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Skew Correction and Density Detection of Knitted and Woven Fabric

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Abstract

Automatic identification of fabric structure is a vital area of research. The skewing phenomenon is inevitable during the scanning process, so the fabric skew correction method based on projection profile analysis is proposed. First, Butterworth low-pass filter is applied to remove noises after skew correction of the fabric image. Then, power spectrum is obtained by Fast Fourier Transform (FFT), in which the peaks are extracted from the vertical and horizontal direction, respectively. Finally, the reconstructed image is obtained via Inverse Fast Fourier Transform (IFFT) according to the peaks, so that the information of warp and weft can be separated to calculate the warp and weft density. Experimental results show that the accuracy of the skew correction can be controlled within $[-1°, 1°]$, and the detection accuracy of yarn density can reach 98%. The proposed method can accurately detect skew angle and density of woven and knitted fabrics.

Keywords: Skew Correction; Projection Profile Analysis; FFT; Density Detection

1 Introduction

Fabric density is an important parameter to measure the quality of the fabric. As people continue to improve the requirements of textile quality, fabric density detection has become one of the most important steps to ensure the fabric quality in the textile, printing and dyeing industry. The traditional method of density detection takes advantage of the fabric density mirror artificially, which is time-consuming, inefficient and sensitive to subjective factors of human inspectors. Therefore, many researchers have tried to develop a new objective method to measure the yarn density automatically, thereby the efficiency of textile production can be improved.

At present, domestic and foreign scholars have proposed lots of methods to detect the fabric density. J. J. Lin [1] proposed a method based on GLCM to detect fabric density, but it confirmed that the method only applies to the plain fabric density detection. In [2], X. Wang et al. utilized the secondary local maxima for fabric density detection which is only effective for solid color fabric. Dejun Zheng et al. [3] employed a method which combined Radon transform with gray projection to locate and segment the yarn. Then, they completed the calculation of fabric density

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and classification based on fabric woven structure. R. R. Pan et al. [4] made use of gray projection obtained directly from the reflected images to get fabric density. Under this condition, some hairiness among the yarns interstice would lead to large errors for fabric density detection. Wavelet transform was utilized to measure woven fabric density [5]. In [6-8], Fourier transform was applied to get spectrum to extract relevant information, thereby analyzing warp and weft density. Fourier transform was also used to extract vertical and horizontal density of knitted fabric. However, fabric skew was not taken into account [9-11].

A method, which combines FFT with Projection profile analysis, is presented in this paper. The influence of fabric skew is eliminated by this method, and the fabric density can be obtained accurately. The frame of this article is divided into four parts: skew correction, density detection, experimental results analysis and conclusion.

2 Skew Correction

2.1 Projection Profile Analysis Principles

Weft knitted fabric is formed by one or more yarns winding along the vertical and horizontal each other. The cyclical characteristics are obvious, and points which reflect cyclical characteristics can be found in the spectrum [11]. Woven fabrics are usually intertwined by two mutually perpendicular yarn systems, and the yarns are distributed evenly [12].

The situation of skew is inevitable during the scanning process, which will bring considerable difficulties to subsequent image processing. Although the operator can adjust the fabric to right position during the scanning process, there is a certain degree because of the error of the human eyes.

The Projection profile analysis [13, 14] is proposed to correct fabric skew, and the largest amplitude of fluctuation is treated as fabric skew angle. Projection profiles were detected by calculating the standard deviation (SD) between adjacent elements. First, the vertical projection profile (VPP) and horizontal projection profile (HPP) are calculated out. We take average of the sum of the pixel gray-scale in each row and column of the image to obtain HPP and VPP of an image. The image size is M*N, and HPP and VPP are the size of M*1 column vector and 1*N row vector, respectively. The calculation processes are shown in Eq. (1) and Eq. (2) :

$$HPP(x) = \frac{\sum_{y=1}^{N} I_{x,y}}{N}, x \in [1, 2, 3, \cdots, M] \tag{1}$$

$$VPP(y) = \frac{\sum_{x=1}^{M} I_{x,y}}{M}, y \in [1, 2, 3, \cdots, N] \tag{2}$$

where $I_{x,y}$ is the intensity of pixel gray-scale at coordinate(x, y).

