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Automated Yarn Density Measurement from Fabric Images

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***Abstract*—The price of fabrics has reduced to a high percentage due to the presence of defects. The quality of fabrics is determined by the defects present in it. The fabric defects include variation in color or width inconsistencies, hairiness, slubs, broken ends, etc. Yarn density measurement is an important factor for fabric quality and difference in yarn density in same cloth is considered as major fabric defect that should be rectified without fail. This process of yarn density measurement take place after production process and rectification if any is done in the appropriate weaving stage. The thread density of woven fabric is currently measured with manual operations. One of the methods is to count the number of warp and weft yarns in a unit length is with a textile analysis magnifying glass. The manual methods are not only time consuming but also require more attention and concentration from an expert analyst. The error percentage of such detection is more. Also, the thread density detection results are influenced by the physical and mental conditions of the operators. Thus, it is highly desirable to develop an automatic measuring system for the thread density of woven fabric.**

***Index Terms*—Textile, Yarn Density, Fringe Moiré, Wefts, Warps**

I. INTRODUCTION

In the textile industry, before any exports or final delivery is done inspection of fabrics are needed to find defects. Image analysis has been proved to be an efficient method for analyzing the yarn density of woven fabric [1]. The work can be divided into two steps: The first step is to count the number of yarns in the fabric image and the second is to measure the physical dimensions of the fabric image. Usually, the second step is done in the procedure of image acquisition and current researches focuses on first step.

Weaving is the oldest and traditional method to produce fabrics. In this process two sets of yarns are interlaced horizontally and vertically using a predefined pattern[2]. Woven fabrics are not only important in wear and apparel applications but also in military and aerospace applications. Examples are fiber-reinforced composites and armed fabrics used in ballistic rated body armor, ballistic composites, canvas, bullet proof, fire proof clothing etc. The four main characteristics of woven fabric are determined by its yarn material and composition, the grammage (weight of the material per unit area), the pickage (yarn density), and the braiding pattern which is called weave.

Woven fabrics consists of vertically and horizontally passing yarns denoted as warps and wefts, respectively, and intersection points between wefts and warps are called float points. The basic weave patterns are the plain, twill, and satin weave. The physical and visual properties of fabrics are the major research subjects in textile industry. The yarn density of a woven material is an important characteristic of fabrics which affects quality and is defined by the number of wefts per unit length. The warp density is not so relevant for measurement because it is a constant that is determined mechanically by the operator when the weaving machine is set up for operation. The exact measurement of weft densities is of importance in quality assurance and to detect material grammage.

In a weaving system, the warps are interlaced into the wefts using the warp beam. The final product is obtained in fabric beam. The image acquisition for analysis is done just before the final product obtaining. The structure of a woven fabric is characterized by many features such as the thickness of the threads (judged by Thread density), the type of interlacing of threads, the density of the weave etc. The properties and appearance of a woven fabric are determined by the fabric structure, by the properties of the threads, and by the fabric finishing.

1) Preprocessing: The preprocessing step is an important stage that improve the image interpretability, remove noise in an image etc. It works in such a way

that it improves the image quality by eliminating the regions which reduce the accuracy and reducing image artifacts. This stage removes defects caused by the image acquisition process such as noises and artifacts. The main methods for preprocessing are: Median Filtering, Weiner filtering, Contrast Limited Adaptive Histogram Equalization etc. Preprocessing using histogram equalization greatly improves the interpretability of fabric images as it equalizes no: of yarn pixels and inter-slice pixels.

2) Wavelet transform and reconstruction: Wavelet are used as it has a good localization property in both space domain and frequency domain with multi-resolution and orthogonality. It can focus on any details of the analysis image, which is widely used in the field of fabric density measurement. Contrasted with Fast Fourier Transform, wavelet transform has high efficiency and high precision. It can be used to analyze non-stationary signals such as threads in fabric image with its localization properties. In fabric image processing, wavelet is mainly used for reducing image noise, image compressing, enhancement, fusion and analysis of the image in frequency domain. Wavelet transform is defined in Equation 1.

$$C_{a,b} = \sum_{-\infty}^{+\infty} f(t)\Psi_{a,b}(t)dt \quad (1)$$

While the reconstruction function is given in Equation 2.

$$f(t)=c\sum_{-\infty}^{+\infty} \sum_{-\infty}^{+\infty} C_{a,b}\ \Psi_{a,b}(t) \quad (2)$$

A fabric image at level s can be decomposed into four components: the approximation at level s + 1 and the details in three orientations (horizontal, vertical, and diagonal) via two- dimension (2D) DWT. The reconstruction is done via inverse wavelet transform.

3) Morphological Operation and inspection: Erosion at this stage is performed for thinning the warps pixels so that it is overlapped with the nearby yarn. Inspection is done using an equation and result obtained in threads/cm. Goals of the automated system are as follows: -

Improve accuracy in density measurement;

Assist in early detection of defects;

Reduce the time of the manual labors in evaluation.

