GLOBAL JOURNAL OF ENGINEERING, DESIGN & TECHNOLOGY
(Published By: Global Institute for Research & Education)
www.gifre.org

OVERVIEW: METHODS OF AUTOMATIC FABRIC DEFECT DETECTION

Priyanka M. Shanbhag[1] , Manish P. Deshmukh[2]& Shekhar R. Suralkar[3]

[1]PG Student (E&TC), SSBT's COET, Jalgaon, India
[2]Asso .Prof (E&TC), SSBT's COET, Jalgaon, India
[3]Asso .Prof (E&TC), SSBT's COET, Jalgaon, India

Abstract

Fabric inspection has an importance to prevent the risk of delivering inferior quality product. Automated inspection systems are much needed in the textile industry, especially when the quality control of products is a significant problem. The fabric defects inspection process is carried out from a long time with human visual inspection that proves to be insufficient and costly. Hence in order to reduce the cost and wastage of time, automatic fabric defect detection is required. Robust and efficient fabric defect detection algorithms are used for inspection. This paper presents different methods of fabric defect detection to extract the different features from the fabric. Thus, the inspection of 100% fabric is necessary mainly because of two reasons, first to determine its quality and second to detect any disturbance in the weaving process.

1. Introduction

Fabric defect detection is a quality control process that aims at identifying and locating defect of fabric. Human inspection is the traditional means to assure the quality of fabric. It helps instant correction of small defects, but human error occurs due to fatigue and fine defects are often undetected. Therefore, automated inspection of fabric defect becomes a natural way to improve fabric quality and reduce labor costs. In the textile industry, before any shipments are sent to customers, inspection is needed for maintaining the fabric quality.

The most challenging industrial inspection problems deal with the textured materials such as textile web, paper, and wood. The inspection problem encountered in textured materials become texture analysis problems at microscopic levels. Textured materials take many forms and while there is a remarkable similarity in overall automation requirements for visual inspection, the cost-effective solutions are application specific and generally require extensive research and development efforts. Defect detection in web materials normally depends upon identification of regions that differ from a uniform background. The web inspection problems are also associated with textured materials such as textile, ceramics, plastics, etc. The characterization of defects in textured materials is generally not clearly defined. The textured materials can be further divided into uniform, random, or patterned textures. Brazakovic *et al.* [6] have detailed a model-based approach for the inspection of random textured materials. The problem of printed textures (e.g., printed fabrics, printed currency, and wallpaper) requires the evaluation of color uniformity and consistency of printed patterns, in addition to any discrepancy in the background texture.

Textile quality control involves the detection of defects that cause a distortion of the basic structure of the material that shows a high degree of periodicity. Performance and assessment are never constant and effectiveness decreases quickly with fatigue. Due to the very slow speed of human visual inspection compared to production rate, automatic inspection is more important than ever. Many researchers have worked on the automation of inspection systems. For a weaving plant, in harsh economic times, first quality fabric plays the main role to insure survival in a competitive marketplace. First quality fabric is totally free of major defects and virtually free of minor structural or surface defects. Second quality fabric is fabric that may contain a few major defects and/or several minor structural or surface defects. Nickoloy et al. [8] have shown that the investment in the automated fabric inspection system is economically attractive when reduction in personnel cost and associated benefits are considered.

2. Methods

2.1Statistical Approach

Statistical methods represent the texture indirectly according to the non-deterministic properties that manage the distributions and relationships between the gray levels of an image. The objective of defect detection is to separate the inspection image into regions of distinct statistical behavior. The statistics of defect-free regions are stationary, and these regions extend over a significant portion of the inspection images [2].

A) Defect Detection Using Fractal Dimension (FD)

Conci and Proenca [13] have implemented the differential box counting method with few modifications to minimize computational complexity and to enhance efficiency. They used the estimate of FD on inspection images to detect fabric defects. The decision for defect declaration is based on the variation of FD. The defect detection approach is performs simple computations but presents very limited experimental results, suggesting 96% accuracy detection. The localization accuracy of detected defects is very poor and have high false alarm as this method does not cover all possible (FD) ranges for textiles i.e. any value from 2.0 to 3.0.

