High Speed online Detection of Fabric Density Based on Multi-resolution Wavelet Basis

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Abstract: The textile industry is a pillar industry in China. Domestic demand and foreign exports are huge. With the improvement of living standards, the public demanded that textiles be both aesthetical and comfortable. New indexes should be added to the processing of fabrics, which increase the difficulty to detect. Density detection is an important part of fabric quality inspection. However, the current detection methods still rely heavily on labour, with high error and low detection efficiency. Wavelet basis combines machine vision are introduced to achieve high speed automatic detection. Firstly, the images are preprocessed, and several wavelet basis reconstruction effects are compared. The wavelet transform is used to extract the feature information in both latitude and longitude directions, and binarization and smoothing processing are performed for better calculation of density information. Finally, the density of fabric is obtained. The results show that the method can detect the density of the fabric quickly, and the speed and efficiency are high.

1 INTRODUCTION

Density inspection is an essential task in the fabric. Many experts have studied this issue. A foreign scholar combined the optical field with fabric organization for the first time and studied the structure of fabrics by diffraction images, and calculated the interval through the highlights of the photo (Akiyama R, 1986).The two-dimensional spectrum of the fabric was obtained through the Fast Fourier Transform (FFT), and the feature was extracted through the frequency analysis of the fabric images to obtain the density of the fabric (Xu B, 1996). Taiwan scholar calculated the gray level co-occurrence matrix according to the different intervals and angles of pixels, and obtained the eigenvalues. Then the fabric density of circular arrangement can be calculated (Huang C, 2000). Domestic scholars added adaptive filtering to the fabric image to obtain a picture containing only the longitudinal and latitudinal texture information. (He Feng,2007). According to this research, a detection method was proposed which combining wavelet image decomposition and Radon transform for the image texture of the inclined image. The method can classify fabrics and measure density (Shen Jianqiang, 2007). For the fabrics with different texture patterns on both sides, a two-sided fusion technique was proposed. A double-sided imaging system is applied to obtain images containing front and back information of fabrics, and affine and wavelet transform are used to fuse two-sided fabric images. A fast Fourier transform is performed to measure the warp and weft yarn densities of the fabric in the frequency domain (Zhang R, 2016). In this paper, the high speed online detection of fabric density based on multi-resolution wavelet basis is proposed. It can not only save time, reduce labor, but also improve efficiency while ensuring accuracy.

2 PRINCIPLE OF DWT

Wavelet transform is a time-frequency analysis method, which has multi-resolution characteristics and can provide a time-frequency window with frequency. The discrete wavelet transform(DWT) of the size image is defined as follows:

$$W_{\varphi}(0,m,n)=\frac{1}{\sqrt{MN}}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}f(x,y)\varphi_{(0,m,n)}(x,y) \qquad (1)$$

$$W_{\varphi}^{i}(j,m,n)=\frac{1}{\sqrt{MN}}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}f(x,y)\varphi^{i}_{(j,m,n)}(x,y) \qquad (2)$$

$$i=\{H,V,D\}$$

where $W_\varphi(j,m,n)$ and $W_\varphi^i(j,m,n)$ are low and high frequency approximation coefficients of images respectively. $\varphi^i_{(j,m,n)}(x,y)$ is scaling and translation transformation of wavelet functions in horizontal, vertical and diagonal directions.

When the 2D wavelet transform is applied to image processing, it can be decomposed into two steps: horizontal wavelet transform and vertical wavelet transform. The wavelet and scale functions are applied to the rows and columns of the image respectively. The figure 1 shows the two-dimensional discrete wavelet decomposition and reconstruction process of the image. The decomposition process can be described as follows: Firstly, one-dimensional *DWT* is performed on each row of the image to obtain the low-frequency component *L* and high-frequency component *H* of the original image in the horizontal direction. And then one-dimensional *DWT* is carried out on each column of the transformed data to obtain the four parts of the original image: Low-frequency components *LL* in the horizontal and vertical directions, Low-frequency in the horizontal direction and High-frequency in the vertical direction *LH*, High-frequency in the horizontal direction, and Low-frequency in the vertical direction *HL*, and High-frequency components *HH* in both horizontal and vertical directions. The reconstruction process can be described as follows: Firstly, *IDWT* is performed on each column of the transform result. Then one-dimensional *IDWT* is performed on each row of the transform data, and a reconstructed image can be obtained. It can be seen from the above that the wavelet decomposition of an image is a process of separating a signal in accordance with low-frequency and directed high-frequency. Further decomposition of the acquired *LL* component can be performed according to the requirements in the decomposition process until the requirement is satisfied.

