IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 10, Issue 1, January 2020, ||Series -I|| PP 61-65

A Systematic Review of Fabric Defect Detection Approaches

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Received 31 December 2019; Accepted 15 January 2020

Abstract*:* In the textile production, defect detection is an important factor on quality control process. The investment in automated texture defect detection becomes more economical reducing labor cost. The cost of fabric is often affected by the defects of fabrics that represent a major problem to the textile industry. Manual inspections have the problems as lack of accuracy and high time consumption where early and accurate fabric defect detection is an important phase of quality control. Therefore automate fabric inspection i.e. computer vision based inspection is required to reduce the drawbacks discussed above. Robust and efficient fabric defect detection algorithms are required to develop automated inspection techniques. From last two decades so many computer vision based methods have been proposed. This paper attempts to categorize and describe these algorithms. Categorization of fabric defect detection techniques is useful in evaluating the qualities of identified features.
Index Terms*:* fabric defect, automated visual inspection, quality control, defect detection, textile inspection;

I. INTRODUCTION

Fabric quality is one of the most important factors in textile industry. For this industry, to keep the quality of fabric at high level, automated inspection system is required. Based on computer vision and artificial intelligence, fabric defect detection system has been developed in recent years. After comparing, automatic defect detection system with human inspection, it can be inferred that prior one has high efficiency, consistency and reliability.[1]

The defects are responsible for reduction in price the textile fabric by 40% to 70%[2]. When the fabric quality control system is thought of, Manual defect detection is a seen as difficult task to be performed by inspectors. The job of an inspector is time consuming and very mind-numbing.The inspector has to check the wider area moving through their visual field for detecting small details.The rate of identification is nearly 70%.[3]Furthermore, the fatigue caused the decrease in the effectiveness of visual inspection. As a solution to this, over the past several years, Digital image processing based methodologies have been increasingly applied to textured sample analysis. When reduction in the personnel cost and associated benefits are considered, the investment in the automated fabric inspection methods founds more economical. The important task in the quality control is to identify the defects that are causing a distortion of fabric structure of the material. For this, inspection of 100% of fabric is necessary first to determine the quality and second to detect any disturbance in the weaving process to prevent defects from reoccurring.

If a segment of a fabric does not meet the requirement, then it is called the fabric defect which results in customer dissatisfaction. Yarn quality and loom defects decide the fabric quality. There are many kinds of fabric defects. Machine malfunctions are the cause of most of them and has the orientation along pick direction (broken pick yarn or missing pick yarn), they tend to be long and narrow. Faulty yarns or machine spoils are responsible for some of the other defects Slubs are mostly appeared as point defects; machine oil spoils are often along with the direction along the wrap direction and they are wide and irregular. If the factory is enabled with an automated defect detection and identification system, the product quality would enhance along with improved productivity to achieve customer needs and to reduce the production costs also associated with quality.[4]

II. FABRIC DEFECT DETECTION METHODS

Various approaches based on Digital Image Processing concepts have been studied and reviewed in this section. On the basis of the nature of features from the fabric surfaces, the approaches have been categorized into three categories statistical, spectral and model-based.[5] Before discussing these approaches in details, structural approach, the first of the methods for fabric defect detection is discussed. Structural approaches assume that the textures are composed of primitives. These primitives can be as simple as individual pixels, a region with uniform gray levels, or line segments. Consequently, the main objects of these approaches are firstly to extract texture primitives, and secondly to model or generalise the spatial placement rules. The placement rules can be obtained through modelling geometric relationships between primitives or learning statistical properties from texture primitives. However, these approaches were not successful on fabric defect detection, mainly due to the stochastic variations in the fabric structure (due to elasticity of yarns, fabric motion, fiber heap, noise, etc.) which poses severe problems in the extraction of texture primitives from the real fabric samples.

2.1 Statistical Approaches

Statistical approaches are based on the spatial distribution of gray intensity levels[6]. In this approaches, the statistics of the defect free regions are stationary and these regions extend over a significant portion of the inspection images while the defected regions having dynamic statistics.Statistics based on a number of pixels defining the local features can be used to further classify the said approaches.

A)Bi-level Thresholding basedApproach

Gray level thresholding is very simple method to detect high contrast defect. The presence of high contrast defect causes the received signal to rise or fall momentarily, and the resultant peak and trough can be detected by thresholding. Authors in [7] have invented a fabric defect detection method that uses thresholding with 86.2% of accuracy, but with 4.3% of false alarm.

B) Morphological operations basedApproach

Zhang et al. [1] have introduced the morphological approach to detect the defects. Use of Rank-order filtering resulted in greatly improving the detection capability and this filtering is termed as morphological operations. In an image, mathematical morphology extract useful component for the geometric representation and description of regional shape. Erosion and dilation are two basic operations in morphological processing for smoothing, sharpening and noise removal. For erosion, the value of the output pixel is the minimum value of the input pixel's neighborhood. For dilation, the value of the output pixel is the maximum value of the input pixel's neighborhood. Pixel's neighborhoods are determined through structure element. It is a matrix consisting of only 0's and 1's that can have any arbitrary shape and size. The techniques used in morphological approach are basically nonlinear. The most successful method is an optimal morphological filter designed by Mak et al. [8] for plain and twill fabric defect detection.