B) Defect detection using cross-correlation

Correlation is used for locating features in one image that appear in another providing a direct and accurate measure of similarity between two images. Any significant variation in the values of resulting measure indicates the presence of a defect. The correlation approach yields satisfactory results when detecting imperfections in regularly textured backgrounds. On the other hand, randomly textured backgrounds do not correlate well and demonstrate a limitation of this approach.

C) Multilevel thresholding approach

This approach is used to inspect uni-coloured fabrics without consideration of texture. The defective regions are segmented by using two thresholding methods. The limitation of this approach is one should ensure that all imaging conditions are always constant and that the non-defective fabric samples are all identical. The dust particles, lint, and lighting conditions on the test sample may introduce false alarms.

D) Optimal filter design approach

This approach concerns the determination of a filter that provides the largest discrimination between two textures. The classifications were made on the basis of either gray level statistics or morphological operations. The autocorrelation function was used to identify fabric structural-repeat units to carry out either statistical or morphological computations. They first equalized all acquired images histogram to obtain more clearly identifiable autocorrelation maxima and minima. After equalization, the images become more comparable as their contrast and brightness are more closely similar.

E) Independent Component Analysis

ICA aims to find a linear transformation of the original data such that the new representation is one that minimizes the statistical dependence of the components present in the representation. ICA tries to find the hidden components that capture the essential structure of the data. The representation achieved by ICA facilitates the analysis of the data encountered in such fields like, data compression, pattern recognition, de-noising [4]. The aim of ICA is to make the image pixels as mutually independent as possible. (ICA) has very low real time computational requirements, as it involves simple matrix multiplication. It gives good detection results with 96-97% [4].

F) Statistical moments approach

Mean, standard deviation, skewness provides statistical information over a region while the values are used for image segmentation. In these techniques a statistical sample is gathered by preferring large windows. The algorithm of obtaining texture features directly from the gray-level image by computing the moments in local regions has successfully segmented binary images containing textures with iso-second order statistics as well as a number of gray level texture images. Due to non-uniform illumination conditions on the image, statistical moments reveal the necessity of a pre-processing step to correct the image illumination in-homogeneities. The main advantage of these techniques is their computational simplicity [15].

G) Rank order function approach

This approach is based on histogram analysis which is a simple statistical approach. It is given by the sequence of gray levels in the histogram when this sequence is sorted in the ascending order. There exists 1:1 correspondence between the rank function and the related histogram, which does not exist between histogram and the image. Therefore the histogram and the rank function provide exactly the same information. The median filter and other rank-order filters like minimum or maximum are the best known examples of order statistics based filers. The advantage of using rank functions lies in the fact that there is a very efficient definition of rank-distances that can be efficiently computed. These nonlinear filters are especially useful because of their robustness toward the modifications of the image local properties. The use of local information gives also the possibility of performing other operations like adaptive modifications of local histograms. Harwood et al. [14] found that, local rank-order correlations of images with Laws' masks could perform better than the basic convolutions, for suitable image and mask sizes. These more robust measures of correlation are less sensitive to local random pattern and grey-scale variabilities which are everywhere apparent in large textured images. The fabric texture information regarding spatial distribution and orientation, etc., is not uniquely determined from the knowledge of rank-order functions. Due to such drawbacks the approaches based on rank-order functions or classical histogram analysis have failed to generate any further interest for fabric defect detection.

2.2Spectral Approaches

Many common low-level statistical approaches break down for several fabric defects that appear as subtle intensity transitions. It is therefore critical to explore other robust and efficient computer-vision approaches for fabric defect detection. Spectral approaches occupy a big part of the latest computer vision research work. It simulates the human vision system where the psychophysical research has indicated that human visual system analyzes the textured images in the spatial frequency domain. The primary objectives of spectral approaches are to extract texture primitives or generalize the spatial placement rules. Spectral approaches require a high degree of periodicity and are developed to overcome the efficiency drawbacks of many low-level statistical methods. The high degree of periodicity of basic texture primitives, such as yarns in the case of textile fabric, permits the usage of spectral features for the detection of defects. The spectral approaches are summarized in the following sections.

A) Fourier analysis approach

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**.** This characterizes the textured image in terms of frequency components. Fourier techniques have desirable properties of noise immunity, translation invariance and the optimal characterization of the periodic features. The periodically occurring features can be observed from the magnitude of frequency components. These global texture patterns are easily distinguishable as concentration of high-energy bursts in the spectrum. 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 [1].

