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Fourier Transform and Image Processing in Automated Fabric Defect Inspection System

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***Abstract*-Automated fabric inspection system is important to prevent delivering of inferior quality fabric and designed to increase the accuracy, consistency and speed of defect detection in fabric manufacturing process to reduce labor costs, improve product quality and increase manufacturing efficiency. Fabric inspection is still carried out offline and manually by humans with many drawbacks such as tiredness, boredom and inattentiveness. The continuous development in computer technology introduces the online fabric inspection system based on image processing as an effective alternative of offline inspection system. This paper proposes an effective and accurate approach to automatic fabric inspection system. The defect free fabric has a periodic regular structure, the occurrence of a defect in the fabric breaks the regular structure. Therefore the fabric defects can be detected by monitoring fabric structure. The Fabric inspection system first acquires high resolution, high contrast and minimum noise of image with suitable format. In this paper Fast Fourier transform technique and cross correlation techniques are implemented on plain fabric to examine the structure regularity features of the image.**

Keywords-Cross Correlation technique, Fabric Inspection, Fourier Transform, Image Processing.

I. INTRODUCTION

Quality control means conducting observations, tests and inspections. The success of weaving mill depends on producing low cost defect free fabrics and just in time delivery. A fabric is a flat structure. First quality fabric is free of major defects and minor structural or surface defects. The second quality fabric may contain few major defects and minor structural or surface defects [7]. The non-detected fabric defects of second quality fabric is responsible of loss in revenue for the manufacturer since the product will sell for only 45%-65% of first quality price, while using the same amount of production resources. Woven fabrics are produced by weaving, which is the textile art in which two distinct sets of yarns or threads – called the warp and weft – are interlaced with each other at right angles to form a fabric or cloth.

The warp represents the threads placed in the fabric longitudinal direction, while the weft represents the threads placed in the width-wise direction. The weave pattern is periodically repeated throughout the whole fabric area with the exception of edges. The plain weave is the most made weave in the world, it is relatively inexpensive, easy to weave and easy to finish. Online system provides images from current production and is located directly on the production line, while offline system is located after the production line. Till now the fabric inspection is undertaken offline manually by skilled staff with a maximum accuracy 0f 75%.

The dream of textile manufacturers is to achieve optimum potential benefits such as quality, cost, comfort, accuracy and speed. Therefore automated inspection system is increase the importance in weaving industry. Automated fabric inspection system requires very high resolution imaging to enable defects as small as a single missed thread, a fine hole or stain to be detected. Plain fabric inspection systems still a challenge due to the variable nature of the weave. The application of digital image processing is useful in textile manufacturing and inspection [1]. The fabric defect is a change in or on the fabric construction.

The weaving process may create a huge number of defects named as weaving defects. These defects appear in the longitudinal direction of the fabric (warp direction) or in the width direction (weft direction). Presence or absence of the yarn causes defects such as miss-ends or picks, end outs, and broken end or picks. Some defects are due to yarn defects and additional defects are due to machine related and appeared as structural failures.

All fabrics consist of fabric repeat therefore frequency analysis based that is a Fourier Transform method gives a possible way to characterize the weave. Fourier transform gives the possibility to monitor and describe the relationship between the regular of the fabric in the spatial domain and its Fourier spectrum in the frequency domain. Presence of a defect of woven fabric causes changes in its Fourier spectrum. By comparing the power spectrum of an image containing a defect with that of a defect free image, changes in the normalized intensity between one spectrum and the other means the presence of defect. Automatic fabric inspection systems are designed to increase the accuracy, consistency and speed of defect detection in fabric manufacturing process to reduce labor costs, improve product quality and increase manufacturing efficiency[6][7]. The operation of an automated fabric inspection system can be broken down into a sequence of processing stages. This paper is organized with the techniques image acquisition, preprocessing, defect detection technique [4], feature extraction, comparison and decision as follows.

II. PROPOSED APPROACH

The fabric inspection is a texture segmentation and identification problem so fabric defects can be detected by monitoring its structure. By considering the periodic nature of woven fabrics, the image in the Fourier domain is decomposed into its sinusoidal components. It is easy to examine certain frequencies of the image corresponding to the geometric structure in the spatial domain.