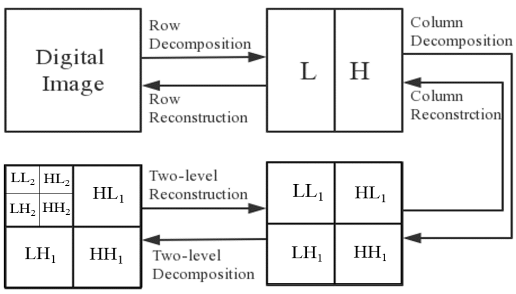

Figure 1: Two-dimensional discrete wavelet decomposition and reconstruction process of the image.

The warp and weft yarns in the fabric are perpendicular to each other according to certain rules. The texture information of the warp and weft can be obtained after the fabric image is decomposed. Since the information is distributed in the high frequency regions, the vertical high frequency subimage and horizontal high frequency subimage after wavelet decomposition can be used to analyze the fabric density.

3 IMAGE PROCESSING

3.1 Image Acquisition

As shown in the figure 2, an area array CCD industrial camera is used for image acquisition, with an optical zoom lens and a ring light source to facilitate the adjustment of the detection system. For better measurement, the collected objects are clean, neat and clear texture. The collected image samples are shown in figure 2.

Figure 2: Collected image samples.

The workflow chart is as figure 3:

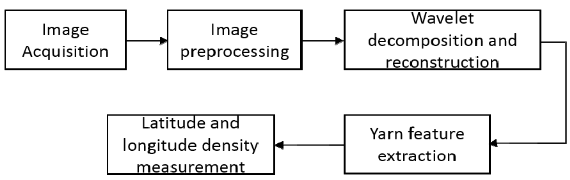

Figure 3: Workflow chart.

3.2 Image Pre-processing

In the process of image acquisition, the imaging quality is affected by many factors, such as uneven illumination, distortion of the optical system, and noise pollution. It is difficult to meet the detection requirements. After obtaining the target image, the acquired image sample needs to be pre-processed to improve the image quality (Ji Shi, 2012). The pre-processing process includes the following steps: (1) Transform the color space. The color of the image affects the image quality and needs to be converted into a grayscale image; (2) Histogram equalization process .It can enhance the contrast of the original image and makes it evenly distributed; (3) Noise removal. It can suppress background; noise and preserve image details as much as possible. Median filter is used for noise reduction; (4) Local enhancement, which can increase the contrast of the image; (5) Image correction. The Canny edge detector is used to extract the edge information of the fabric warp and weft yarn, and then Hough transform is used to detect the angle of the fabric image to correct it (Kaicheng Fu, 2016).The equalized image is shown as figure 4.

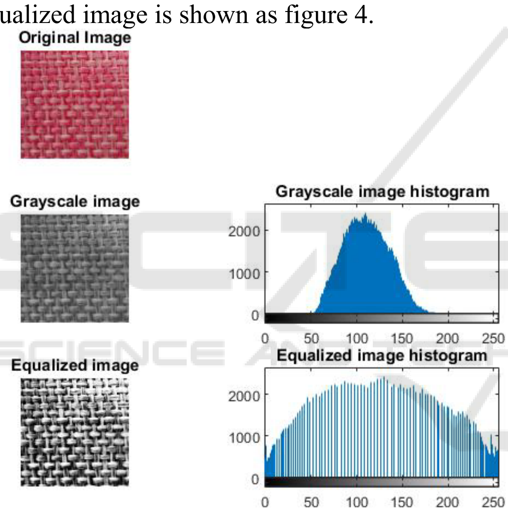

Figure 4: Equalized image.

3.3 Feature Extraction of Latitude and Longitude

Multi-level wavelet decomposition of fabric images is required in order to obtain clearer images of warp and weft yarns. The Mallat wavelet basis function is applied to multidimensional wavelet decomposition of fabric images. It is found that the four-layer wavelet decomposition has the best effect. The two-dimensional decomposition effect is shown in figure 5. After wavelet decomposition, the approximate component, horizontal component, vertical component and diagonal component of the fabric image are obtained, and the horizontal component and vertical component are selected for wavelet reconstruction. As shown in Figure 6, the first half is the result of first order wavelet decomposition, and the second half is the result of two level wavelet decomposition.