HPP is considered in the experiment. Horizontal projection profile differential data vector ($HPPD$) can be computed by the difference between the elements adjacent of HPP. The SD of $HPPD$ and the mean ($\overline{HPPD}$) of $HPPD$ can be computed by using Eq. (3,5) :

$$HPPD = [HPP(2) - HPP(1), HPP(3) - HPP(2), \cdots, HPP(M) - HPP(M-1)] \tag{3}$$

$$\overline{HPPD} = \frac{1}{n} \sum\nolimits_{i=1}^{n} HPPD \tag{4}$$

$$SD = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(HPPD - \overline{HPPD})^2} \tag{5}$$

where n is the number of elements in the original image.

2.2 Projection Profile Analysis Principles

The proposed algorithm for horizontal alignment of the woven and knitted fabric images is as follows:

(1) Input original image I, and turn it to gray-scale image.

(2) Within the scope of [$-10°$, $10°$], the image is rotated in $1°$ increment.

(3) Each rotated image is cropped to avoid the influence of the edge region, as shown in Fig. 1.

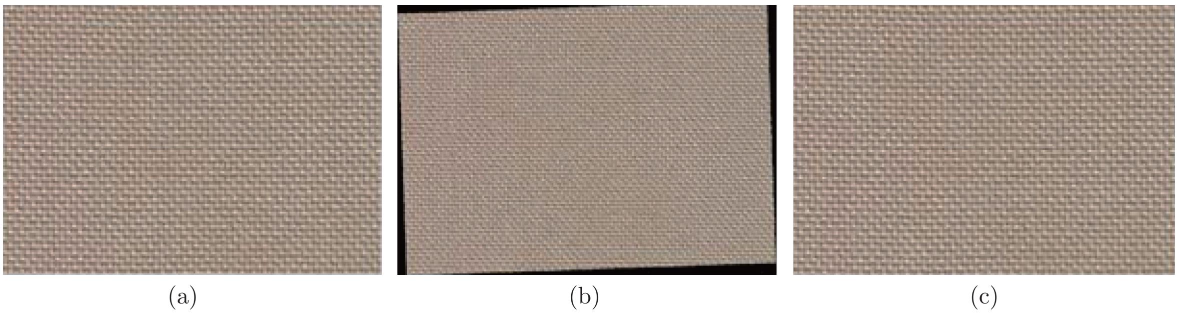


Fig. 1: Image cropping result: (a) Original image; (b) Rotated image; (c) Cropped image

(4) HPP of cropped image is calculated out after each rotation.

(5) $HPPD$ of HPP is computed at each rotation angle.

(6) The standard deviation (SD) of $HPPD$ is calculated out at each rotation angle.

(7) The angle which maximizes the SD value is the estimate of the fabric skew angle.

(8) Image is corrected by the obtained skew angle.

(9) Cut off the edge portion after the correction.

(10) Within the scope of [$-1°$, $1°$], the image is rotated in $0.1°$ increment.

(11) Repeat the processes from (3) to (8).

(12) Output the final result.

The image is rotated in $0.1°$ increment within the scope of [$-10°$, $10°$], and 201 values need to be calculated out. The proposed method requires only 22 calculations, so the efficiency of calculation is greatly improved. The detection accuracy is controlled within [$-1°$, $1°$].

3 Density Detection

3.1 Image Preprocessing

The noise exists mainly in high-frequency part during the image transmission process. To improve image quality, high-frequency component is suppressed and low-frequency is passed by using low-pass filter. So the Butterworth low-pass filter is applied to enhance the image. Then the Inverse Fourier Transform is utilized to obtain filtered image.

The characteristic of Butterworth low-pass filter is continuity attenuation, not as steep as the ideal filter. Supposing the image size is $M*N$, and $D(u,v)$ is the distance from frequency point (u,v) to the origin in the frequency domain. Butterworth low-pass filter is defined by Eq. (6) and Eq. (7):

$$D(u,v) = [(u - M/2)^2 + (v - N/2)^2]^{\frac{1}{2}} \tag{6}$$

$$H(u,v) = \frac{1}{1 + [D(u,v)/D_0]^{2n}} \tag{7}$$

where, D_0 is the cut-off frequency of the filter and n represents the order of the filter. The second-order Butterworth low-pass filter is selected, namely n=2.

