Research Journal of Applied Sciences 3 (1): 26-31, 2008
ISSN: 1815-932X

Automatic Fault Analysis of Textile Fabric Using Imaging Systems

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Abstract: Quality is the watchword for any type of business. A product without quality leads to only loss and lack of customer satisfaction. This is true in the case of textile industries also. The various faults occurring in the fabric leads to low quality cloth material. Many fabric defects are very small and undistinguishable, which are very difficult to detect by only monitoring the intensity change. Faultless fabric is a repetitive and regular global texture and Fourier transform can be applied to monitor the spatial frequency spectrum of a fabric When a defect occurs in fabric, its regular structure is changed so that the corresponding intensity at some specific positions of the frequency spectrum would change. In this study, a simulated fabric model is used to understand the relationship between the fabric structure in the image space and in the frequency space. Based on the three-dimensional frequency spectrum, 2 significant spectrum diagrams are defined and used for analyzing the fabric defect. These 2 diagrams are called the central spatial frequency spectrums. The defects are broadly classified into 3 classes: Double yarn; missing yarn and webs or broken fabric. After evaluating these 3 classes of defects using some simulated models and real samples, seven characteristic parameters for central spatial frequency are computed.

Key words: Fabric defects, intensity change, spatial frequency, fourier analysis, histogram equalization, texture analysis

INTRODUCTION

Our study deals with an effective mechanism of applying fourier analysis for the detection of various faults that may occur in the cloth materials that are produced in the textile industry. Fabric faults or defects are responsible for nearly 85% of the defects found in the garment industry. Manufacturers recover only 45-65% of their profits from second or off quality goods. It is imperative therefore to detect, to identify and to prevent these defects from reoccurring. Currently much of the fabric inspection is done manually and even with the most highly trained inspectors, only about 70% of the defects are being detected.

There is a growing realization and need for an automated fabric inspection system in the textile industry. An automated defect detection and identification system enhances the product quality and results in improved productivity to meet both customer needs and to reduce the costs associated with off-quality. Higher production speeds make the timely detection of fabric defects more important than ever. Recently, the fault detection is done manually after a sufficient amount of fabric has been produced, removed from the production machine and then batched into larger rolls and then sent to the inspection frame.

An optimal solution for this would be to automatically inspect the fabric as it is being produced and to alert the maintenance personnel when the machine needs attention to prevent production of defects or to change process parameters to prevent automatically to improve product quality. This is done by identifying the faults in the fabric using the image processing techniques and then based on the dimension of the faults; the fabric is classified and then graded accordingly.

Computer vision systems do not suffer from some limitations of humans while offering the potential for robust defect detection with few false alarms. Reducing the number of defects produced by timely maintenance or control would result in obvious savings. Some of the methods that we tried for detecting such defects are filtering and thresholding. But these methods provide inconsistent results which are ineffective for analysis. Further, these involve enormous amount of calculations and long execution times.

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BACKGROUND KNOWLEDGE

Fourier transform: Fourier transform states that it is possible to form any function as a summation of a series of sine and cosine terms of increasing frequency (Chi-Ho-Chen, 2000). In other words, any space or time varying data can be transformed into a different domain called the frequency space.

Now that you know a thing or two about Fourier transform, we need to figure out a way to use it in practice. When we transform an image by taking brightness values from pixels, those pixel values are never continuous to begin with. Our mathematicians came up with a good solution for this, namely the discrete Fourier transform. Given p discrete samples sampled in uniform steps,

$$F(x) = \frac{1}{N}\sum_{x=0}^{N-1} f(x)e^{-42\pi a\omega/N}$$

for u = 0,1, 2,……, N-1

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Fourier transform in image processing: Let a 2 dimensional image be f (x, y), which is a real function representing the gray level in x, y spatial coordinates and let the image width and image length be N. Then F(n, m) denotes the Fourier transform of f(x, y) with nand m spatial frequencies. The general equation of 2-dimensional discrete Fourier transform is shown (Wood, 1990):

$$F(n,m) = \frac{1}{N^2}\sum_{y=0}^{N-1}\sum_{x=0}^{N-1} f(x,y)\ e^{-f\,2x(xm,jm)J,N}$$