II. SURVEY OF DEFECT DETECTION SYSTEM

Malek et al. [3], specifies the traditional methods of measuring the yarn density. Human inspectors are employed for visual inspection of fabric defects as well as yarn density measurement. Magnifying glasses may be used for this process. It also specifies various automated methods such as statistical, spectral and model based approaches for fabric flaw detection.

Priya S et al. [4], this paper specifies the fabric flaw detection by dividing the image into bit planes and then applying morphological operations to detect defects. This method is used because most of the image features are concentrated on higher order bit planes.

Ruru Pan et al. [2], specifies an image processing technique was used to find warp and weft densities of woven textile fabrics. From the vertical and horizontal frequencies of textile images the FFT analysis was performed. It quickens the textile production measurements and makes the process easier.

Ajay Kumar et al.,[5] specifies statistical, spectral and model based approaches for fabric flaw detection.

A. Statistical methods

1) Defect Detection Using Bilevel Thresholding: One of the simplest methods to detect high contrast defects is to directly use gray level thresholding. The advantage of defect detection techniques based on bilevel thresholding lies in its ease of implementation. However, such techniques fail to detect those defects that appear without altering the mean gray level in defect-free areas.

2) Defect Detection Using Gray-Level Statistics: This is done by dividing the inspection images into arbitrary blocks and classifying these blocks into defect or defect-free classes using their first-order gray level statistics. However, if the block size chosen is too small, discrimination among the similar defect-free textures may be difficult.

3) Defect Detection Using Morphological Operations: Every inspection image is histogram equalized and then thresholded to pro- duce a binary image. The binary image of a defect-free fabric (during training) is used to extract the optimal size and shape of structuring element (SE) using an autocorrelation function. Every binary test image is subjected to erosion and then to dilation using this SE. The distance between the resulting defective pixels (if any) has been used to

group defects into slubs or knot defects.

4) Defect Detection Using Edge Detection: The distribution of the number of edges per unit area is an important feature in the textured images. The amount of gray level transitions in the fabric image can represent lines, edges, point defects and other spatial discontinuities. These features have been used to detect fabric defects.

5) Defect Detection Using Normalized Cross-Correlation: The cross-correlation function provides a direct and accurate measure of similarity between two images. Any significant variation in the value of this measure indicates the presence of a defect.

6) Defect Detection Using Eigen filters: The information content of defect-free fabric image can also be extracted by registering the variations in an ensemble of macro windows within the image, independent of any judgment of its texture. The important information in most fabric textures is contained in higher order relationships among image pixels. Therefore, fabric defect detection using independent component analysis (ICA) of fabric texture has been suggested.

7) Defect Detection Using Local Linear Transforms: Several popular bidimensional transforms such as Discrete Cosine Transform (DCT), Discrete Sine Transform (DST) or Discrete Hadamard Trans- form (DHT) can be used for the extraction of local texture properties.

8) Defect Detection Using Rank-Order Functions: The rank- function of a given image is derived from its histogram, and is given by the sequence of gray levels in the histogram when the sequence is sorted in an ascending order. A 1: 1 correspondence exists between the rank function and the related histogram, which does not exist between the histogram and the image. Therefore, the histogram and the rank function provide the same information. However, the advantage of using rank functions instead of histograms lies in the fact that there is a very efficient definition of rank-distances that can be efficiently computed. Artificially included defects can be detected in this method.

9) Defect Detection Using Neural-Networks: Neural networks are among the best classifiers used for fault detection due to their nonparametric nature and ability to describe complex decision regions.

B. Spectral Approaches

1) Defect Detection Using Discrete Fourier Transform (DFT): Fourier transform has the desirable properties of noise immunity, translation invariance and the optimal characterization of periodic features. The woven fabric image is a combination of warp and weft yarn patterns. Each of these yarns is effectively 1-D and may be modeled by a comb of impulses that are modulated by the profile of one yarn.

2) Defect Detection Using Optical Fourier Transform (OFT): he Fourier transform of textile fabrics can also be obtained in optical domain by using lenses and spatial filters. Therefore, the detection of fabric defects using OFT is relatively easy and fast.

3) Defect Detection Using Windowed Fourier Transform (WFT): Defect detection methods based on DFT and OFT are inadequate when the location of defects, i.e., spatial localization is desired. Furthermore, the small or the local defects may be swamped in the inevitable averaging that takes place in the feature estimation of large image regions. Thus, the DFT- and OFT-based techniques are suit- able for global defects rather than local defects. Detection of local defects requires the techniques that can localize and analyze the features in spatial as well as frequency domain. Therefore, features based on space-dependent Fourier transform or running- window Fourier trans- form or WFT have been suggested for fabric defect detection.

4) Defect Detection Using Optimized Fir Filters: Some fabric defects that produce very subtle intensity transitions may be difficult to detect using the above spectral approaches. A potential solution to the detection of such defects is to employ optimal finite impulse response (FIR) filters.

