Application of the fiber image detection algorithm based on the Grey system theory and Directed graph

Xiaodong Wang[1*], Jianhui Yang[2]

[1]*Department of Mathematics and Physics, Zhengzhou Institute of Aeronautical Industry Management, China*

[2]*School of Mathematics and Statistics, ZhouKou Normal University, Henan, China*

**Corresponding author's e-mail: 2364970768@qq.com*

Received 1 March 2014, www.cmnt.lv

Abstract

After doing research on fiber image with low quality and the Grey prediction model, the Grey correlation degree, directed graph and existing edge detection algorithm, this article proposed a new edge detection algorithm to obtain complete and continuous edge and to improve the defects in traditional operators profiled fiber contour extraction, such as the discontinuous edge, the false edge. This article obtains the fiber outline firstly, and then the edge detection algorithm is applied to the adhesive fibers. Thus, filling algorithm and contour tracking algorithm are used to get the fibers' outer contour. After that applying the directed graph algorithm to edge detection and the complete edge is gained after the burr is eliminated. Proven by the experimental results, the proposed edge detection algorithm can overcome the defects of the conventional edge detection algorithm, such fracture as edge, false edge, etc.

*Keywords: g*rey correlation degree, directed graph, edge detection algorithm, directed graph

1 Introduction

In recent years, digital image processing technology which is widely used in textile industry has obtained certain achievement in the field of fiber composition detection. In the process of the digital image processing, test analysis to the microscopic images of the fiber, the way of extraction from the edge of the fiber, adhesion of the fiber separation accurately has a direct impact on fiber composition detection, is also an important part of fiber microscopic image recognition.

In 1982, the Chinese scholar, Professor Julong Deng proposed Grey system theory which is a new method researching minority and the of poor uncertainty question. In recent years, the Grey system theory received the wide attention of scholars both at home and abroad, the Grey prediction and Grey relational analysis among Grey system theory are applied to the research of edge detection, the corresponding improved algorithm is proposed, the detection has been improved effectively, but cannot meet the requirements of continuous fiber edge. Based on this, this paper proposed edge detection algorithm based on Grey system theory and the direction. This method combined the Grey forecasting model with Niblack algorithm, obtaining the edge of the fiber information for part of the fiber within the phenomenon of false edge, using area filling algorithm, direction graph algorithm and contour tracking algorithm to extract the edge of fiber completely.

Some domestic scholars attributed the problem of the image edge detection to poor information uncertainty systems, the Grey system theory is applied to the image edge detection, and has achieved certain results. Application of Grey system theory in this paper is mainly the Grey prediction model GM (1, 1) and Grey absolute correlation degree, which is used to detect the fiber edge. Among them, the Grey prediction is based on the difference between the size of the gray gradation values of a predicted image and the actual point of the gray value to determine whether the point is an edge point; while the gray correlation is mainly based primarily on collating sequence associated with the reference sequence determine whether the point is an edge point.

2 The basic principles of Grey prediction

Through the neighborhood in one-pixel point build Grey prediction equation, and then use the Grey values of these points and the establishment of Grey prediction equations to predict this pixel Grey value, if the difference between the predicted and the actual value of the pixel Grey values is in the predetermined threshold value, the pixel is considered with its neighborhood in the same Grey value Grey on stage, which does not think the point of this pixel on the image edge; otherwise, consider this pixel and its neighborhood is not the same Grey level, which determines the pixel is an edge point of the image. This method takes full advantage of the mutation of edge point gray value.