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. Because of the stochastic textured components on the real fabric images, the local maxima peaks in the 2-D frequency plane are not properly localized. Therefore, Sari-Sarraf and Goddard [12] have used perfectly contiguous and non overlapping concentric rings of constant width to include various amounts of loosely localized frequency components. An approach based on Fourier transform has been described to detect the structural defect in fabric. The simulated models are used to understand the behavior of frequency spectrum. Since the three-dimensional frequency spectrum is very difficult to analyze and many defects occur along the horizontal and vertical axes, the central spatial frequency spectrum approach has been proposed to increase the efficiency of the analysis process. Seven significant characteristic parameters can be extracted from the central spatial frequency spectrums for describing the defect type. Experiments have shown that the extracted parameters can be used to classify fabric defects. The Fourier transform of textile fabric can be obtained in optical domain by using lenses and spatial filters.

B) Defect detection using Wigner distributions

The Wigner distribution function is Fourier-like but offers better co-joint resolution than Gabor or difference of Gaussians for co-joint spatial and spatial-frequency image representation. Song *et al.* [11] have used a computational approximation to the Wigner distribution, i.e., pseudo-Wigner distribution, to demonstrate the detection of cracks in complex background textured materials. The proposed method has shown to be quite accurate and this algorithm is effective when implemented for online fabric defect. The major drawback of this technique is the presence of interference terms between the different components of the image.

C) Defect Detection Using Optimized FIR Filters:

A potential solution to detect fabric defect that produce very subtle intensity transitions is to employ optimal finite impulse response (FIR) filters. A FIR filter has generally more free parameters that offer advantage of computational ease. The biggest advantage of FIR filters is that they can implement any impulse response, of finite length. The optimization offers the potential of large feature separation between the defect-free and the defective regions of the filtered image. Kumar [10] emphasized on smaller spatial masks, as compared to those from optimal Gabor filters, and demonstrated fabric defect segmentation with optimal FIR filters as small as 3×3 or 5×5 mask size. Also, Kumar and Pang proposed a linear FIR filter with an optimized energy separation. They investigated the approach performance with the size variation of both optimal and smoothing filters. They concluded that the size of optimal filter has appreciable effect on the performance for the defect detection. These filters can be used to supplement the performance of the existing inspection systems that fail to detect a class of specific defects.