3.2 Density Calculation

Since the woven and knitted fabric images contain periodic structures, it is feasible to find points which can characterize the frequency features. In particular, FFT is one of the most commonly used methods to determine periodic characteristics of the image.

The Discrete Fourier Transform (DFT) and Inverse Discrete Fourier Transform (IDFT) can be described by the following Eq. (8) and Eq. (9):

$$F(u,v) = \sum_{x=0}^{m-1} \sum_{y=0}^{n-1} f(x,y) e^{-j2\pi(\frac{ux}{m} + \frac{vy}{n})} \tag{8}$$

$$f(x,y) = \frac{1}{mn} \sum_{u=0}^{m-1} \sum_{v=0}^{n-1} F(u,v) e^{j2\pi(\frac{ux}{m} + \frac{vy}{n})} \tag{9}$$

where u=0, 1, ..., m-1; v=0, 1, ..., n-1. The calculation of DFT is relatively slow. Therefore, the Fast Fourier Transform (FFT) [15] has been developed to reduce the amount of calculation, and the amount of calculation will decrease from n^2 to $nlog_2n$.

The power spectrum is compressed by logarithmic transformation [16]. It is shown as Eq. (10):

$$P(u,v) = log(1 + |F(u,v)|^2) \tag{10}$$

The outline of the image is formed by the low-frequency part, while the edge of the image is constituted by the high-frequency part. Since it is relatively easy to determine the peaks in the power spectrum, power spectral image is effective to analyze the cyclical structures in the original image [11].

In the power spectrum, four brightest peaks, which are close to the origin point, are extracted in the horizontal and vertical directions, respectively. Then, an image can be reconstructed through the two extracted peaks only corresponding to the warp/vertical yarns by the Inverse Fast Fourier Transform (IFFT). Similarly, an image can be reconstructed through the two extracted peaks only corresponding to the weft/horizontal yarns. The results are shown in Fig. 2 and Fig. 3. Eventually, warp/vertical and weft/horizontal density can be calculated based on the two reconstructed images.