This algorithm in this paper is mainly based on fiber Grey value and the background on the edge of the area and the characteristics of internal Grey value of relatively large differences. Its basic algorithm thought: put image in the each pixel points corresponding to gray value considered initial series of Grey forecast model, then, put image in the pixel points x and its neighborhood pixel points into original sequence, accumulate the original sequence by using data processing for a regular series of Grey modeling, again for

Grey forecast, after getting the forecast value sequence, for data reduction by that point in the actual forecast data, if the difference between forecast value and actual value is larger, which is for edge points, otherwise, for non-edge points. The main steps of the algorithm of GM (1,1) model are shown as follows:

1) Let the original sequence as

$$x^{(0)} = (x_{(1)}^{(0)}, x_{(2)}^{(0)}, \cdots, x_{(n)}^{(0)})$$

2) Generates a sequence for the record

$$x^{(1)} = (x_{(1)}^{(1)}, x_{(2)}^{(1)}, \cdots, x_{(n)}^{(1)})$$

among them,

$$x_{(k)}^{(1)} = \sum_{i=1}^{k} x_{(i)}^{(1)} \quad k = 1,2,...,n.$$

3) $z^{(1)}$ is close to $x^{(1)}$ as the mean value generates a sequence

$$z^{(1)} = (z_{(2)}^{(1)}, z_{(3)}^{(1)}, \cdots, x_{(n)}^{(1)})$$

among them,

$$z_{(k)}^{(1)} = 0.5x_{(x)}^{(1)} + 0.5x_{(k-1)}^{(1)}, \quad k = 2,3,...,n$$

4) GM (1,1) model that is an order of one yuan gray model, which is defined as

$$x_{(k)}^{(0)} + az_{(k)}^{(1)} = b$$

where a is a factor of development; b is the Grey action.

5) The whiting model of GM (1,1) is

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = b$$

6) The albino-response of GM (1,1) is

$$\hat{x}_{(k+1)}^{(1)} = (x_{(1)}^{(0)} - \frac{b}{a})e^{-ak} + \frac{b}{a}$$

$$\hat{x}_{(k+1)}^{(0)} = x_{(k+1)}^{(1)} - \hat{x}_{(k)}^{(1)}$$

7) Under the least-squares criterion parameter

$$\begin{bmatrix} a \\ b \end{bmatrix} = (B^T B)^{-1} B^T y^n$$

among them,

$$B = \begin{bmatrix} -z_{(2)}^{(1)} & 1 \\ -z_{(3)}^{(1)} & 1 \\ \vdots & \vdots \\ -z_{(n)}^{(1)} & 1 \end{bmatrix}, \quad y^n = \begin{bmatrix} x_{(2)}^{(0)} \\ x_{(3)}^{(0)} \\ \vdots \\ x_{(n)}^{(0)} \end{bmatrix}.$$

The strong edge detection based on Grey prediction of Grey forecasting model of image edge detection studies focus on the sequence of points on the options, and options for sequence points improvements are only detects the edges more informative, does not meet the requirements of full fiber edge. Based on Grey forecast detection out of edge exists serious of fracture phenomenon, but its can accurate to find fiber edge of location, this paper has a new idea, puts Grey forecast application into fiber image of strong edge of detection, based on strength edge connection of thought, and put this strong edge and by Niblack value of the two algorithm get of weak edge for connection, then get fiber of edge information.

Based on the Grey prediction model in sequence point selection scheme and fiber image Gray scale characteristics analysis, the paper selected 12 masked sequences, and choose GM(1,1) model to model, thus get the strong edge in the fiber. The specific Grey prediction algorithm of the main steps is described below.

Let the size of an M×N image I, the Grey value of midpoint $I(i, j)$ is $g(i, j)$, $i = 1,2,...,M$, $J = 1,2,...,N$

1) For each pixel in the image I, in turn, use mas sequences and GM (1,1) model to calculate the gray forecast value of the center point x and constitutes the forecast image II.

2) Original I minus the predicted figure II get error images III, its gray value of each point is $\xi(i, j)$.

3) According to the error histogram of the image, the threshold value T, if $\xi(i, j) > T$, the pixel image $B(i, j) = 1$ is the binary image of strong edges, otherwise, $B(i, j) = 0$, thus, getting the binary images of edges obtained by gray forecast model.