C. Model based approaches

Model-based approaches are particularly suitable for fabric images with stochastic surface variations (possibly due to fiber heap or noise) or for randomly textured fabrics for which the statistical and spectral approaches have not yet shown their utility. Several probabilistic models of the textures have been proposed and used for the defect detection.

1) Defect Detection Using Gauss Markov Random Field (GMRF) Model: The stochastic models based on the GMRF have been successfully shown to model many natural and man-
Made textures.
2) Defect Detection Using Poisson's Model: The stochastic models of some of the randomly textured materials that are produced in the industry are based on the nature of the Manufacturing process.
3) Defect Detection Using Model-Based Clustering: The problem of locating possible clusters in a data set (image) is a recurrent one with a long history. We can use model-based clustering to detect relatively faint aligned defects in denim fabrics.
Another approach [4] for defect detection in fabrics is dividing the image into various bit planes. Lower order bit planes consist of more information. Then we find exact locations using mathematical morphology such as erosion and dilation.

[2] Fourier theorem states that any signal can be represented by the sum of the sine and cosine wave with various amplitudes and frequencies. That is, the relationship between a Repetitive, regular, and uniform fabric pattern in the image space and its spectrum in the spatial frequency can be linked by operating two-dimensional Fourier transform. Periodic frequencies of warp and weft densities can be used to evaluate yarn density defects.

[6] Beta gauge and Hough transform methods provide yet another two methods for inspection of yarn density measurement. Fringe projection moiré techniques can also be used for yarn density measurements. In this method, the formation of a specific moiré pattern caused by the interaction between fabric and grating is the guide for measurement of density. By making use of this technique, it is possible to measure a quantity on a large scale (scale of cm where the distance between grating and fabric is read) and report a quantity on a small scale (with precision of 0.01 mm, where the density of yarns in a fabric or the space between yarns in the fabric is calculated).
The most advanced method for finding yarn densities is using Fourier transform method to analyze frequency spectrum. As a two-dimension discrete array can be seen in the gray-scale image, the two-dimension discrete (2D) Fourier transform is selected to analyze the woven fabric image. Log Transform is applied to narrow the numerical range of amplitude spectrum. Reconstruction is done using inverse Fourier transform for obtaining warp and weft separately. Segmentation is done using thresholding for more accurate results.

III. PROPOSED METHOD

A. Preprocessing stage
Image Enhancement is done in the preprocessing stage. The aim of image enhancement is to improve the interpretability of information in images, or to provide better input for other image processing techniques. Histogram equalization is done because the no: of pixel of yarns and inter slices should be equalized for better results. It is a method that improves the contrast in an image, because it stretches out the intensity range. Equalization implies mapping one distribution (the given histogram) to another distribution (a wider and more uniform distribution of intensity values) so the intensity values are equalized for all pixel's intensities. To accomplish the equalization effect Cumulative Distribution Function is used.

B. Wavelet transform and reconstruction
Wavelet are used as it has a good localization property in both space domain and frequency domain with multi- resolution and orthogonality. It can focus on any details of the analysis image, which is widely used in the field of fabric density measurement. Contrasted with Fast Fourier Transform, Wavelet transform has high efficiency and high precision. It can be used to analyze non-stationary signals such as threads in fabric image with its localization properties. In fabric image processing, wavelet is mainly used for reducing image noise, image compressing, enhancement, fusion and analysis of the image in frequency domain. Wavelet transform is defined in Equation 1. While the reconstruction function is given in Equation 2.
A fabric image at level s can be decomposed into four components: the approximation at level s + 1 and the details in three orientations (horizontal, vertical, and diagonal) via two- dimension (2D) DWT. The reconstruction is done via inverse wavelet transform.

C. Morphological Operation and inspection

A Nick thresholding method is applied for binarization. It is a local thresholding technique. The major advantage of this method is that it considerably improves binarization for white and light images by shifting down the binarization threshold. The thresholding we propose is $T = m + k (p_i^2 - m^2)/NP$

Where k is the Niblack factor

m = mean grey value

pi = pixel value of grey scale image

NP = number of pixels

Geodesic erosion at this stage is performed for thinning the warps pixels so that it is overlapped with the nearby yarn. Finally, the eroded image is inspected using the following steps.

- A standard point which is in middle of the left boundary is selected for traversal.
- The first pixel which has the opposite gray value of first point is selected as start point.
- The last pixel which has opposite gray value of start point is selected as end point.
- Alternative points are traversed and whenever a gray value same as that of start point occurs a new yar count is added.
- Continued until the end point.
- Warp density is calculated by $D_{warp} = N/((EP-SP+1)\ Scale)$ where N is the no: of warp yarns, P=Coordinate of end point, SP=coordinate of start points and Scale is the magnification value in cm/pixel.

IV. CONCLUSION

In this paper, it aims at measuring the yarn density of fabrics using images. Spectral methods such as wavelet transform are used, as frequency components provide more relevant information for feature extraction. More optimal method with low time complexity and accurate results could be used for measuring yarn density.

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