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Automatic Density Measurement of Striped Woven Fabrics Based on Adaptive Filtering

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Abstract. In order to reduce the interference of stripe signal on the density automatic measurement of woven fabric and extend the the application scope, an adaptive Gaussian Notch Filtering (GNF) algorithm based on Fast Fourier transform is proposed. In the pre-proceesing stage, the Fourier transform was utilized to transform the woven fabric bitmap to spectral image, as to obtain the spectral characteristics of the striped fabric. The improved GNF algorithm was used to identify the peak of stripe signal, which determined the bandwidth radius and locate the stripe bright area. Based on the fused Fourier and GNF spectral map, interference frequency information was accurately removed and spatial map was restored to approximate pure color fabric image. Finally, the Morlet wavelet is utilized to analysis the density of the striped printed fabric. The experimental results show that the average subjective-objective consistency rate (AS-OCR) of the designed sample is 99.34%, and the range is 97.33% ~ 100%. The AS-OCR of the actual sample is 98.73%, ranging from 95.00% to 100%. The proposed method can effectively obtain the density of stripe printed woven fabric and expand the application scope of fabric density automatic detection.

Keywords. Image analysis; woven fabric; wavelet transform; adaptive Gaussian Notch Filter; density detection

1. Introduction

Printed, or yarn dyed striped woven fabrics, showing a simple, orderly and reorganizable decorative, is a more common type of garment fabrics. Fabric density affects the strength, handle, air and water vapor permeability performance, that is one of the important observed performances in the fabric selection.

Currently, the image analysis methods were mainly classified as the spatial and frequency domains, to parse the warp and weft interweaving pattern of woven fabric yarns. In spatial domains,commonly used methods include grey-scale projection[1-2], grey co-generation matrix[3-4], template matching[5], etc.. In frequency domain, Fourier[6-7] and wavelet transform[8-10] methods were utilized to obtain fabric yarn

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texture information, and present well results in density detection of solid colour fabric. However, the surface stripes and yarn texture are mixed in fabric image, which can easily lead to detection miscalculation, and the robustness and coverage of the algorithm need to be improved.

Therefore, in this paper, an effective strategy combined Fourier and GNF, is proposed to separate and reduce the interference of stripe signal in the frequency domain. Besides, Morlet wavelet is used to decompose the frequency signals of warp and weft yarn and determine the woven fabric density.

2. Experiment

2.1. Methods

Experiment includes three modules−specimen imaging and designing, stripe texture filtering and density detection. The overall pipeline is shown as Figure 1. Firstly, the Fourier transform was utilized to obtain a spectrum map of the striped printed woven fabric. The difference in spectral characteristics between the design sample and the solid color fabric were compared. Furthermore, an improved Gaussian notch filter was proposed to identify and locate the striped signal area. After denoising the striped signal, the frequency domain map of the striped woven fabric in the weak interference state was obtained and reconstructed into a fabric bitmap. Besides, the wavelet transform is used to obtain the warp and weft yarn texture signals and computer fabric density.

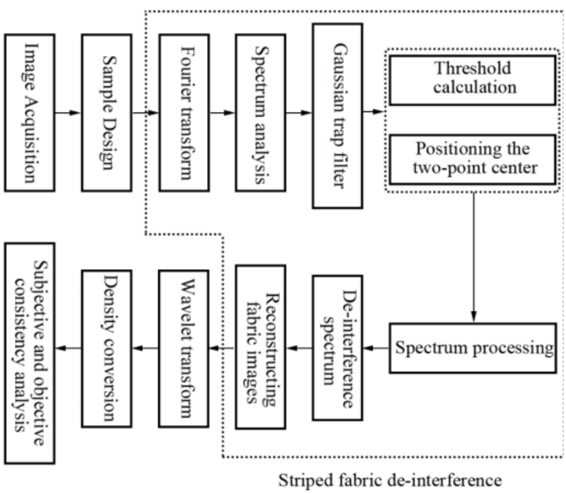
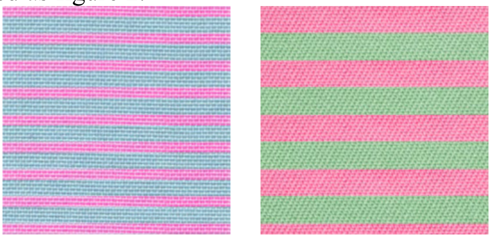


Figure 1. Experiment Pipeline.