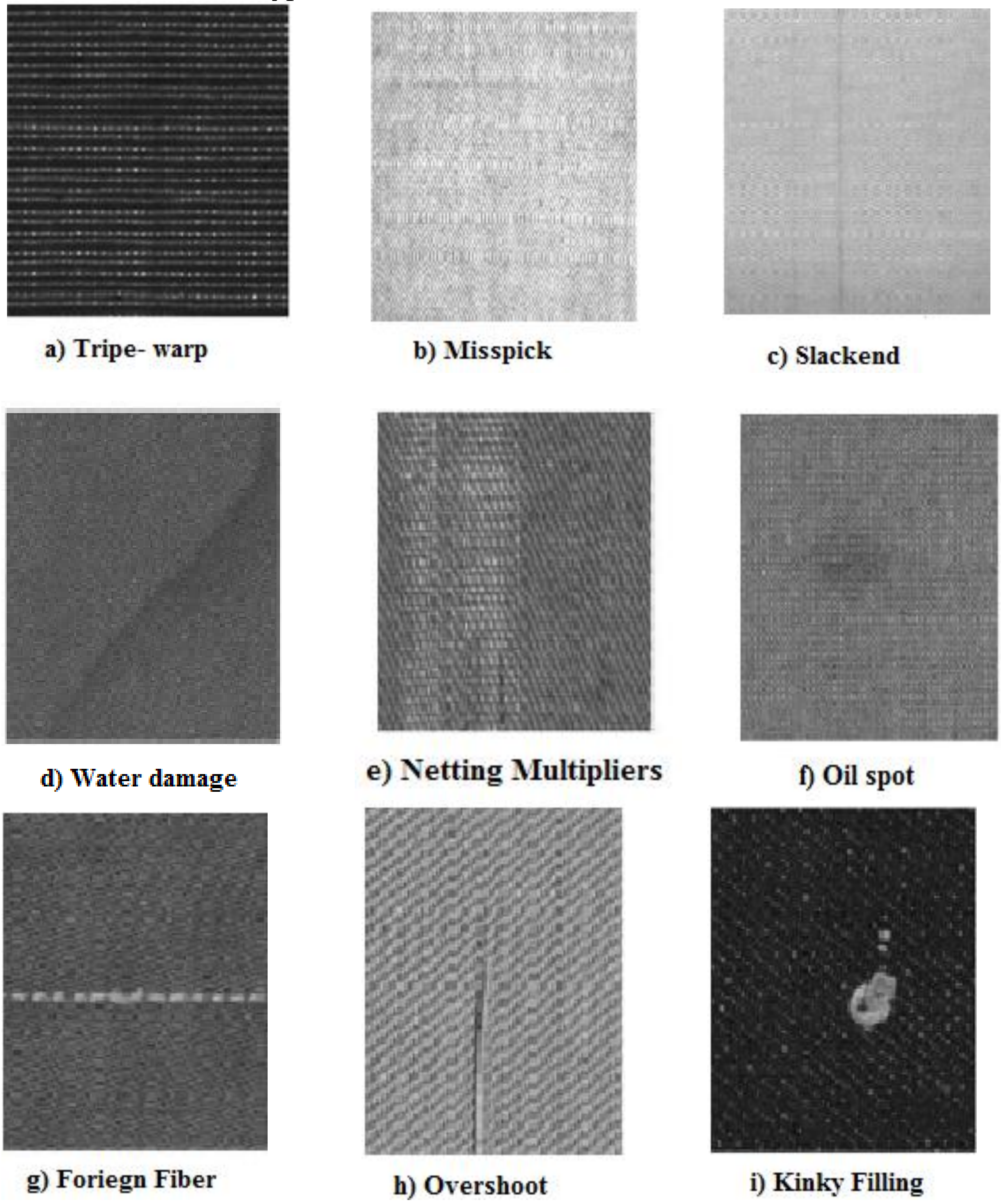
2.3Model Based Approaches

This approach tries to capture the process that generates the texture. This is done by determining the parameters of a pre-defined model. Texture is a complex pictorial pattern and defined by a stochastic or a deterministic model. The real textures can be modeled as stochastic processes, and textured images can be observed as the realizations or the samples from parametric probability distributions on the image space. When the statistical and spectral approaches fail to show their utility, fabric inspection is done through model based approaches. The advantage of this modeling is that it can produce textures that can match the observed textures. These approaches often require that the image features at different levels of specificity or detail match one of possible models of different image classes. This task is very tedious and computationally intensive if the models are complex and if a large number of models are considered. Several probabilistic models of the textures have been proposed and used for the defect detection.

Model based texture analysis such as Fractal model and Markov are based on the construction of an image that can be used for describing texture and synthesizing it [9]. These methods describe an image as a probability model or as a linear combination of a set of basic functions. The Fractal model is useful for modelling certain natural textures that have a statistical quality of roughness at different scales and also for texture analysis and discrimination. This method has a weakness in orientation selectivity and is not useful for describing local image structures. Pixel-based models view an image as a collection of pixels, whereas region-based models view an image as a set of sub patterns. There are different types of models based on the different neighborhood systems and noise sources. These types are one-dimensional time-series models, Auto Regressive (AR), Moving Average (MA) and Auto Regressive Moving Average (ARMA). Random field models analyze spatial variations in two dimensions, global random and local random. Global random field models treat the entire image as a realization of a random field, and local random field models assume relationships of intensities in small neighborhoods. A widely used class of local random field models is Markov models, where the conditional probability of the intensity of a given pixel depends only on the intensities of the pixels in its neighborhood (the so-called

Markov neighbors). Campbell *et al*.[8] combined image-processing techniques with a powerful new statistical technique to inspect denim fabrics. The clustering approach employs model based clustering to detect relatively faint aligned defects.