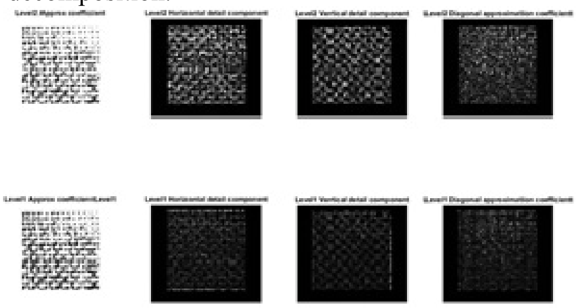

Figure 5: Two-dimensional wavelet decomposition of fabric images.

The warp and weft yarn information in the fabric image is best retained in the high-frequency horizontal and vertical reconstruction map of a certain layer.

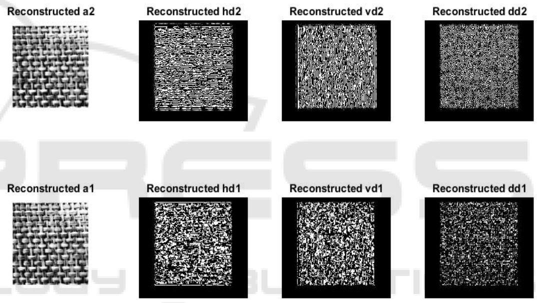

Figure 6: Two-dimensional wavelet reconstructed of fabric images.

The number of layers selected during reconstruction affects the correctness of the final result directly. When determining the level of reconstruction, the correlation coefficient method can be used to determine the optimal level of reconstruction. After multi-level decomposition of the image, the correlation coefficients between the horizontal and vertical reconstruction map of the layer and the original image are calculated. The highest correlation coefficient is used as the coefficient of reconstruction. The correlation coefficient between A and B as equation (3).

$$t=\frac{\sum_{m}\sum_{n}(A_{mn}-\bar{A})(B_{mn}-\bar{B})}{\sqrt{(\sum_{m}\sum_{n}(A_{mn}-\bar{A})^2)}\sqrt{(\sum_{m}\sum_{n}(B_{mn}-\bar{B})^2)}} \tag{3}$$

where $\bar{A}$ and $\bar{B}$ are the average gray value of the two images. A and B are the gray scale matrices of the images, which have the same dimension of $m \times n$.

In order to evaluate the reconstructive performance of the image objectively, three kinds of wavelet functions Harr, Bior, and Mallat were selected for comparison. The commonly used information entropy(IE), average gradient(AG), and oprating time(OT) three statistical indicators were used to evaluate the reconstructed images(Jun Yang, 2007). IE represents the amount of information in an image and is an index to measure the abundance of information. AG reflects the sharpness, detail and texture of the image. The larger the first two indicators, the better the image quality. The specific statistical results are shown in table 1 and figure 7.

Table 1: Objective evaluation of reconstruction effect.

	IE	AG	OT
Harr	6.1251	3.5014	4.935156
Biorthogonal	6.6144	3.7380	5.131282
Mallat	6.7628	3.8163	4.852911

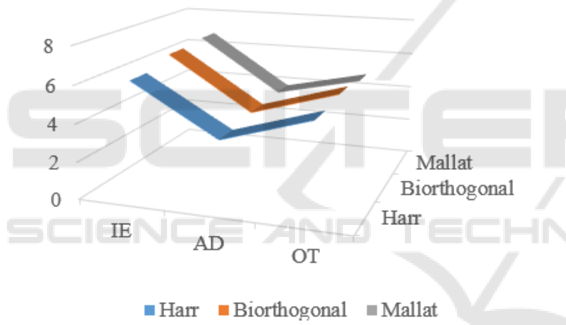

Figure 7: Comparison of different wavelet function reconstruction effects.

From the above, it can be seen that since the sawtooth of Harr operator reconstructs the image, the IE is obviously small, and the biorthogonality of Bior. affects the calculation time, which has the longest RT. Combining three indexs, the Mallat operator has the best effect of extracting image features among the three functions.