2.2. Materials

Sepcimens in this experiment can be classified as two sources--designed samples and real fabric images. Sorts of stripe were mapped as layer on the solid colour fabric as designed sample, while the real fabric images were captured from stripe printed fabrics. Specimens' textures include plain, twill and satin.

9 types of samples were designed and 24 real samples were chosen as representative samples. Concretely, the key differences among designed samples present in stripe size, colour and texture. Numbering rule as "fabric texture - stripe colour - stripe size", in which, colour include red(R), green(G), blue(B), and stripe size are 40,60 100 pixel in image. Stripe size is represented by D, Z and X for large, medium and small within specified ranges. Besides, texture include P, T, S, respectively represent plain, twill and stain. A sample named as figure 2.



(a)"P-R-X" (b)"T-R-D"

Figure 2. Designed stripe fabric sample

3. Interferenced spectrum analysis

3.1. Image Preprocessing

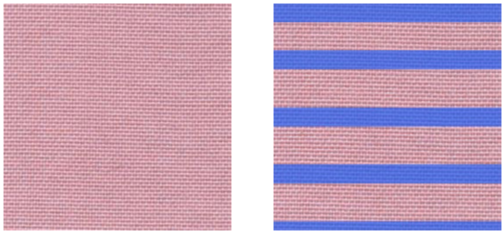
Prior to spectral analysis, sample colour images are first processed into grey image, then be denoising and brightness equalization, as to obtain available specimen images for subsequent processing.

Certain factors such as placement deviations and tilting of the structured texture, could easily lead to a lack of concentration of the vertical and horizontal components after frequency domain decomposition. Therefore, Hough transform [9] is used to obtain a more easily extractable image of the fabric yarn features.

3.2. Spectrum Analysis

In order to effectively compare the interference of stripes on the fabric spectrum, a designed "virtual fabric" image is used here. Striped image layer was fused with solid colour fabric image as "virtual striped image", which can be convenient for density comparison with solid colour fabric with same parameters. Besides, this method can be actively controlled to analyse the differences in the fabric spectrum with or without stripe interference.

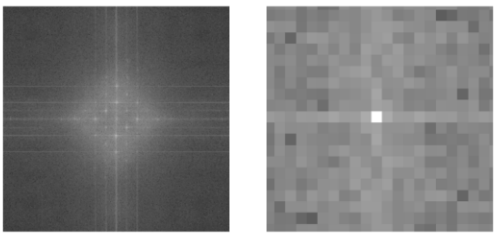
Taking the specimen "P-S-R" as an example, the stripe interference is "added" to the surface of the solid colour fabric in Figure 3 (a), and form a stripe-like printed fabric as shown in Figure 3 (b), with the number set to "PD-S-R".



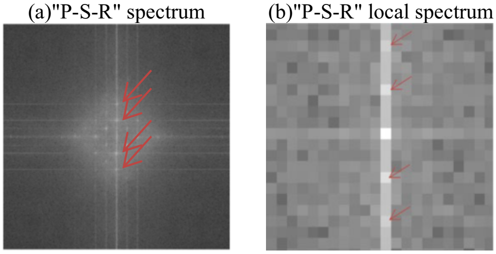
(a)Solid color fabrics“P-S-R” (b)Striped fabric“PD-S-R”

Figure 3. Pure color samples and stripe design samples

The Fourier transform of sample "P-S-R" and sample "PD-S-R" shifts the low-frequency information towards the centre, and the resulting spectrum is shown in Figure 4.