3 Grey correlation degree

Basic principles of grey correlation degree.

According to the gray correlation analysis of the gray system theory, the size of the gray correlation reflects the reference sequence and comparative sequence similarity. According to the different features between the gray value of the image edge points and the gray value of the background area is large, it is understood that the edge and its neighboring pixel values consisting of comparison sequence associated with the reference sequence is relatively small. The calculating process of Grey absolute correlation degree is described as follows.

The calculation steps of correlation degree is as follows.

Let the reference sequence $X_0 : \{x_i(k), k = 1,2,...,n$, comparison sequence $X_i : \{x_i(k), k = 1,2,...,n$.

1) Initialization:

$$Y_0:\{\frac{x_0(k)}{x_0(1)}=y_0(k),\quad Y_1:\{\frac{x_i(k)}{x_i(1)}=y_i(k)$$

Initialized so that all sequences comparable.

2) Calculate the correlation coefficients of each point:

$$r(y_0(k),y_i(k))=\frac{1}{1+|(y_0(k+1)-y_0(k)-y_i(k+1)-y_i(k))|}$$

where $k=1,2,\ldots,n-1$.

3) Calculate the correlation degree:

$$r(x_0,x_i)=\frac{1}{n-1}\sum_{k-1}^{n-1}r(y_0(k),y_i(k))$$

4 Extract the region of interest based on grey correlation

In this paper, through the analysis and research on the Grey correlation degree, and basing on the gray value changes of background regions in fiber image is small and characteristics of gray value change of fiber internal is larger, the Grey correlation degree is applied to fiber area, namely extraction of region of interest, and realize the innovation of Grey correlation degree of application. In this paper, on the basis of predecessors' research to improve the selection of comparison sequence, were selected for eight neighbourhoods, up, down, left and right of four neighborhood pixels were composed of comparison sequences. So the selection of two comparison sequence, respectively

$$k_1=(g_{i,j},g_{i-1,j},g_{i+1,j},g_{i,j-1},g_{i,j+1},g_{i-1,j-1},g_{i-1,j+1},g_{i+1,j-1},g_{i+1,j+1}$$

$$k_2=(g_{i,j},g_{i-1,j},g_{i,j},g_{i,j-1},g_{i,j},g_{i,j+1},g_{i,j},g_{i+1,j},g_{i,j}$$

and let an equivalent sequence $k_0=(1,1,1,1,1,1,1,1,1)$ as reference sequence. $g(i,j)$ as the gray-scale values of point $I(i,j)$. The algorithm steps are as follows:

1) Determine the reference sequence k_0, and according to point $I(i,j)$ of the original image to determine the comparison sequence $k_1(i,j)$ and $k_2(i,j)$.

2) Absolute correlation $r_1(i,j)$ and $r_2(i,j)$ were calculated between k_0 and $k_1(i,j)$ with $k_2(i,j)$, take $r(i,j)=\min(r_1,r_2)$, whereby correlation diagram.

3) Threshold T is determined by the histogram of correlation chart, if $r(i,j)>T$, $I(i,j)$ is not a region of interest; otherwise, $I(i,j)$ is the region of interest and obtain a binary image of the region of interest.

5 Principles of pattern

Pattern is used on the outline of each pixel in the direction to fiber images. Using edge direction of gradient operators obtained method has been widely used, including: divide the image into small M×M window, for each pixel within the window according to the Sobel operators calculate the gradient along the horizontal and vertical direction G_x and G_y and the angle θ. If the image size is M×N, the Grey value of point $I(i,j)$ in image is $g(i,j)$. Its specific calculation steps are as follows:

