the data require as simple as possible. Therefore, take the use of system stability, and analyze the middle of several columns in the acquired images. It reduces the amount of data analysis, to ensure the accuracy and effectiveness of the detection.

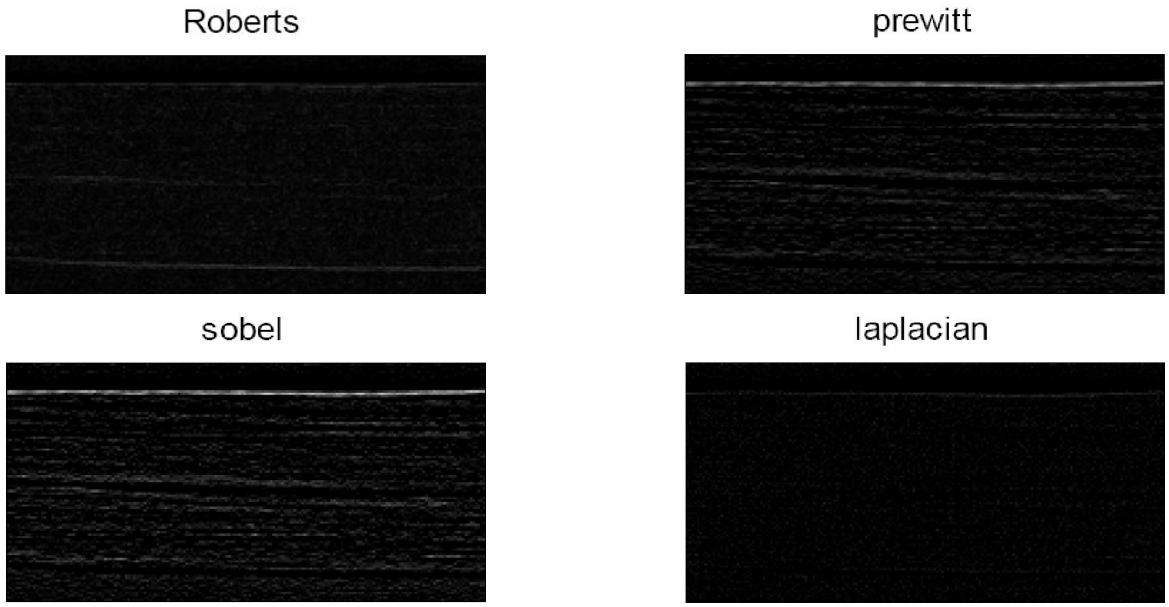

Figure 1 : Results of four kinds edge detection

Crimping tow has some shadows because of the environmental impact, and the shadows' exist makes the tow images have peak mutations on the edges. Its change of peak is the key to detect crimping tow. Use several columns in middle of the image to numerically analyzed, and choose the best detection from Roberts operator, Sobel operator, Prewitt operator and Laplacian operator. Compared with Roberts operator, Sobel operator, Prewitt operator and Laplacian operator, they only can detect one peak, even no peak. So, three operators are not suitable for crimping detection.

In summary, we select Roberts operator to detect crimping tow images. Since the algorithm is a 2×2 matrix, its numerical analysis of the peaks is not obvious, but its advantage is to meet the system requirement for running speed. To make the numerical analysis peaks more obvious and detect crimping tow more accurately, we need to improve Roberts operator based on the theory.

The improvement of detection algorithm

Improved detection algorithm mainly reflected in two aspects. First, Roberts operator changes in the theory. Second, analyze the images which have been detected deeply, use binarization and filter to find out the exact width of the tow, to achieve the purpose of judgment.

(a) The improvement of Reborts operator

Roberts operator proposed is main based on the mutation of gray value and make a difference of gray value image. For such an RGB tow image, after its grayscale being transited, RGB values have being changed, and lose their characteristic about numerical mutation. Full use of each component's characteristics of the original image, and find out the most obvious impact of color components in image for Roberts operator edge detection that its image process's effect will be better. Roberts edge detection of RGB color components are shown in figure 2 respectively.

From the above components of Roberts operator detection can be seen that Roberts operator detection of three components gets more obvious tow edge than grayscale image. But R and B components have more noise, increase the difficulty of subsequent processing, choose G component for final Roberts operator edge detection. Thus, the improvement of Roberts operator has achieved. The improvement is reflected in grayscale image into G component Roberts operator. The goal is to make the process easier in behind, reduce the computation time and accelerate the detection speed.

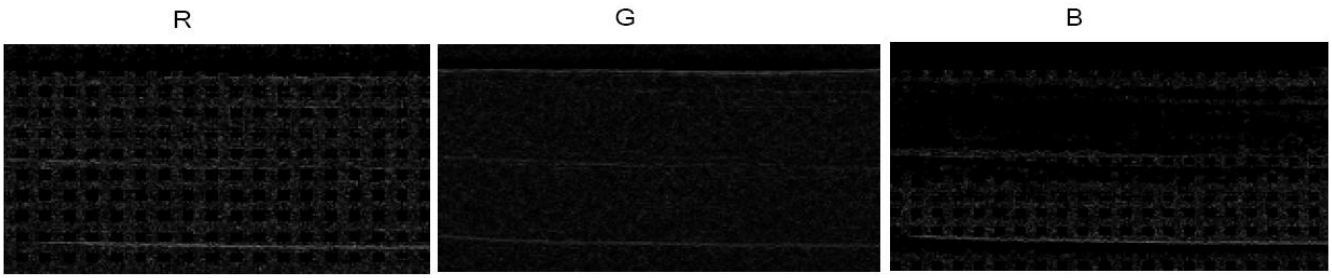

Figure 2 : Three color components of Roberts operator

(b) Binarization and filtering of image

In order to make the G component Roberts edge detection more evident, use binarization[10,11] to process detected image, and the key of image binarization is to find the threshold. Since the condition of tow shooting is very stable, all images have not be great changes in color values, only need to find several random columns in crimping image as a typical. The graph which draws numerical analysis of G component values after operator detection is shown in figure 3, the abscissa is the width of tow and the horizon is the size of the corresponding pixel. The principle of threshold is that judge greater values than threshold as edge points, and judge less values than threshold as background, then can get the binarization shown as figure 4, from graph it can illustrate the actual width of tow. According to this principle of selection, take 25 as threshold value from G component images, and mark it in figure 3. The value is less than 25 sentenced to 0 and greater than 25 sentenced to 255 to achieve the purpose of image binarization.