(a)"P-S-R" spectrum (b)"P-S-R" local spectrum



(c)“PD-S-R” spectrum (d)"PD-S-R" local spectrum

Figure 4. Spectrum comparison effect

In Figure 4 (b) and Figure 4 (d), the horizontal striped fabric in the longitudinal center band of the local extreme value brighter, and the center band in addition to the local extreme value points are brighter than the corresponding points on the center band of the solid color fabric. There are multiple same periodicities on the peak feature points, so it can be judged that the brightest extreme point is the extreme point that needs to stay in the spectrum diagram of striped woven fabric. The weaker extreme points around this point are shown as interference points, and their corresponding frequency components are the interference frequencies.

4. Stripe printing filtering

4.1. Gaussian notch filter

The notch filter [11] is usually used to remove noise, Position of horizontal and grid lines can be located by removing horizontal line and grid periodic noise. Here a improved notch filtering was designed as to locate and filter the peak feature points signal. Gaussian notch filter could be defined as follow:

$$H(\mathrm{u},v)=1-\exp\left\{-\frac{1}{2}\left[\frac{D_1(u,v)D_2(u,v)}{D_0^2}\right]\right\} \quad (1)$$

Let $p1(u0,v0)$ and $p2(u0,v0)$ be a pair of frequency points to be located, then the shape of the trapped region can be chosen to be a circle centred on $p1$ and $p2$, D_0 is the radius of the circle and is the order. Suppose the image size is $M\times N$ pixels and the center point of the frequency rectangle is O , D_1 and D_2 is defined as follows:

$$D_1(u,v)=\sqrt{(u-\tfrac{M}{2}-u0)^2+(v-\tfrac{N}{2}-v0)^2} \quad (2)$$

$$D_2(u,v)=\sqrt{(u-\tfrac{M}{2}+u_0)^2+(v-\tfrac{N}{2}+v_0)^2} \quad (3)$$

4.2. Interference signal location

Gaussian notch filter in the frequency domain can be locate the bright spot (the point pointed by the red arrow) and remove the interfering frequency (the point not pointed by the red arrow) is to determine exactly how to determine the notch filter parameters.

Using the position of each point in the longitudinal central band of the spectrum as the horizontal coordinate and the spectral value of each point as the vertical coordinate, the spectrum curve is shown in Figure 5. According to the curve shown, there are several local extreme points in the longitudinal central band, and the centre of the bright spot indicated by the arrow in the figure is the local extreme point. The frequencies contained in these more obvious local extreme points are the components to be retained, and there are some weaker extreme points near them, which are the interference parts and need to be filtered out.

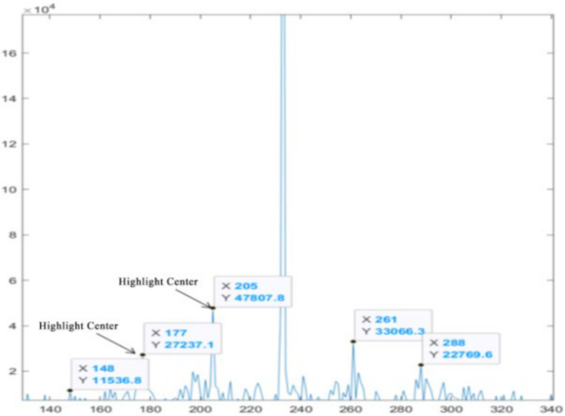


Figure 5. Spectrum curve

These feature points can be located by Gaussian notch filter, and the spectrum formed by these feature points can be used for Fourier reconstruction to obtain an image of a striped printed machine fabric in a weakly disturbed state.