1) Calculation of the horizontal gradient:

$$G(i,j)=\sum_{u=i-m/2}^{i+m/2}\sum_{v=j-m/2}^{j+m/2}S_x(m,n)\cdot g(i+m,j+n)$$

among them,

$$S_x=\begin{bmatrix}-1&0&1\\-2&0&2\\-1&0&1\end{bmatrix}.$$

2) Calculation of the gradient of the vertical direction:

$$G_x(i,j)=\sum_{u=i-m/2}^{i+m/2}\sum_{v=j-m/2}^{j+m/2}S_y(m,n)\cdot g(i+m,j+n),$$

where

$$S_y=\begin{bmatrix}-1&-2&1\\-2&0&2\\-1&2&1\end{bmatrix}.$$

3) Calculating the direction of the edge angle

$$\theta(i,j)=\arctan\left(\frac{G_y(i,j)}{G_x(i,j)}\right),$$

among them,

$$G(i,j)\neq 0,\ -\frac{\pi}{2}<\theta(i,j)<\frac{\pi}{2}.$$

6 Edge detection based on direction

We can find out the image edge according to the direction of graph algorithm, and carries on the increase, but the direction graph algorithm is prone to edge discontinuity and fracture phenomenon. Therefore, this ideological pattern and bound algorithm is applied to the gray prediction, gray correlation degree and Niblack value of the two algorithm to obtain fiber outer contour map strengthen, which can be used to overcome the weaknesses of pattern edge detection

algorithm, thereby detecting the outer contour of the complete fiber, while the adhesion can be well separated from the fibers, the purpose of the fiber can be accurately detected edge information.

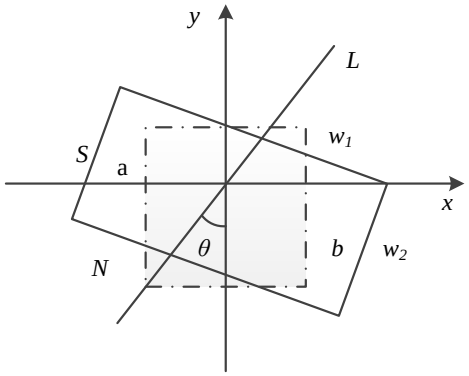

FIGURE 1 The diagram of direction graph

Because fiber edge line and profile directions are basically the same, so it can be based on edge direction of consecutive points on a line to define the outline of the current direction. Graph edges define algorithm motioned in the direction as shown in Figure 1, the image is divided into 3×3 fiber widget w_1 (shown in dashed box in Figure 1), the average direction of the inner edge points w_1 substituted approximation to the center direction of the contour direction, and assume the contour true direction is L, and the contour line L is the vertical angle θ. While setting the window defining edge w_2=S×N (solid line rectangle in Figure 2, the selected paper size 3×5), w_1 and w_2 coincide with the center phase, S-side of the fiber parallel to the contour line L, N-sided contour line L and perpendicular to the fiber. Then, based on the image obtained by the Sobel operator for each point along the horizontal, vertical gradients G_x and G_y, and the direction angle θ. Using of Canny operator edge points obtained contour and the statistics of the number of edge points. Then according to the contour line L divided W_2 into two parts a and b, respectively, a and b values of statistical gray midpoint, and the two parts with respect to the calculation of the membership of the contour line L, and to determine the true profile by the fuzzy search in order to detect the edge of the fiber, to be separated from the effect of the adhesion area.

7 Algorithm in this paper

Based on fiber identification system to extract the full edge of the grey prediction and grey correlation degree requirements and characteristics, this paper presents a grey forecasting, grey correlation degree and direction graph based edge detection algorithm, the algorithm flow as shown in Figure 2.