The computational time for Fourier transform is generally long. For 2-dimensional discrete Fourier transform, it is proportional to the second order of the image size. In order to reduce the computation time, Fast Fourier Transform (FFT) is used. Fast Fourier transform is a discrete Fourier transform with some reorganization that can save enormous amount of time. For one-dimensional FFT, the computation time is NLog2N. Because of the separable transform being used to perform the two dimensional transform, the computation time is proportional to 2N Log2N. One of the advantages for the spatial frequency spectrum approach is the translation property of Fourier transform, which means that the magnitude of frequency spectrum does not change when the fabric moved up. The spectrum is only varied by the change of fabric structure.

$$F(x-a, y-b) \Leftrightarrow F(f_x, f_y) * e^{\int 2\pi(Mj,0+Nj,h)iMN}$$

In this study, the defects are broadly classified into 3 classes: Double yarn; missing yarn; webs or broken fabric; The double yarn (fill) is a change of spatial periodicity on the vertical axis (Schicktanz, 1993). The spectrum on the x-axis (fill direction) denotes the corresponding change of spatial frequency. In a simulated model of the double yarn, d(x,y), the defect can be regarded as a subtraction from a faultless fabric to a series of rectangle function, d(x,y). Because of the distributivity property of the Fourier transform,

$$F\ \{(D(x, y)\} = F\ \{f(x, y)- d\{x, Y)\} = F\ \{f(x, y)\} - F\ \{d\{x,y)\}$$

Which means that the defect in the frequency space can be formed by subtracting the faultless fabric frequency spectrum to the Fourier transform of an irregular structure function d(x, y).

Central spatial frequency: Due to the nature of the fabric structure, many defects would occur along the x and y axes, which mean that those characteristics would appear on the wrap (f_y) and fill (f_x) direction in the frequency spectrum. In addition, a 3 dimensional graph of the frequency spectrum is very difficult to analyze. The method of central spatial frequency spectrum is therefore proposed in this study. This method extracts 2 diagrams along the f_x and f_y direction (F (f_y, 0) and F (0, f_y)) from the three-dimensional graph.

Seven significant features can be extracted in these two diagrams for describing defect characteristics. The equations of these parameters are shown below:

$$P_1 = F(0,0)\ p_2 = 100 \times F(f_{x)}, 0)/F(0,0)$$

$$P_3 = f_{x1}\ P_4 = 100 \times \left(\sum_{f(x)=0}^{f(x)} F(f_x, 0)/F(0,0)\right)$$

$$P_5 = 100 \times F\ (0, f_y)/F(0,0)\ P_6 = f_{y1}$$

$$P_7 = 100 \times \left(\sum_{f(y)=0}^{f(y)} F(0, f_y)/F(0,0)\right)$$

where, f_{xl} and f_{yl} correspond to the first harmonic frequency. The first feature P1 is the average light intensity of the image, which is used to characterize the

Table1: Difference in parameters predicted between the fabric and its defects given by researchers

	P1	P2	P3	P4	P5	P6	P7
Double(fill)yarn	L	L	NC	H	NC	NC	NC
Double (wrap) yarn	L	NC	NC	NC	L	NC	H
Missing (fill) yarn	H	L	NC	H	NC	NC	NCL
Missing (wrap) yarn	H	NC	NC	NC	L	NC	H
Broken fabric	H	L	NC	H	L	NC	H
Low fabric density	H	L	L	L	L	L	H
High fabric density	L	L	H	L	L	H	L

yarn density. Higher yarn density decreases the light intensity and P_1 is decreased and vise versa. P_5, P_6, P_7 are used to monitor the wrap (vertical) threads structure whereas P_2, P_3 and P_4 are for detecting the fill (horizontal) threads structure. When defects occur, the amplitude of harmonic frequencies plus other changes would appear in the central spatial frequency spectrum. Features P_2, P_4, P_5 and P_7 are used to describe and detect these characteristics. Feature P_3 and P_6 are used to monitor the wrap and fill threads density in the image. Feature P_3 and P_6 are used to monitor the wrap and fill threads density in the image. Those features are more concentrated on analyzing the region between the central peaks and first peak (first harmonic frequency) because higher harmonic frequency components are significantly distorted in real environment.

