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Research on Rapid Image Recognition Method of Foreign Fibers in Lint

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Abstract—An efficient online method of detecting the foreign fibers in lint is proposed. In this method, Look Up Table is used to reduce the time consumption of transformation from RGB color space to HSI color space effectively. Using the improved two-dimensional Otsu algorithm to segment and recognize the image of foreign fibers in Hue and Saturation of HSI color space. Experimental results show that, compared with the original two-dimensional Otsu algorithm and the fast two-dimensional Otsu algorithm, the proposed method meets the requirement of real-time and improves the accuracy effectively.

Index Terms—Foreign Fibers, Look Up Table, HSI color space, Otsu.

I. INTRODUCTION

The lint is the basic material of textile industry. Foreign fibers are non-cotton fiber or clutter which are mixed in the lint in picking, trading, transporting or processing link, such as chemical fibers, animal hair, plastic film, color line(rope) and cloth. Although less foreign fibers content in lint, the defects and the yarn breakage in spinning, which are caused by foreign fibers, would seriously affect the quality of cloth [1]. In order to remove the foreign fibers, the most textile enterprises use artificial sorting method at present, which is inefficient, low detection and high cost. With the difficulties of recruitment and increase of labour costs, this method is not sustainable obviously. Therefore, researching a real-time and accurate online detection method has an important significance for improving the quality of lint.With the improvement of automation in textile industry, Machine Vision Technology has been applied to the online detection of foreign fibers in lint and got a great progress. In [2], one-dimensional Otsu algorithm is proposed to recognize gray-level image of foreign fibers. In [3], the authors recognize the foreign fibers by reducing the traversing range of two-dimensional Otsu algorithm. The authors in [4] recognize the foreign fibers by different densities when X-ray penetrates the lint. In [5], Otsu algorithm and Gabor filters are adopted to recognize the foreign fibers image. Various segmentation methods have their respective advantages and disadvantages. Although the above methods have their own certain effect, the time consumption most algorithms processing is long, which is difficult to satisfy the requirement of real-time for high-speed online detection system. This paper proposes a foreign fibers detection method which is based on improved two-dimensional Otsu algorithm.

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Experimental results show that, the proposed method satisfies the requirement of real-time and improves the accuracy effectively.

II. IMAGE ACQUISITION AND QUANTITATIVE ANALYSIS

The core of the foreign fibers detection device is digital image recognition system, which is divided into fluorescent lights detection and UV lights detection. The lights detection devices are composed of different CCD cameras and light source. The basic structure of the image acquisition is shown in Figure 1.