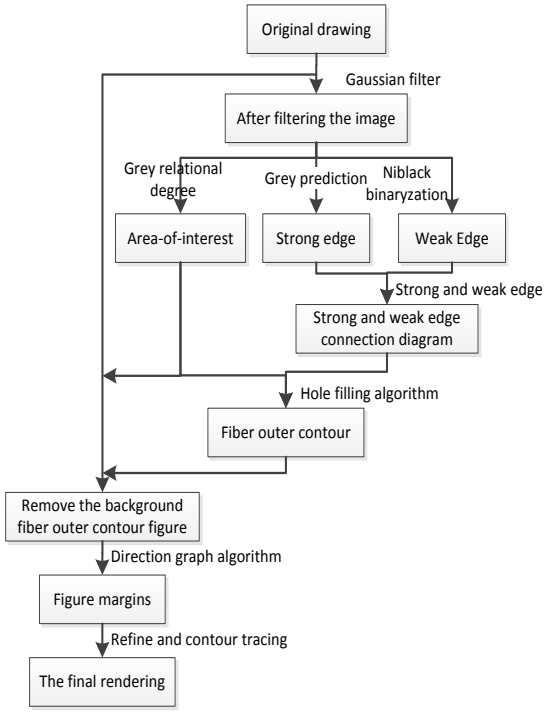

FIGURE 2 The algorithm process

This algorithm example schematic is shown in Figure 3.

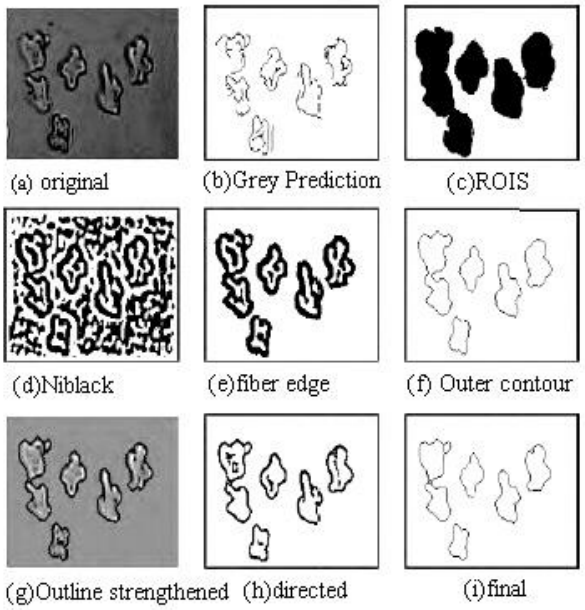

FIGURE 3 The diagram of proposed algorithm

1) The use of Gaussian filter pre-treatment original Figure 3a;

2) Using the algorithm of Grey prediction and Grey correlation degree towards the filtered images obtained in Figure 3b of the edges as shown in diagram and Figure 3c shows regions of interest;

3) The strong edges obtained from the gray forecast connected to the weak edge map from the Niblack value algorithm (Figure 3d), and then combined with the region of interest, the edge of the fiber are obtained as shown in Figure 3e;

4) The cavity is filled by the algorithm (for filling fiber edge map and use contour tracking algorithm, and obtained as shown in Figure 4f of the external profile;

5) For the adhesion of the fibers, the outer contours and regions of interest to get this article combined with the original, non-interested in image area fills to mean, and (4) the obtained fiber on the outer profile is added to the original image, to obtained in Figure 3g as shown in the background of the outer contour of the fibers to strengthen;

6) Using pattern-and-bound algorithm for edge detection, obtained as shown in Figure 3h are shown in the picture, and then refine and use contour model tracking algorithm for removing burrs, and obtained as shown in Figure 3i the ultimate fiber edge.