The difference between missing yarn and double yarn is their fabric threads count (Srinivas *et al.*, 1992). Average light intensity P_1 can show this characteristic. For missing yarn, higher P_1 is expected because there is less thread in this defect (Sari and Goddard, 1996). Broken fabric and yarn densities variation are a change of periodicity in both x and y axis and both |F (fx, 0)| and |F (0, fy)| I diagrams are mostly changed. P3 and P6 values are not changed in the broken fabric. This is because this defect is a instant change of the fabric density and it only affects P_1, P_2, P_4, P_5 and P_7 values. The P_1 is high because the fabric is broken and leads to increase of light intensity. Details of the expected results given by the researchers are tabulated in Table 1.

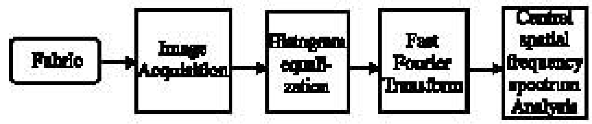

Fig. 1: System flow for fabric defect detection

Fig. 2: Original flawless sample used for comparison in the detection of double yarn class of defects resized and gray scale converted images

Fig. 3: Original flawless sample used for comparison in me detection of missing yarn class of defects

EXPERIMENTAL SETUP

The experimental setup is as follows. It consists of an image acquisition system used to capture the image of the fabric which has to be inspected; histogram equalization is used to provide uniformity in density and then finally the operations of fast fourier transform is performed followed by central spatial frequency spectrum analysis. The system flow for this is as in Fig. 1.

Image acquisition: In this study, plain white fabrics are used. Defects with double yarn, missing yarn, web and fabric density variation were inspected and compared with the faultless fabric. The image acquisition system includes a personal computer (Pentium-200 Mm), frame Dabber, CMOS-imager and a system monitor. The fabric image is captured by a CMOS imager and a frame grabber digitizes the video signal into a 768×576 pixel with eight-bit gray level resolutions image and stores it into computer memory. This image data is then processed by the defect detection procedures (Fig. 2 and 3).

Histogram equalization: Histogram equalization is performed to obtain a uniform density image histogram.

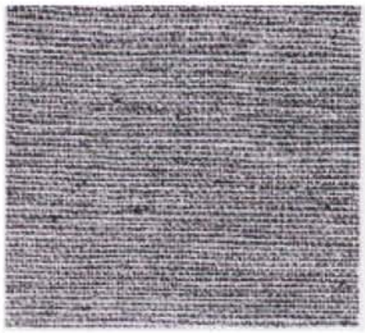

Fig. 4: Histogram equalised image of faultless sample

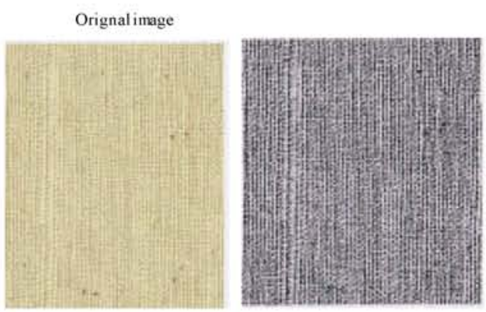

Fig. 5: Histogram equalised image of a faulty and Sample Resized and gray scale converted images