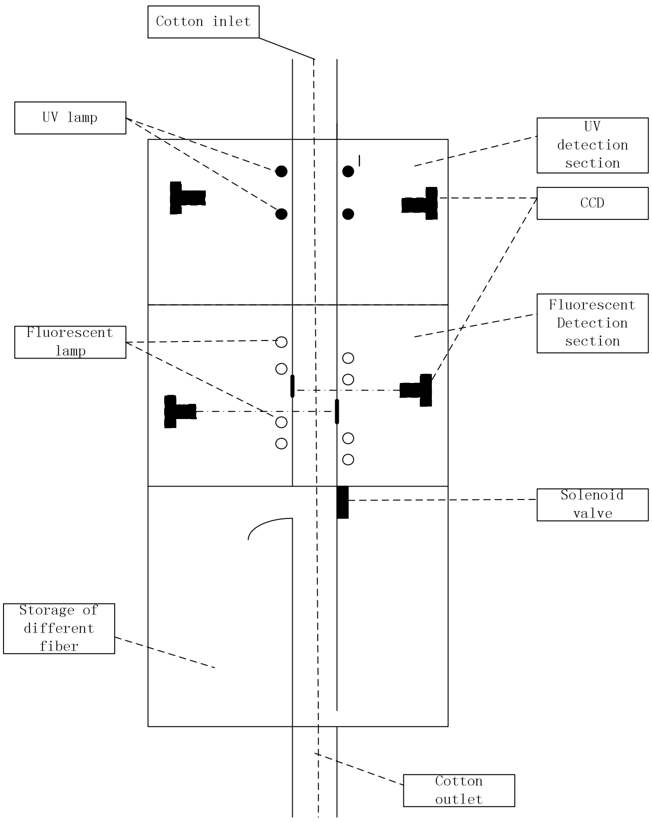

Fig. 1: The Basic Structure of Image Acquisition

The UV lights detection device is used to detect the white or similar color foreign fibers that emit bright fluorescence under the irradiation of ultraviolet ray. The Dalsa S2-1x-02k40 is used as CCD camera, which is a black and white linear array camera. About this camera, 2048 effective pixels per line and line frequency reachs up to 18KHz. Nikon 35MM F/2D AF is used as lens and F408LB is used as black light source. The fluorescent part, which is used to detect colored foreign fibers, is the main content of this paper. The CCD camera adopts JAI CV-L107CL model that is color linear array camera based on RGB splitting prism. The CV-L107CL model camera has 2048 effective pixels per line, and its line frequency can reach 19KHz. Nikon 35MM F/2D AF is used as lens and Philips TL-D 90 De Luxe is used as

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light source. In order to get a high resolution lint image, the line scanning frequency is set at 7000 lines/s, 2048 effective pixels per line and the horizontal lint road is 1200mm wide. Therefore, the horizontal resolution is 0.585mm. Assuming the velocity of lint flow is 10m/s, the resolution on flight direction is 1.429mm. A 70 lines color image acquisition requires 10ms, it also means, in order to meet the requirement of real-time, the completion time which contains the image transmission, converting from RGB color space to HSI color space, foreign fibers recognition and other operations, must be less than 10ms.

III. RECOGNITION OF FOREIGN FIBERS

HSI (hue, saturation, brightness) color space is used in this paper. HSI color space has the following advantages:

a. Based on human visual system, the model is totally accord to the way that human eyes describe and explain the color.
b. Hue, saturation and brightness can be separated independently, H component and S component are not affected by I component. A large number of gray-level processing algorithms in image processing and machine vision can be used in each component conveniently.

Experiment platform test of this paper founds that, the time consumption that image acquisition card outputs a 70 lines image in RGB color space is 2ms, the time consumption that image acquisition card outputs a 70 lines image in HSI color space is 20ms. Therefore, a lot of time is consumed at transformation from RGB color space to HSI color space. In order to meet the requirement of real-time, the problem of time consumption must be solved. LUT (Look Up Table) is used to reduce the time consumption of transformation from RGB color space to HSI color space effectively, the strategy use space for time is achieved. Experimental result draws that, through introducing LUT, the time consumption that image acquisition card outputs a 70 lines image in HSI color space is 4ms. As long as the subsequent image recognition algorithm consumes less than 6ms, the requirement of real-time would be met. On the choice of foreign fibers recognition algorithm, the edge segmentation [6] can't guarantee the recognition rate, because the foreign fibers are small and mixed with lint. The algorithm such as neural network and artificial intelligence cannot meet the requirement of real-time because of complexity. An improved two-dimensional Otsu algorithm is proposed to meet the requirement of real-time and recognition rate in this paper. Otsu algorithm [7] means dividing the image into target and background, and taking the maximum variance threshold between target and background as the best segmentation threshold. Although this algorithm is simple, the recognition rate is low because the foreign fibers accounted for a small proportion in the image. The author of [8] extended the Otsu algorithm into two-dimensional. For a gray-level image of m × n, if the value of pixel (i, j) is defined as $f(\mathrm{i,j})$, then the mean value of 3×3 pixels is :

$$g(\mathrm{i,j}) = \frac{1}{9}\sum_{m=-1}^{1}\sum_{n=-1}^{1} f(\mathrm{i}+\mathrm{m},\mathrm{j}+n) \qquad (1)$$

Therefore, **s**= $f(\mathrm{i,j})$, **t**= $g(\mathrm{i,j})$, if taking Pst as the occurrence probability of (**s, t**), then the two-dimensional histogram with **s**, **t** as the variables and Pst as dependent variable can be shown in Figure 2.