Gaussian notch filter requires determining the bandwidth radius of the notch filter:

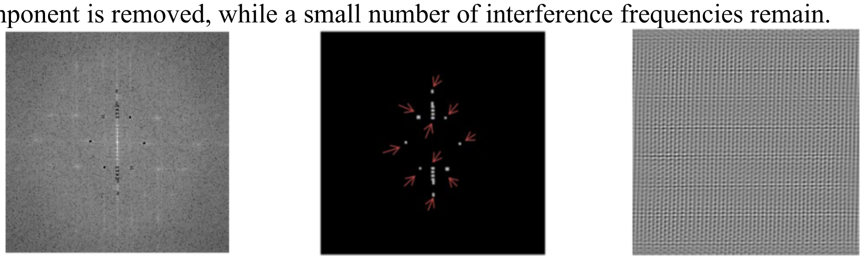
$$T = T_{min} + 3(T_{max} - T_{min}) / 4 \tag{4}$$

Where T_{min} and T_{max} are the minimum and maximum values of the searched spectrum, excluding the centre point and points in its vicinity.

After determining the threshold detect the local maximum, (the brighter point in the spectrum), if the value is greater than or equal to the threshold T, the point is considered a feature point. Find the first local minima to the left and right of the feature point, calculate the distance between the feature point and the two minima, noted as D_1 and D_2 respectively, and take the maximum of D_1 and D_2 as the bandwidth radius of the notch filter.

Gaussian notch filter for sample "PD-S-B" to locate the bright spots (peak feature points), as shown in Figure 6, where the black dots and their surroundings are the areas of bright spots located.

By subtracting the "PD-S-B" spectrum of the original striped fabric from the spectrum in Figure 6 (a), the spectrum of the image in the weakly disturbed state is obtained, as shown in Figure 6 (b), and is referred to here as the characteristic spectrum. According to the spectrum, most of the characteristic bright spots are located using Gaussian notch filter as indicated by the red arrows. A part of the interference frequency component is removed, while a small number of interference frequencies remain.



(a)Location highlights of 'PD-S-B' Gaussian notch filter (b)"PD-S-B" characteristic spectrum (c)"PD-S-B" Reconstruction of Weak Interference Image

Figure 6. "PD-S-B" image reconstruction

An inverse Fourier transform of the characteristic spectrum was obtained to the reconstructed image shown in Figure 6 (c). Its overall difference between the stripes and the other regions is reduced and close to the solid colour fabric image, but the processing on the edges of the image is poor.

5. Automatic density measurement

The optimized Morlet wavelet based on method [12-13] was used for density identification on the weak interference image in Figure 6 (c). Based on the advantages of Morlet wavelets, the number of yarns can be calculated directly from grey-scale projections without the need for processing such as erosion and expansion, open and closed operations, and direct skeleton extraction. The greyscale projection calculates the projection of grey values in the horizontal and vertical directions.

Determine the actual size of the fabric photographed by calibrating it with a ruler when photographing the fabric,the density calculation formula is as follows:

$$D_x = \frac{10N_x}{a} \tag{5}$$

$$D_y = \frac{10N_y}{b} \tag{6}$$

Where N_x and N_y are the number of warp and weft yarns, D_x and D_y are the warp and weft densities respectively, a and b are physical size of fabric

6. Experimental results and discussion

The judgement of yarn position relationships and the resulting fabric density measurements are usually based on manual discrimination. In order to evaluate the accuracy of machine recognition, this paper compares the manual counting method with the research method., Test results for design and actual samples are exhibited in tables 1 and 2.