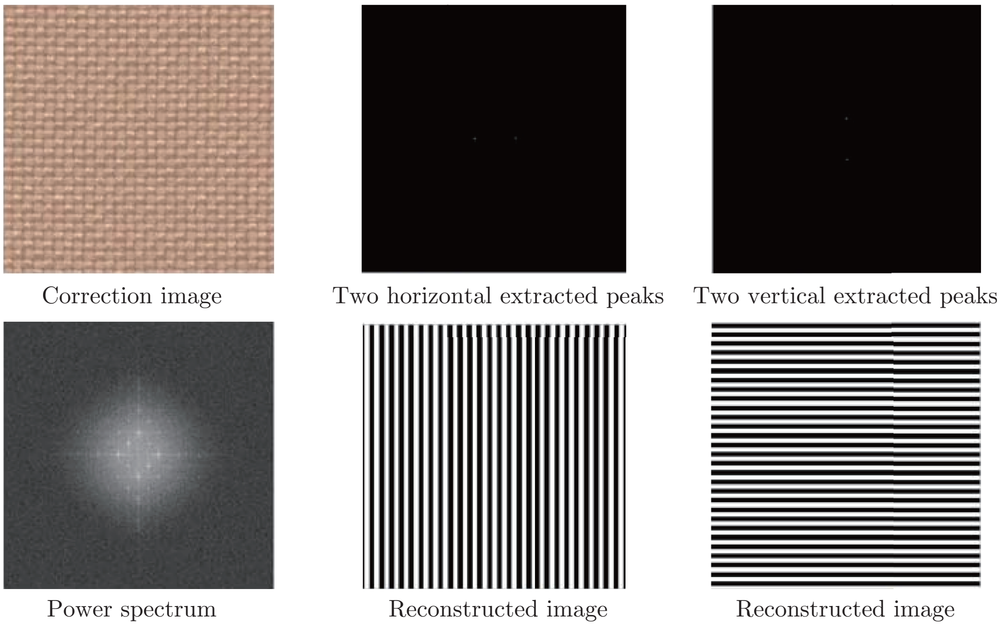


Fig. 2: The reconstructed images of plain woven fabric

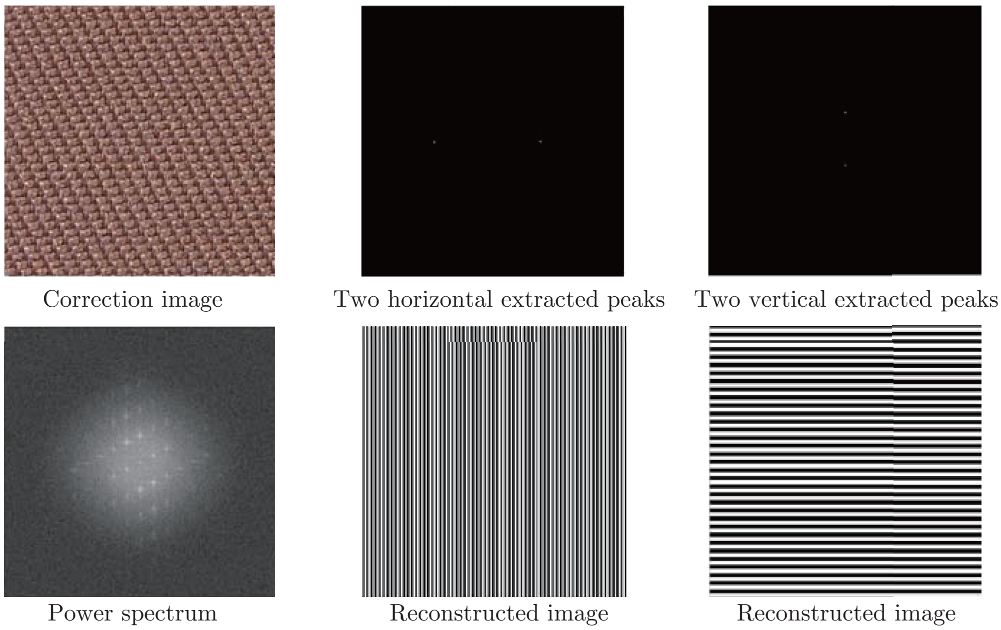


Fig. 3: The reconstructed images of twill woven fabric

Warp/vertical and weft/horizontal density are calculated by Eq. (11):

$$\begin{aligned} d_1 &= \frac{m}{u_1}, d_2 = \frac{n}{v_2} \\ d_{warp} &= d_1 \frac{2.54}{R}, d_{weft} = d_2 \frac{2.54}{R} \\ Y_{warp} &= 10 \frac{1}{d_{warp}}, Y_{weft} = 10 \frac{1}{d_{weft}} \end{aligned} \tag{11}$$

where m is the width of the original image, n is the height of the original image. (u_1, v_1) and $(u_2,$

v_2) are the frequency of extracted peaks in the horizontal and vertical directions, respectively. d_1 and d_2 are the distance between the warp and weft yarns in the reconstructed image. R is the resolution of the image in dpi. d_{warp} and d_{weft} are the actual distance between the warp and weft yarns. Y_{warp} and Y_{weft} are the density of warp/vertical and weft/horizontal yarns (the number of yarns or coils in 10 cm).

4 Experimental Results Analysis

4.1 Experimental Results

The Projection profile analysis and FFT are used for skew correction and density detection of different fabrics, including plain, twill woven fabrics and knitted fabrics. The fabric skew correction results are shown in Fig. 4 to Fig. 6, and the density detection results obtained by the proposed method are presented in Table 1.