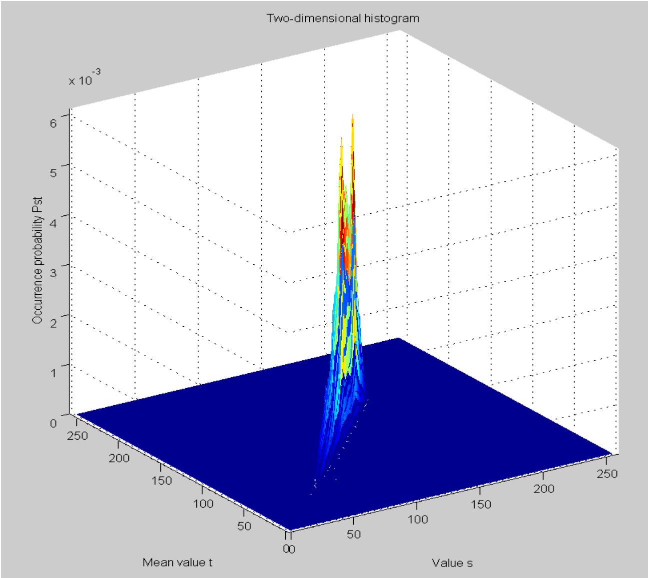

Fig. 2: Two-Dimensional Histogram

Figure 2 shows that most thresholds (**s**, **t**) are located in the area of main diagonal, in other words, **s** is equal to **t** substantially. Figure 3 shows that the two-dimensional histogram divides the **st** plane into four regions: A, B, C and D, which represent the target, noise, background and edge respectively. In most cases, the noise and edge accounts for a small proportion of an image, it is feasible to lead to two-dimensional Otsu algorithm if assuming $Pst\approx0$ in B and D regions as well as $Pst\approx1$ in A and C regions.

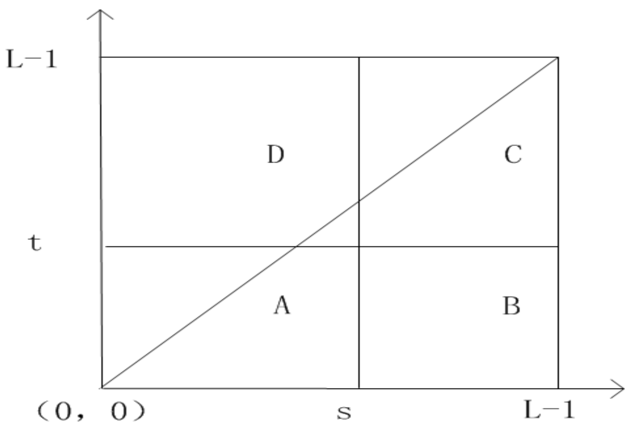

Fig. 3: Distribution of 2D Histogram in ST

Priori probabilities corresponding to the target A and background C are as follows:

$$\omega_a(\mathrm{s,t}) = \sum_{i=0}^{s}\sum_{j=0}^{t} p_{ij}\ ,\ \omega_c(\mathrm{s,t}) = \sum_{i=s+1}^{L-1}\sum_{j=t+1}^{L-1} p_{ij} \qquad (2)$$

p_{ij} represents the joint probability of thresholds (**s, t**) appears, L is the value of gray-scale image, 0≤**s, t**≤L-1. As $p_{ij}\approx0$ in regions B and D, so:

$$\begin{aligned}
&\omega_a(\mathrm{s,t}) \approx \omega_a(\mathrm{s,t}) + \omega_b(\mathrm{s,t}) \approx \omega_a(\mathrm{s,t}) + \omega_d(\mathrm{s,t}) \\
&\omega_a(\mathrm{s,t}) \approx \sum_{i=0}^{L-1}\sum_{j=0}^{t} p_{ij} \approx \sum_{i=0}^{s}\sum_{j=0}^{L-1} p_{ij} \\
&\omega_c(\mathrm{s,t}) \approx \omega_c(\mathrm{s,t}) + \omega_b(\mathrm{s,t}) \approx \omega_c(\mathrm{s,t}) + \omega_d(\mathrm{s,t})
\end{aligned} \qquad (3)$$