8 Experimental results and analysis

This article selects 320 fiber images as experiment objects, including the MTS form, VY type, W type, U type, cross five types of fiber image. By the algorithm in this paper and the other edge detection algorithms fiber edge detection results are shown in Figure 4. The Figure 4 shows that although these fibers original image edge is not obvious, the phenomenon such as adhesion. This algorithm can well extract fiber edge information. But the Log operator, Prewitt operator is not well detected fiber weak edge, and the fracture phenomenon is serious. Canny operator can better extract the weak edge fiber, but the phenomenon of false edges are prone to fracture; background level set algorithm for image noise pollution is not serious, which can better extract the outer contour of the fiber, but cannot apart the fibers adhesions , when noise pollution is serious. The method cannot find the outline of the fibers accurately. The proposed algorithm has better robustness, with good noise immunity, and out of the fiber edge detection both accurate and complete, but also avoiding the LOG operator, Prewitt operator, Canny operator edge algorithms are prone to false fracture edges and phenomena, but also overcoming the noise pollution level set algorithm is sensitive to defects and shortcomings cannot be separated adhesions fibers. Algorithm on adhesion of fiber can effectively detect the adhesive part of the contour lines, achieving accurate segmentation of complex fiber image purposes.

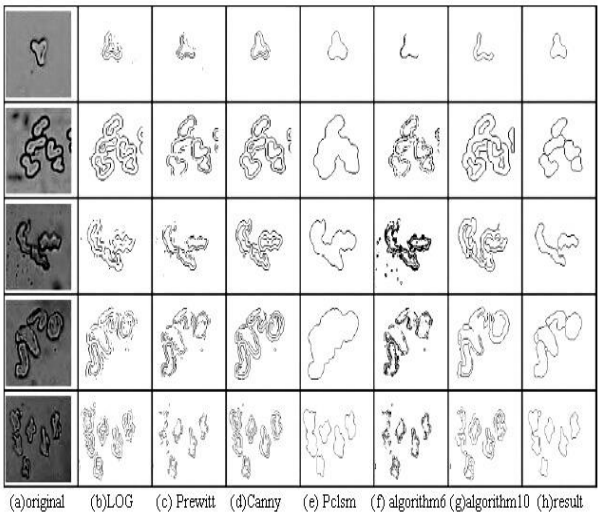

FIGURE 4 comparison with other edge detection methods

5 Conclusions

This paper is based on the situation LOG operator, Prewitt operator, Canny operator and gray prediction model and gray correlation algorithm used double edge and contour extraction fiber fracture edge of existence. This algorithm not only can extract the edge of the fiber image accurately, but also can get the edge of the adhesive fibers effectively, which provide a guarantee of the subsequent separation and identification. And the level set algorithm cannot extract the exact position of the edge and fiber adhesion defects cannot be separated, on the basis of gray system theory, the use of algorithms to detect patterns of fiber edge and using contour tracking well removing, which reach the purpose of a good prospect of noise suppression, detection of precise and continuous fibers edge. The results of this study for subsequent fibers separation provide a very good foundation.

References

[1] Miao Ma, Song-yun Xie, etc 2003 The image edge detection new algorithm based on Grey system theory *Chinese journal of image and graphics: A edition* **8**(10) 1136-9
[2] Liu S, Fang Z-g, etc 2010 *The grey system theory and its application* Beijing: science press 195-210
[3] He R, Chen J 2005 Image edge detection based on grey prediction model *Journal of northwestern polytechnical university* **23**(1) 15-8
[4] Siddiqi K, Bouix S, etc. 2010 Hamilton-Jacobi Skeletons *Computer Version* **48**(3) 215-31
[5] Dimmit P, Phillips C, Siddiqi K 2008 Robust and Efficient Skeletal Graphs *IEEE Conf. Computer Vision and Pattern Recognition* 1417-23
[6] Mayya N, Rajan V T 2004 Diagrams of Polygons: A Framework for Shape Representation *IEEE Conf. Computer Vision and Pattern Recognition* 638-43
[7] Nello, Shawe-Taylor J 2003 An Introduction to Support Vector Machines and Other Kernel-based Learning Methods *Cambridge University Press* **7**(12) 23-5
[8] Deng J Basic Methods of Grey System Wuhan: Huazhong University of science and technology press
[9] Jie Yan 2006 Image edge algorithm based on grey relational analysis and Canny operator *Computer engineering and application* (28) 68-71
[10] Xue-lian Li 2011 Grey system theory and its application in medical image processing Harbin engineering university