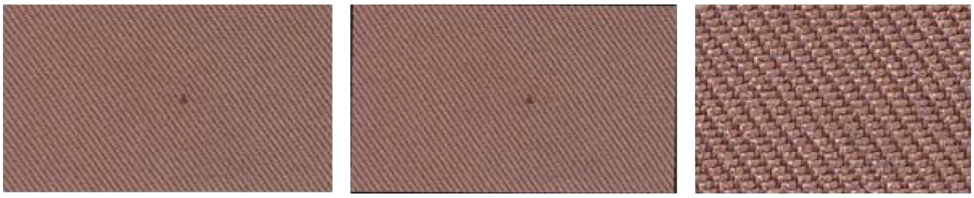


Fig. 4: The skew correction results of twill woven fabrics

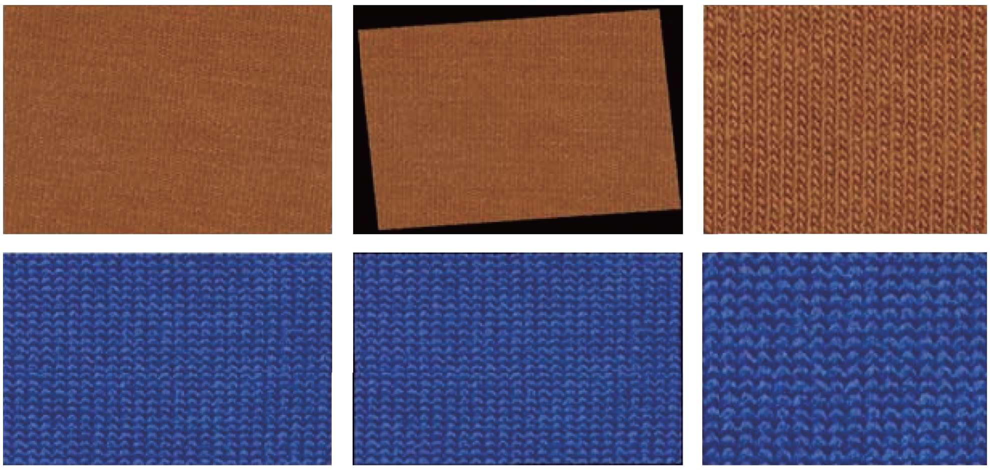


Fig. 5: The skew correction results of knitted fabrics

From Fig. 4 to Fig. 6, it can be seen that the algorithm for correcting woven and knitted fabrics is effective. Experiments results reveal the high precision of Projection profile analysis for skew correction, which reduces the error of fabric density detection. Table 1 shows the density detection results based on FFT. Compared with manual detection, the error can be controlled within 2% by using FFT. The accuracy of fabric density detection can reach 98%. The proposed method is not only suitable for woven fabrics, but also for knitted fabrics.