From figure 3, we can see that there are more than values of two peaks greater than threshold, several values between two peaks are greater than threshold, and those values produce some salt and pepper noise in process. If the threshold is increased, it will make some useful information lost in image, and affect the result of the judgment. In order to detect crimping tow more accurately in computer, need a simple median filter after binarization. Median filter[12-14] is useful for eliminating the isolated points and the interference of lines, and at the time of eliminating noise, it can protect boundary information[15]. The figure after median filter is shown in figure 5:

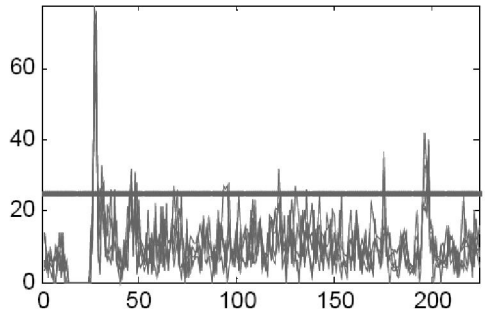

Figure 3 : Choose of threshold

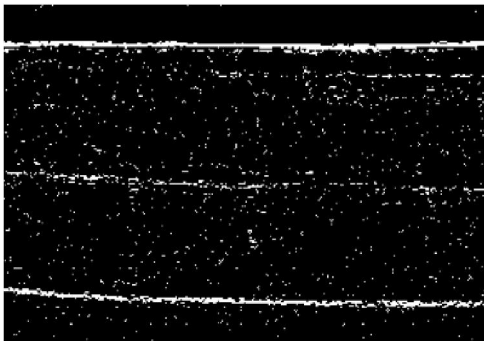

Figure 4 : Image after binarization

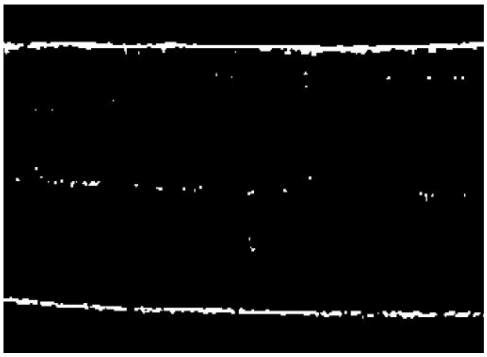

Figure 5 : Image after median filter

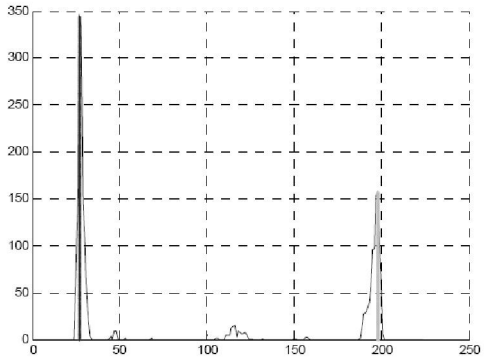

Figure 6 : The width of tow

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The judgment of crimping tow

In order to achieve online detection, we need to analyze data of image which has been filtered, and find the actual width of crimping tow in image. By analyzing data after binarization and filter, we know that there are only 0 and 255 in images, and the pixel of 255 is the width of tow. Only to add up the value of 255 in each line and look out the most two lines of image, and take the distance between the two lines as the width of tow. The actual width of tow can be approximated as the width of image, and the rate of crimping tow can be got by comparing. The standard of judgment is when the ratio of width is less than 0.75, it is determined to crimping tow. Otherwise, it is determined to no crimping. In figure 6, curve shows each row statistic of pixel about a crimping image, there are two peak values which correspond to the edges of tow and the distance between two vertical lines is the width of crimping tow.

THE RESULT OF CRIMPING TOW

Image analysis uses the improved Roberts operator for image edge detection. Instead of the consistent grayscale image detection, the method uses G component of RGB to detect image and reserve some characteristics and data of image itself. On the basis of edge detection, use binarization and filter to detect. Image analysis is also included analyzing image data after filter, using simple methods to judge whether the tow is qualified. It can achieve online detection and ensure high accuracy.

In the field, use the above algorithm to detect crimping tow, which has the accuracy rate of 95% and exceeds the expected achievement of factory. At the same time, the system records the time of crimping tow and the figure of data statistics after image process to make workers more easily find the crimping tow.

SUMMARY

In tow production field, the system uses improved Roberts operator and common methods of image process to make the system real-time, accurate and efficient. Use the G component's gray image of Roberts operator to detect tow, retain the sensitive information of image process and reduce data lost. Meanwhile, the algorithm is simple and will not affect speed of detection.

The above detection method has been able to determine crimping tow accurately, but it remains to be improved. For example, the threshold of binarization image uses a fixed value; it is not able to achieve adaptive selection. In the future, we will focus on research of adaptive threshold algorithm and improve the accuracy of the crimping tow to make the whole system more intelligent and integration testing.

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