Fig. 6: 2D FFT of the flawless fabric sample

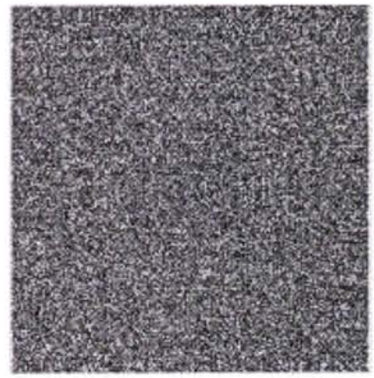

Fig. 7: 2D FFT of the faulty fabric sample

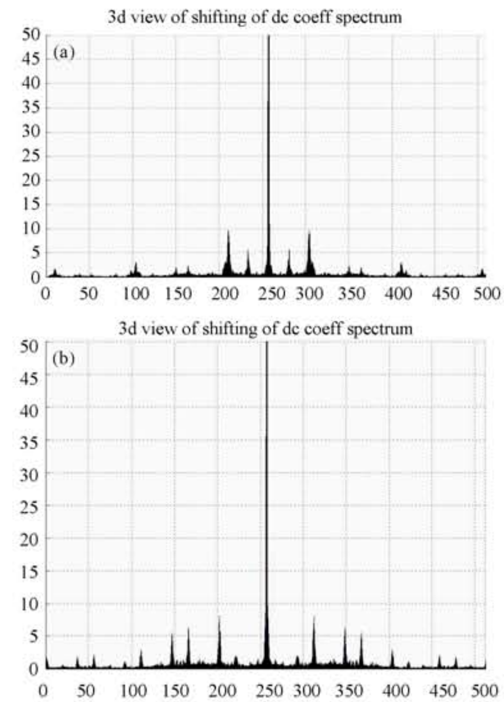

Fig. 8 (a, b): Central spatial frequency spectrum of original flawless sample used for comparison in the detection of double yarn defect

This process extends the dynamic range of gray levels and increases the image contrast. The aim is to standardize the brightness and contrast of the images. Figure 4 and 5 are the images obtained by applying histogram equalization to a faultless and a faulty fabric.

Fast fourier transform: A Fast Fourier Transform (two-point) transform is used for fast computation, which means that the image size is cut to 512×512 pixels in our experiment. This is because the image length and width should be a power of two. A software package, MAT LAB, is used for this experiment. After the Fourier transform, the central spatial frequency diagram is extracted from the three-dimensional diagram (Zhang and Bresee, 1995). By observing these two diagrams and comparing them with the simulated diagrams of double wrap, the orientation of the defect mainly affects the particular diagram. For example, double wrap affects the parameters in diagram and double fin only affects the parameters |F (0, fy)| and |F (fx, 0)| I in the diagram (Fig. 6 and 7). However, the high spatial frequency peaks aer loosely localized and embedded with some noise. A number of reasons can explain this result. For example, the surface tufts give a random textured component in the fabric images that distort the periodic structure. In addition, the illumination fluctuation gives high frequencies noise background. Because of these effects, only parameters around the central peaks and the first peaks can be extracted for defect characteristics. The brighter spots that form a vertical line is caused by missing yarn.

Central spatial frequency spectrum: Many defects would occur along the x and y-axes, which means that those characteristics would appear on the wrap and fin direction in the frequency spectrum (http://www.isi.edu/nsnam/ns). In addition, a three dimensional graph of the frequency spectrum is very difficult to analyze. So, the method of central spatial frequency spectrum is used to simplify this to a great extent (Fig. 8 and 9).

RESULTS

In our project, we have taken several samples and performed the following operations listed in Fig. 10 and 11. The results given in the tabular column I was found to be conflicting with the results obtained by our experiments which were found to be quite consistent.