A. Image acquisition

The first step in the automate fabric inspection is image acquisition. The most important parameter used in the image acquisition is the resolution. The resolution of an image can be referred either by the size of one pixel or the number of pixels per inch. The lower the image resolution, the less information is saved and higher resolution means more information is saved but larger memory size is required to store [2]. The scanning of fabric images begins from 300 DPI (Dots Per Inch) resolution because human vision is approximately 300 DPI at maximum contrast. The scanned image is stored in 'tif' format and grayscale image. A flat scanner is used to capture various plain fabric samples containing different types of defects. Initially the resolution level is set to 300 DPI and then gradually increased by step of 100 DPI till 1200 DPI as a maximum resolution [3]. The images are stored in matrices of size 500x500 pixels.

B. Preprocessing

The acquired image must be converted into gray scale to eliminate the hue and saturation information while retaining the luminance. A filter is defined by a kernel, which is a small array applied to each pixel with its neighboring pixel within an image. In most of the applications, the center of the kernel is aligned with the current pixel, and is a square with an odd number of elements in each dimension [5]. The process used to apply filters to an image is known as convolution, and may be applied in either the spatial or frequency domain. The CONVOL function performs this convolution process for an entire image.

The histogram of a digital image with intensity levels in the

$$\mathrm{h(rk)} = nk \tag{1}$$

where, rk = k^{th} intensity value

nk = Number of pixels in the image with intensity rk

Histograms are frequently normalized by the total number of pixels in the image. Assuming a M x N image, a normalized histogram.

$$p(rk) = \frac{nk}{MN}, k = 0,1,2 \dots \dots \dots L-1 \tag{2}$$

Where L = Number of Intensity values.

is related to probability of occurrence of rk in the image. The histogram provides a convenient summary of the intensities in an image.

C. Defect Detection Technique

Fourier Transform will be the basic tool. Fourier transform gives an image in the Fourier space which is a frequency space, in this space, the coordinates are spatial frequencies. According to Fourier theorem any signal can be represented by the sum of sine and cosine waves with various amplitudes and frequencies. The input of the transformation represents the image spatial domain while the output of the transformation represents the image in the Fourier or frequency domain where each point represents a particular frequency contained in the spatial domain image [8-12].

i. Fourier Transform

Fourier transform (FT) transforms the image encoded as luminance values of pixels. Such values are spatially sampled and sampled image does not contain all frequencies forming the original image [2, 7]. In order to lose as little information as possible, the sample frequency must twice as much as the higher frequency of interest. Here we use Discrete Fourier Transform (DFT), the digital implementation of Fourier Transform.

DFT transform an MxN image into another MxN image. Without loss of generality, we will consider square images of size NxN. f(x,y) is the gray level at pixel (x,y) in the original image of size NxN. For frequency variables a,b = 0,1,2…..…N-2, N-1, F(a,b) is expressed by

$$F(a,b) = \sum_{x=0}^{N-1}\sum_{y=0}^{N-1} f(x,y)xe^{-j2\pi(ax+by)/N} \quad (3)$$

Where the exponential term is the basic function corresponding to each point F(a,b) in the Fourier frequency domain. Thus F(0,0) represents the DC-component of the image which corresponds to the average luminance while F(N-1, N-1) represents the transform at the highest frequency. It is shown that F(a,b) is periodic, with period NxN. From equation (1) the value of F(a,b) is a complex number which represents as following

$$F(a,b) = \left|F(f_{x},f_{y})\right| / e^{j\theta\,(fx,fy)} \quad (4)$$

The value of the modulus is known as Fourier or frequency spectrum of f(x,y) whereas, the value modulus square is called as power spectrum of f(x,y). The magnitude of Fourier spectrum is an absolute value that is it does not change due to the fabric movement. This means that the frequency spectrum only changes if fabric structure changes. The main disadvantage of DFT is its long computational time.