Table 1. Design sample test results

Fabric number	Manual(yarns/10cm)		Computer(yarns/10cm)		Error%	
	Warp yarn density	Weft yarn density	Warp yarn density	Weft yarn density	Radial error	Latitudinal error
P-B-D	79	79	79.0	79.0	0.00	0.00
P-G-Z	79	79	79.0	79.0	0.00	0.00
P-R-X	79	79	79.0	79.0	0.00	0.00
T-B-D	98	98	99.3	98.0	1.31	0.00
T-G-Z	98	98	97.6	98.3	0.41	0.31
T-R-X	98	98	98.7	98.0	0.71	0.00
S-B-D	321	201	329.8	204.7	2.67	1.81
S-G-Z	321	201	324.7	203.5	1.14	1.23
S-R-X	321	201	324.1	202.8	0.96	0.89

According to the experiment results, stripe fabric density recognition using Morlet wavelet transform after filtering out stripe interference, the average subjective-objective consistency rate was 99.37%, ranging from 97.33% to 100%; the average subjective-objective consistency rate of actual samples is 98.73%, ranging from 95.00% to 100%, overall the two sample densities achieve an overall accuracy of over 95%, and the algorithm has a certain degree of feasibility.

Analysis of subjective and objective consistency rates for warp and weft density detection. The average subjective-objective consistency rate for the design samples was 98.60% for the warp-density detection and 98.85% for the weft-density detection. The average subjective-objective consistency rate for the actual samples was 98.60% for the warp-density detection and 98.85% for the weft-density detection. The data shows that for striped fabrics, the radial density is more difficult to detect than the weft density.

The main design factor of the design sample is the stripe size, according to the statistical error of the stripe size, average subjective-objective consistency rate of the stripe size of large, medium and small are 1.00%, 0.50% and 0.40% respectively, From this data, it can be concluded that the greater the stripe, the greater the impact on the density detection results, in the design sample, the largest error rate is sample "S-B- D", which is a satin black fabric,and the smallest error rate is the plain stripe sample, it can be judged that the satin fabric detection is more difficult.

Overall data shows that automatic density measurement of striped machine fabrics can be achieved by filtering out stripe interference.

Table 2. Actual sample test results

Fabric number	Manual(yarns/10cm)		Computer(yarns/10cm)		Error%	
	Warp yarn density	Weft yarn density	Warp yarn density	Weft yarn density	Radial error	Latitudinal error
1	262	414	261.5	414.3	0.19	0.07
2	300	243	293.3	235.7	2.28	3.10
3	356	283	355.6	288.9	0.11	2.04
4	559	232	559.1	231.6	0.02	0.17
5	321	179	321.1	178.9	0.03	0.06
6	271	493	271.4	492.9	0.15	0.02
7	279	537	278.9	536.8	0.04	0.04
8	417	317	408.3	316.7	2.13	0.09
9	379	507	378.6	514.3	0.11	1.42
10	369	244	361.9	242.1	1.96	0.78
11	277	272	271.4	269.2	2.06	1.04
12	344	303	342.9	300.0	0.32	1.00
13	372	269	366.7	266.7	1.45	0.86
14	250	200	245.6	200.0	1.79	0.00
15	375	321	368.4	331.6	1.79	3.20
16	494	271	492.9	278.6	0.22	2.73
17	299	235	294.7	231.6	1.46	1.47
18	317	267	333.3	275.0	4.89	2.91
19	473	379	471.4	378.6	0.34	0.11
20	272	267	270.2	261.9	0.67	1.95
21	455	224	443.5	220.0	2.59	1.82
22	478	362	471.4	358.3	1.40	1.03
23	475	336	500.0	333.3	5.00	0.81
24	502	454	515.0	458.3	2.52	0.94

7. Conclusion

This paper investigated the automatic measurement of stripe printed woven fabric density, and proposed an new method to remove stripe interference in the frequency domain, the Fourier transform is used to process the stripe fabric image, and the Fourier transform result is used to locate the feature points using Gaussian notch filter template to remove the striped interference frequencies and obtain the weak interference state, uses optimised wavelet for density recognition of weak interference image, and finally the number of yarns is obtained by grey-scale projection. The algorithm was tested by designing stripe samples and collecting actual stripe samples. The experimental results show that the average subjective-objective consistency rate of the designed samples is 99.34%, ranging from 97.33% to 100%; the average subjective-objective consistency rate of the actual samples is 98.73%, ranging from 95.00% to 100%.

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