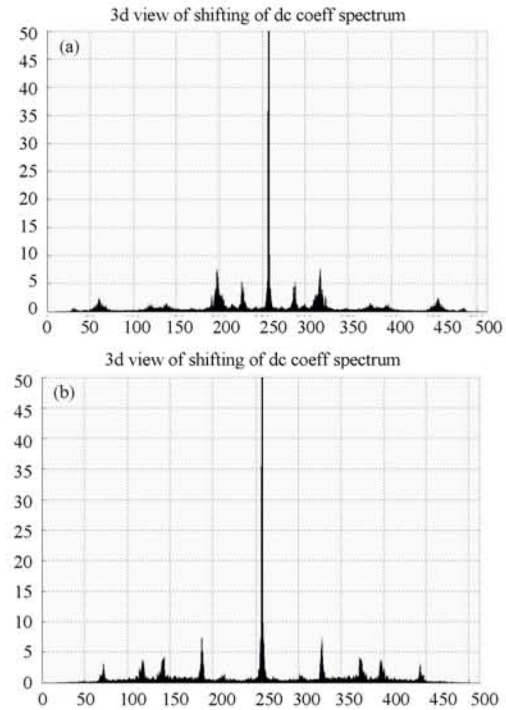

Fig. 9(a,b): Central spatial frequency spectrum of faulty sample used for comparison in the detection of double warp (wrap) defect

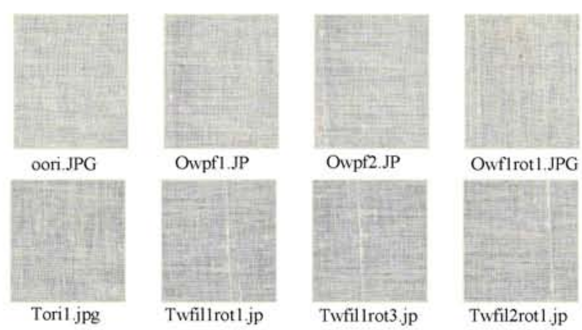

Fig. 10: Real-time fabric sample images acquired

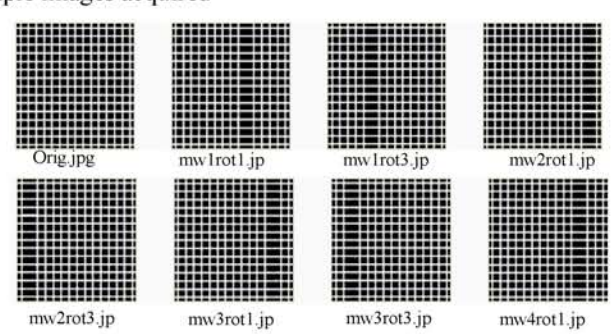

Fig. 11: Synthetic sample images generated

Table.2: Observed difference in parameters predicted between the fabric and its defects

	PI	P2	P3	P4	P5	P6	P7
Double(fill)yarn	L	L	J NC	L	H	NC	H
Double (wrap) yarn	L	L	NC	L	H	L	H
Missing (fill) yarn	L	L	NC	L	H	NC	L
Missing (wrap) yarn	H	L	H	H	H	L	L

Further analysis is being performed on several other samples of various types of textures (Lane and Moure, 1998). Our result on which further analysis is being performed has been listed in the Table 2. Sample Training in MATLAB for Missing Warp(wrap) yarn.

CONCLUSION

In this study, an approach based Fourier transform has been used to detect the various types of fabric defects. The central spatial frequency spectrum is used here because the three dimensional frequency spectrum approaches has been proposed here is very difficult to analyze. Seven significant characteristic parameters can be extracted from the central spatial frequency spectrum s for detecting the type of defect. The variation in parameters in the defective fabric varies from that of the original non-defective sample as tabulated. Further analysis is being carried out to prove that results are consistent for all types of cloth material and for a particular defect. In our study, we have analyzed and tabulated the results to detect only two classes of defects namely: double yarn and missing yarn and we have found our results listed above to be consistent for a number of samples. Further the research is being enhanced for the detection of samples which contain broken end defects as well as density variations also.

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