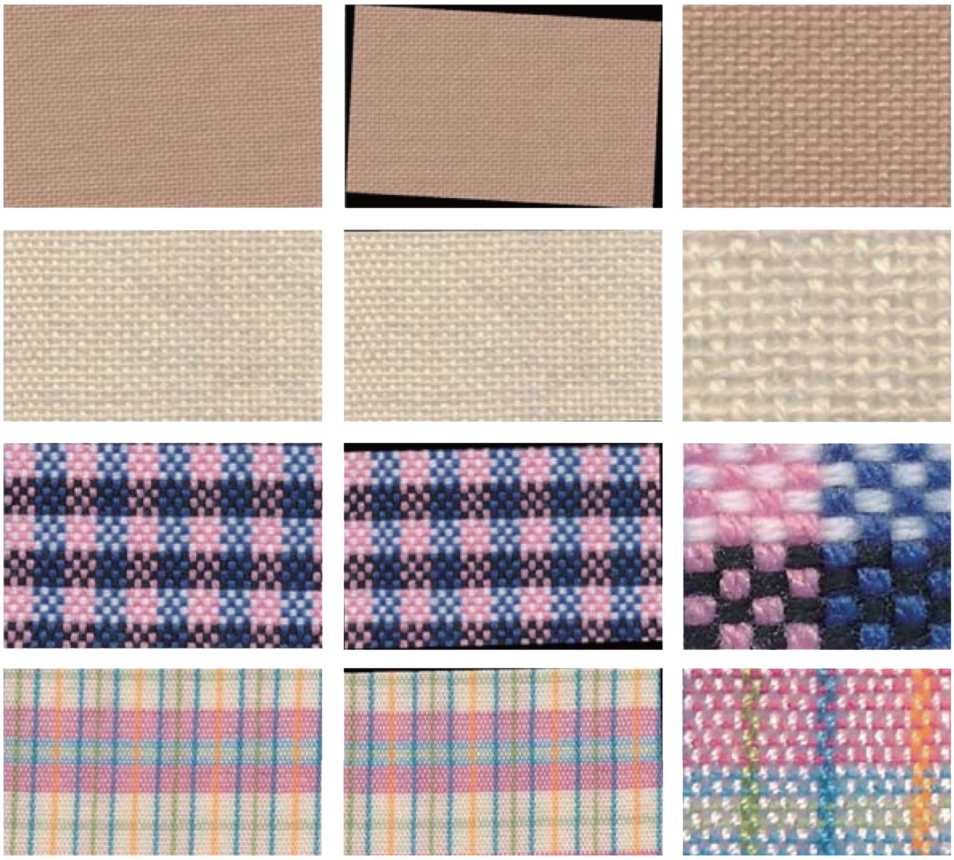


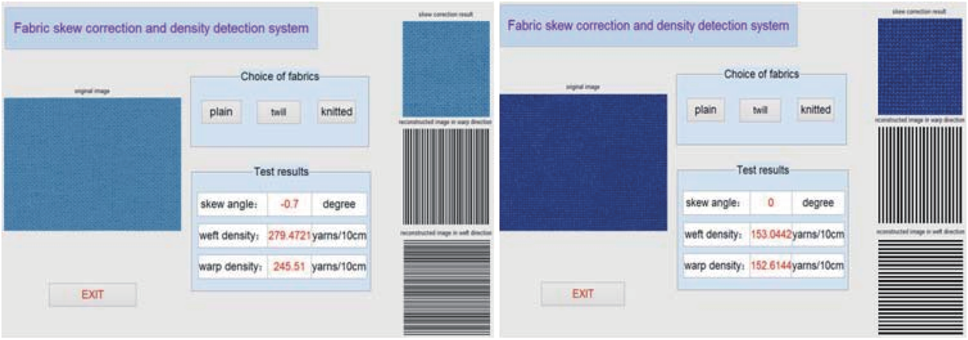
Fig. 6: The skew correction results of plain woven fabrics

Table 1: Density detection results

Samples	Weft/Horizontal density		Warp/Vertical density		Weft/Warp
	FFT	Manual	FFT	Manual	error (%)
1	226.2	227.9	205.7	206.5	0.75/0.39
2	93.2	92.7	112.8	112.0	0.54/0.71
3	96.3	96.3	95.6	96.1	0/0.52
4	116.5	117.4	232.2	231.5	0.77/0.30
5	156.1	155.2	213.1	211.8	0.58/0.61
6	225.8	223.0	187.4	188.9	1.20/0.80
7	153.0	153.0	152.6	152.0	0/0.39

4.2 The System Interface

A fabric skew correction and density detection system GUI interface is established by MATLAB R2012b in this paper. The system interface contains of the choice of fabrics, test results, exit and schematic diagram. The user can choose different fabrics in this interface, including plain, twill and knitted fabrics. After the fabric is processed, it can clearly show the skew angle of the fabric and the warp and weft density in the interface. The interface and results are shown in Fig. 7.



(a) (b)

Fig. 7: Fabric skew correction and density detection system: (a) Test result of plain woven fabric; (b) Test result of knitted fabric

5 Conclusion

The method, which combines Projection profile analysis with FFT, is proposed in this paper for skew correction and density detection of woven and knitted fabrics. First, the Projection profile analysis is used to eliminate skew of the fabric, so that the power spectrum obtained after FFT is not skew in next step. Besides, right peaks can be extracted in the horizontal and vertical directions, respectively. Simultaneously, the image can be reconstructed through the two selected peaks on the principal direction only corresponding to the yarns. Eventually, the number of warp/vertical yarns and weft/horizontal yarns can be calculated based on the two reconstructed images. From the experimental results, the precision of the method for fabric skew correction can be controlled in $[-1°, 1°]$. Due to the improvement of the algorithm, the amount of calculation is reduced. The method described herein for fabric density detection can achieve the accuracy rate of 98%. In summary, the proposed method is valid for skew correction and density detection of woven and knitted fabrics, which will be of great value in developing new approach.

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