3. Fabric Defects and Types



a) Tripe- warp b) Misspick c) Slackend

d) Water damage e) Netting Multipliers f) Oil spot

g) Foriegn Fiber h) Overshoot i) Kinky Filling

Fig.1. Images of fabrics with different types of defects

Figures above show the different types of defects that occur in fabrics. Fabric defects are responsible for nearly 85% of the defects found in the garment industry. Out of them manufactures recover only 45-65% of their profit from second quality goods due to which the prices are reduced. It is therefore necessary to detect, identify and to prevent these defects from reoccurring. There are many kinds of fabric defects such as broken pick yarns or missing pick yarns, Slubs, inconsistencies, hairiness, machine oil. The fabric quality is affected by yarn quality, loom defects, poor quality of raw materials and improper conditioning of yarn. Some of these fabric defects are visible, while others are not. However, some fabric defects may be rectified during weaving and after weaving while others are not.

An automated defect detection and identification system improves the product quality that results in improved productivity to meet customer needs and to reduce the costs associated with off-quality. In automatic detection, the fabric is automatically inspected as it is produced. This process is carried out by identifying the faults in fabric and then the fabric is classified based on the dimension of the faults. The weaving irregularities generated in the weaving machines are due to the change in operating conditions such as temperature, humidity that results in various fabric defects. Figures below show the different types of defects that occur in fabrics.

4. Conclusion

To ensure the quality level, 100% inspection is necessary to be performed. As the work is vast and diverse, the classifications for the automated fabric inspection approaches are improved. Through these classifications, the texture analysis problem is categorized into different approaches according to the used algorithm. These are structural, spectral, model-based approaches. Unfortunately, with these large numbers of implemented approaches, the perfect approach does not exist yet as each of them have some advantages and disadvantages.

References

[1] C.H. Chan, G.K.H. Pang, "Fabric defect detection by Fourier analysis", IEEE Trans. Industry Applications vol.36, no.5 (Sep/Oct 2000) 1267–1276.

[2] Kumar, "Computer-Vision-Based Fabric Defect Detection: A Survey," IEEE Trans. Ind. Electron., vol. 55, no. I, pp. 348-363, Jan. 2008.

[3] Ajay kumar, Grantham K.H. Pang, "Defect detection in textured materials using gabour filters" IEEE, vol. 38, no. 2, March/April 2002.

[4] A. Serdaroglu, A. Ertuzun, A. Ercil, "Defect detection in textile fabric images using wavelet transforms and independent component analysis", Pattern recognition & image analysis, vol.16, no.1, pp.61-64, 2006

[5] K.L.Mak, P. Peng, K.F.C. Yiu, "Fabric defect detection using morphological filters", Image & vision computing, 27(2009), pp. 1585-1592.

[6] D. Brzakovic, N. Vujovic, and A. Liakopoulos, "An approach to quality control of texture web materials," Proc. SPIE, vol. 2597, pp. 60–69, Oct. 1995.

[7] Nickolay B. N. and Schmalfub H. (1993) Mellind Textilberichte, vol. 73, 33-37.

[8] J. G. Campbell, C. Fraley, F. Murtagh, and A. E. Raftery, "Linear flaw detection in woven textiles using model-based clustering," Dept. Statistics, Univ. Washington, Seattle, WA, Tech. Rep. 314, Jul. 1996, pp. 1–15.

[9] Taun Anh Pham, "Optimization of texture feature extraction algorithm" master thesis, Delft University of Technology, 2010.

[10] A. Kumar, "Automated defect defection in textured materials," Ph.D. dissertation, Dept. Elect. Electron. Eng., Univ. Hong Kong, Hong Kong, May 2001.

[11] K. Y. Song, M. Petrou, and J. Kittler, "Texture crack detection," Mach. Vis. Appl., vol. 8, no. 1, pp. 63–76, 1995.

[12] H. Sari-Sarraf and J. S. Goddard, "On-line optical measurement and monitoring of yarn density in woven fabrics," Proc. SPIE, vol. 2899, pp. 444–452, 1996.

[13] Gedziorowski M. and Garcia J.: Programmable optical digital processor for rank order and morphological filtering, Optics Communications, Vol. 119, Issues 1-2, August, 1995, pp. 207-217.

[14] Thilepa R.: A Paper on Automatic Fabrics Fault Processing Using Image Processing Technique in MATLAB, Signal & Image Processing: An International Journal (SIPIJ), Vol. 1, No. 2, December, 2010, pp. 88 - 99.

[15] Anagnostopoulos C., Vergados D., Kayafas E., Loumos V. and Stassinopoulos G. : A Computer Vision Approach for Textile Quality Control, the Journal of Visualization and Computer Animation, Vol. 12, 2001, pp. 31-44.