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$$\omega_c(s,t) \approx \sum_{i=s+1}^{L-1}\sum_{j=0}^{L-1} p_{ij} \approx \sum_{i=0}^{L-1}\sum_{j=t}^{L-1} p_{ij} \quad (4)$$

The mean vector within the class of regions A and C is:

$$m_a = (m_{ai,}\ \mathrm{m}_{aj})^T \approx (m_{ai} + m_{di,} m_{aj+} m_{bj})$$

$$= (\sum_{i=0}^{s}\sum_{j=0}^{L-1} ip_{ij}/\omega_a, \sum_{i=0}^{L-1}\sum_{j=0}^{t} jp_{ij}/\omega_a)^T \quad (5)$$

$$m_c = (m_{ci,}\ \mathrm{m}_{cj})^T \approx (m_{ci} + m_{bi,} m_{cj+} m_{dj})$$

$$= (\sum_{i=s}^{L-1}\sum_{j=0}^{L-1} ip_{ij}/\omega_c, \sum_{i=0}^{L-1}\sum_{j=t}^{L-1} jp_{ij}/\omega_c)^T \quad (6)$$

The total mean vector of two-dimensional histogram is:

$$m_T = (m_{Ti,}\ \mathrm{m}_{Tj})^T = (\sum_{i=0}^{L-1}\sum_{j=0}^{L-1} ip_{ij}, \sum_{i=0}^{L-1}\sum_{j=0}^{L-1} jp_{ij})^T \quad (7)$$

Define the variance between target and background is:

$$\delta_B = \omega_a[(m_a - m_T)(m_a - m_T)^T] + \omega_c[(m_c - m_T)(m_c - m_T)^T] \quad (8)$$

Use the track $tr\delta_B$ of δ_B as the judgment criterion:

$$tr\delta_B = \omega_a[(m_{ai} - m_{Ti})^2 + (m_{aj} - m_{Tj})^2]$$
$$+\omega_c[(m_{ci} - m_{Ti})^2 + (m_{cj} - m_{Tj})^2] \quad (9)$$

It is found from Eq.3-Eq.7 that ω_a , ω_c , m_{aj} , m_{cj} , m_{Ti} and m_{Tj} can be converted into function without s and ω_a , ω_c , m_{ai} , m_{ci} , m_{Ti} and m_{Tj} can be converted into function without **t**.

If: $X = \omega_a(m_{aj} - m_{Tj})^2 + \omega_c(m_{cj} - m_{Tj})^2$ (10)

$Y = \omega_a(m_{ai} - m_{Ti})^2 + \omega_c(m_{ci} - m_{Ti})^2$ (11)

Then: $tr\delta_B = \omega_a(m_{ai} - m_{Ti})^2 + \omega_c(m_{ci} - m_{Ti})^2$ (12)

It is found that X does not contain **s** and Y does not contain **t**. In this case, the problem seeking the best value of $tr\delta_B$ can be transformed to solve partial derivatives of **s** and **t**:

$$\begin{cases} \dfrac{\partial tr\delta_B}{\partial s} = 0 \\ \dfrac{\partial tr\delta_B}{\partial t} = 0 \end{cases} \quad (13)$$

The partial derivative of $tr\delta_B$ to s:

$$\frac{\partial tr\delta_B}{\partial s} = \frac{\partial(X+Y)}{\partial s} = \frac{\partial Y}{\partial s} = 0$$

$$=> \quad \frac{\partial[\omega_a m_{ai}^2 - 2\omega_a m_{ai} m_{Ti} + \omega_c \mathrm{m}_{ci}^2 - 2\omega_c m_{ci} m_{Ti}]}{\partial s} = 0$$

$$=> \quad \frac{\partial[\omega_a m_{ai}^2 + \omega_c \mathrm{m}_{ci}^2 - 2(\omega_a m_{ai} + \omega_c m_{ci}) m_{Ti}]}{\partial s} = 0$$