The function fft(x) implement the transform for vectors of length N by

$$X(k) = \sum_{j=1}^{N} x(j)\omega_N^{(j-1)(k-1)} \quad (5)$$

$$X(j) = \left(\frac{1}{N}\right)\sum_{j=1}^{N} X(k)\omega_N^{-(j-1)(k-1)} \quad (6)$$

Where, $\omega_N = e^{(-2\pi i)/N}$ is an Nth root of unity.

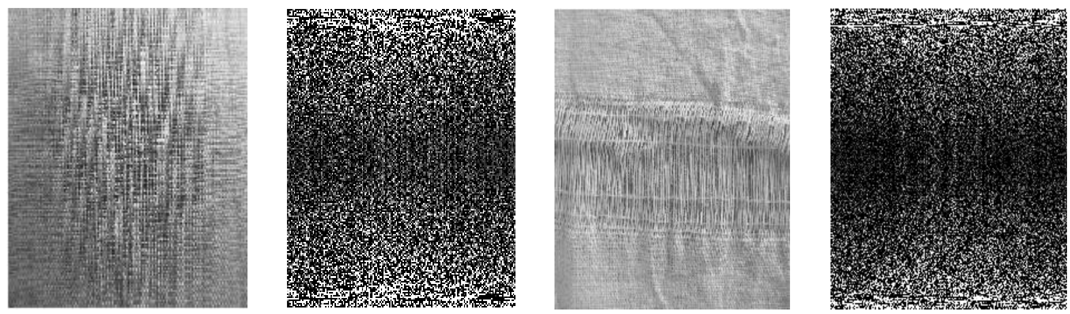


Figure 1. a). Defect free b). Defected

ii. Feature Extraction (Cross Correlation)

The periodic nature of woven fabric is used to monitor and describe the relationship between the regular structure of the fabric in the spatial domain and its Fourier spectrum in the frequency domain [2]. Presence of a defect over the periodical structure of woven fabric causes changes in its Fourier spectrum [7]. Weft yarns information appears in the vertical direction fy and warp yarns information appears in the horizontal direction fx, the following features are extracted.

$$F1 = \left|F(0,0)\right| \quad (7)$$

$$F2 = \left|F(f_{x1},0)\right| \quad (8)$$

$$F3 = f_{x1} \quad (9)$$

$$F4 = \sum_{f_{x2}}^{f_{x1}} \left|F(f_{x1},0)\right| \quad (10)$$

F2, F3 and F4 are for detecting changes in the vertical or warp direction

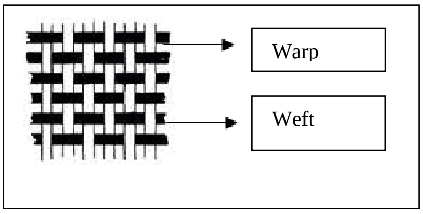
$$F5 = \left|F(0,f_{x1})\right| \quad (11)$$

$$F6 = f_{y1} \quad (12)$$

$$F7 = \left|\sum_{f_{y1}=0}^{f_{y1}} F(0,f_{y1})\right| \quad (13)$$

F5, F6 and F7 detecting changes in the horizontal or weft direction. The average correlation coefficient of a fabric image free of defects is calculated. Then the average feature correlation coefficient of sub image is calculated. The above average coefficient values are compared and if sub image value is smaller than the defect free image it means that the sub image has a defect.

To optimize the correlation coefficient, the detection technique is implemented while it is set to 0.7 and 0.9 as minimum and maximum limits whereas in between it is increased by a step of 0.05. The detection rate at each coefficient value is calculated to find the feature correlation coefficient which gives the higher detection rate. This is repeated for all defect types. There is no relationship between the correlation coefficient and the overlapping of sliding windows. The detection rate is low where lower values of correlation coefficients. The detection rate is low when a low resolution levels. The detection rate for all defect type increases when the level of image resolution is increased till certain limit.



III. Conclusion

In this paper, a real time automated fabric inspection system could be used for fabric inspection. The implementation takes place through the technique of Fourier transform and cross correlation technique simultaneously looks very promising to detect the structural defect of plain weaves. They examine the structure regularity features of the fabric image in the Fourier domain using a random sub image scans the main fabric image. This work provides a way to inspect and detect fabric defects of plain weaves either online and / or offline. This can be expanded to other fabric structures.

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