The approximate direction of the warp and weft yarns can be observed after reconstructing. In order to obtain the warp and weft information more accurately, it is necessary to binarize the reconstructed image (Xunming Zhao, 2011).The global threshold method is applied for image processing. The binarized image is shown in figure 8. White represents yarn, and black represents yarn gap after binarization.

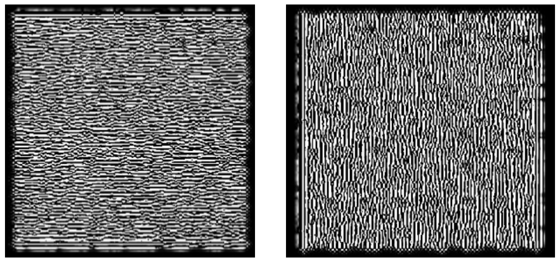

Figure 8: Latitude and longitude binary image.

The warp and weft information of each direction is basically obtained after binarizing. However, the obvious discontinuity in the yarn image interferes the subsequent calculations. To obtain the exact value of the warp and weft density of the fabric, it is also necessary to perform morphological processing and idealization of the yarn image. The idealization idea is as follows: take one column in the weft image or take a row in the warp image, and count the number of 0 pixel values or 1 pixel value in each column and each row of the binary image separately. If the pixel value has a mutation from 0 to 1, the number of yarns adds. The idealized image, shown in figure 9, is used for the density calculation.

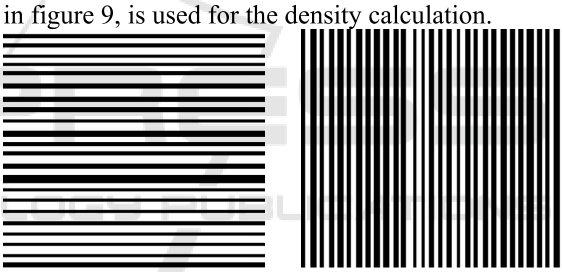

Figure 9: Idealized latitude and longitude images.

3.4 Density Measurement

The warp and weft stripes of the image are obvious after idealizing. The black and white stripes appear alternately in the image. The fabric warp and weft density can be calculated based on the number of white stripes and pixel conversion coefficient. The warp and weft density of a fabric is defined as the number of yarns within 10 cm or 1 inch. The ratio between the pixel distance S_{pixel} and the actual physical distance S is as formula (4):

$$R = \frac{S_{pixel}}{S} \tag{4}$$

4 COMPARATIVE ANALYSIS

A variety of fabrics with different densities and different tissue structures were selected to conduct the measurement of the warp and weft density, and compared with the results of manual measurements. The relative error is defined as

$$\sigma = \frac{|c-d|}{c} \times 100\% \qquad (5)$$

where c is the manual measurement result and d is the image measurement result. The results are shown in Table 2.

Table 2: Test results of Fabric density.

	Warp density			Weft density		
	Manual	Image	Error (%)	Manual	Image	Error (%)
1	40	39.8	0.50	40	39.9	0.25
2	90	89.3	0.78	88	88.7	0.79
3	130	131.1	0.84	128	129.0	0.78
4	196	197.9	1.07	197	195.3	0.86
5	223	220.4	1.13	220	217.6	1.09
6	306	309.2	1.04	303	306.4	1.12
7	361	365.6	1.27	358	362.5	1.25

It can be seen from the experimental results that the accuracy of the image method is mainly affected by tightness of fabric warp and weft arrangement and the type of tissue structure. The higher the warp and weft density of the fabric, the smaller the spacing between the yarns, the more difficult the edge information between adjacent yarns to extract, the more obvious the error. In general, the error between the measurement result of image and the actual is small.

5 CONCLUSIONS

The wavelet basis is introduced into online yarn density detection of fabrics. Firstly, the collected images are preprocessed, and the fabric image is decomposed and reconstructed by multi-scale wavelet to obtain the decomposed warp and weft sub-images. Then the image is binarized and smoothed to obtain the characteristics of warp and weft yarns. Finally, the yarn density of warp and weft is calculated. Experiments have verified the density of different types of pictures and compared them with manual measurements. The experimental results show that the method has small measurement error and is reliable and practical.

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