$$=> \quad s^* = \frac{1}{2}(m_{ai} + m_{ci}) \quad (14)$$

Similarly getting: $t^* = \frac{1}{2}(m_{aj} + m_{cj})$ .Therefore, two-dimensional Otsu algorithm is improved from traversing the entire defined domains of (**s, t**) to achieve in an iterative way about 20 times. Experimental results show that the complexity of the algorithm is reduced greatly and the requirement of real-time is met. In this paper, the whole flowchart of recognition is shown in Figure 4.

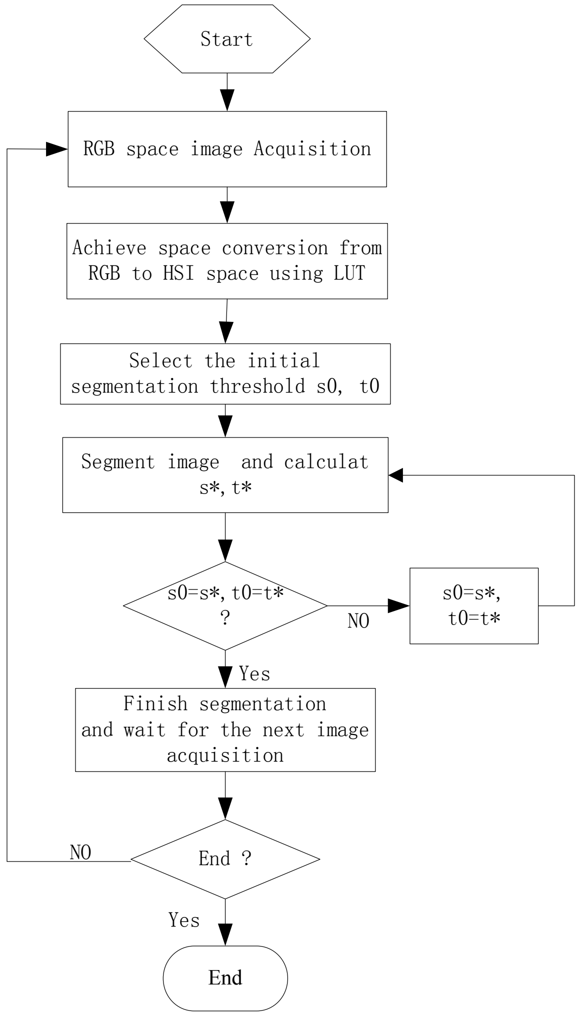

Fig. 4: The Flowchart of the Overall Recognition Method

IV. EXPERIMENTAL RESULTS AND ANALYSIS

The structure is the image acquisition system is shown in Figure 1. Most of white foreign fibers, which glow bright fluorescent under ultraviolet light, are detected by fluorescent part. The emphasis of this paper focuses on the color image recognition of foreign fibers under fluorescent illumination. As already mentioned in this paper, the scanning frequency of high-speed linear array CCD is set at 7000 lines/s, cotton flow speed is about 10 m / s, 2048 effective pixels in the horizontal direction corresponds to 8 solenoid valves, so the pictures size of separate solenoid valve is 70 × 256 (physical dimension is about 150mm length and 100mm width) with 10ms. The image is shown in Figure 5.

Fig. 5: An Acquired Image by High-Speed CCD Camera

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In order to accurately test the recognition rate of the algorithm, using the unified color line which is 40mm length and 1 mm diameter as the sample. A total of seven colors, namely: crimson, orange, dark yellow, light yellow, light green, dark blue and dark purple. Every experiment tests recognition rate in H, S component respectively using 20 color lines through measuring five times. The recognition rate of foreign fibers with different colors is shown in Table 1. From the table, comparing with the recognition rate under S component, the crimson fibers recognition rate under H component is higher， the recognition rate with other colors like Orange, light green, dark blue, dark purple under H component is slightly lower. However, the recognition rate of bright yellow and dark yellow foreign fibers under H component recognition rate is very low, because most of the cotton is not pure white but slightly yellow. The result also proves that H component focuses on the resolution of color tone, while S component focuses on the resolution of color saturation. The overall recognition rate is up to 93.1%.

Table 1. Recognition Rate of Foreign Fibers with Different Colors

	crimson	orange	dark yellow	light yellow	light green	dark blue	dark purple	statistics
H	93	88	23	7	85	96	94	69.4
S	89	91	97	93	86	97	95	92.6
Recognition rate	93	91	97	93	86	97	95	93.1

Take Figure 5 for example, compared the original two-dimensional Otsu algorithm [8], the two-dimensional Otsu fast algorithm [9] and the improved two-dimensional Otsu algorithm under S component the results are shown in Figure 6, Figure 7 and Figure 8. It is observed that, the improved two-dimensional Otsu algorithm can identify the foreign fibers from image segmentation and make good results at the anti-noise ability. The comparison of time consumption among the above three algorithms is shown in Table 2. The time consumption of improved algorithm is 4ms, plus the time consumption that outputting an RGB image and transforming RGB space into HIS space, the time is approximately 8ms, which meets real-time requirements.

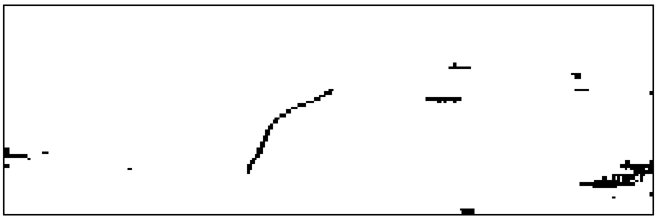

Fig. 6: The Segmented Image by Original Two-Dimensional Otsu Algorithm

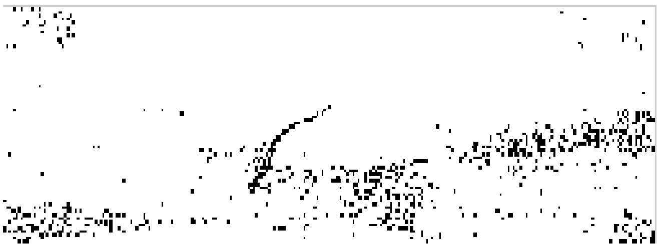

Fig. 7: The Segmented Image by Fast Two-Dimensional Otsu Algorithm

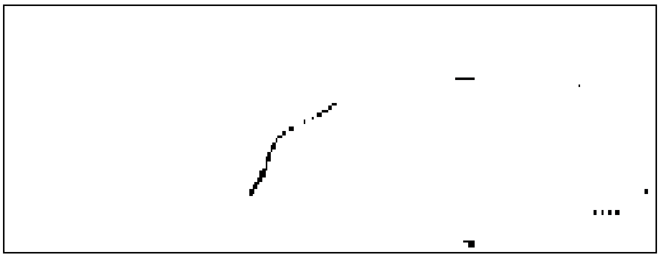

Fig. 8: The Segmented Image by Proposed Algorithm

Table 2. Comparison of threshold and time consumption

Segmentation algorithm	Threshold	time (s)
The original two-dimensional Otsu algorithm	(115, 117)	2.365
The fast Two-dimensional Otsu algorithm	(121, 127)	0.086
The improved Otsu algorithm	(114, 115)	0.004

V. CONCLUSIONS

An improved two-dimensional Otsu algorithm that applies to online detection research of foreign fibers in Lint is proposed in this paper. In this method, Look Up Table is used to reduce the time loss transformation from RGB color space to HSI color space effectively. Using the improved two-dimensional Otsu algorithm to segment and recognize the image of foreign fibers in Hue and Saturation of HSI color space. Experimental results show that, the overall recognition rate is up to 93.1%, which has good practical value. However, the method in this paper is inadequacy to identify foreign fibers which have similar color with cotton like gray polypropylene yarn and are non-fluorescent under ultraviolet light. This problem will be the emphasis of next research.

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