C) Fractal Dimension basedApproach

Fractals are capable and popular to model the statistical qualities like roughness and self-similarity on many natural surfaces. Fractal based methods use more features, both fractal and non-fractal, including fractal matrices, higher order fractals. The differential box counting method [9] used differences in computing non overlapping copies of a set of images and the method gave satisfactory results in all ranges of fractal dimensions. Fractal dimension has many definitions, such as self-similar dimension, box counting dimension, Lyapunov dimension, and correlation dimension etc. in which box counting is most commonly used dimension due to its effectiveness to denote the image surface complexity and irregularity, easy realization by computer, and usefulness for both linear and non-linear fractal images. Conci and Proenca [9] have used to estimate of FD on inspection images to detect fabric defects. They proposed fractal image analysis system using box-counting approach, with an overall detection accuracy of 96%. The approach investigated in [9] is computationally simple but gives very limited experimental results.

D) Edge Detection based Approach

Edge detection techniques are also very effective in detection of defects. Edges can be detected either as micro edges, using small edge operator masks or as macro edges, using large masks. The distribution of number of edges is the important feature in texture images. In an image point, line and edge defects can be represented using number of gray level transition in an image [5]. These features can be used to detect defects. But this method has also some drawbacks. This approach is only suitable to plain weave fabric images [5]. With these method defects nearby edges are hard to detect.

E) Co-occurrence matrix based Approach

Co-occurrence matrix (CM) originally proposed by Haralick et al. [10], characterizes texture features as second order statistics by measuring 2D spatial dependence of the gray values in a CM for each fixed distance and/or angular spatial relationship. Co-occurrence matrix is the most widely used method for texture classification. It uses 2D matrices to accumulate various texture features of images such as energy, contrast, entropy, correlation, homogeneity etc. These texture features are characterized as second-order statistic which is the measure of spatial dependence of gray values for specific distance [3]. Haralick et al. [10] have derived 14 features from the co-occurrence matrix and used them successfully for characterization of texture such as grass, wood, Corn etc.

The size of co-occurrence matrix is important. So number of gray values must be reduced to meet the memory requirements [11]. If the texture features are constructed using large sized primitive than this methods shows poor performance [3]. Two main weaknesses of the CM are poor performance in textures constructed by large sized primitive and intensive computer requirements due to large number of adjacency pixel in calculation

F) Local Linear Transforms based Approach

To extract local texture properties some popular bi-dimensional transforms such as Discrete Cosine Transforms (DCT), Discrete Sine Transforms (DST), Discrete Hadamard Transforms (DHT), Karhunen-Loeve transforms (KLT), eigen filtering can be used.Ade et al. [12] compared law filters, KLT, DCT and DHT for textile defect detection. In their experiments, the KLT performance, particularly on larger window size, was amongst the best. Hadamard transform is primarily defined for sizes, which are in multiples of four. Authors in [12] has detected fabric defects using texture energy features from the Laws masks on 10×10 windows of inspection images. In his approach three 5×5 Laws masks corresponding to ripple, edge and weave features are used to extract histogram features from every window of the image. These features are used for the classification of the corresponding window into defect-free of defect class, using a three-layer neural network. In online fabric inspection, the local transform such as DCT or DST can be directly obtained from the camera hardware using commercially available chips that perform fast and efficient DCT or DST transforms.

G) Local binary pattern based Approach

T. Ojala et al. [13] introduced the LBP operator as a shift invariant complementary measure for local image contrast. It uses the gray level of the center pixel of a sliding window as a threshold for surrounding neighborhood pixel. Usually the neighborhood is in circular form and the gray values of the neighbors which do not fall exactly in the center of pixels are estimated by interpolation. Two dimensional distributions of the LBP and local contrast measures are used as texture features.

2.2 Spectral Approaches

Spectral approaches are based on spatial frequency domain features which are less sensitive to noise and intensity variations than the features extracted from spatial domain. These approaches require a high degree of periodicity thus, applied only for uniform textured materials. Such approaches are developed to overcome the efficiency drawbacks. The main objective of these approaches is firstly to extract texture primitives and secondly to model or generalize the spatial placement rules. These techniques are robust.

A) Fourier Transform based Approach

To characterize the defects Fourier transform uses frequency domain [3]. Fourier transform is derived from Fourier series. This transform includes the properties like noise immunity, optimal characterization of periodic features and translation invariance. Fourier transform can be categorized in two categories: Discrete Fourier transform and Optical Fourier transform. Tsai and Heish [14] have detected the fabric defects using the combination of DFT and Hough transforms [15]. Chan and G. Pang [16] have given the details of the usage of localized frequency components for the real fabric defect identification. Chiu et al. [17] invented Fourier-domain maximum likelihood estimator (FDMLE) has given the significant result which was based on a fractional Brownian motion model for fabric defect detection. Windowed Fourier transform (WFT) is suggested to localize and analyze the features in spatial and also in frequency domain. Campbell and Murtagh [18] have given the detail about WFT methods to detect the fabric defects.

B) Wavelet Transform based Approach

Wavelet transform is a multiresolution algorithm and its multiresolution character corresponds to time–frequency multiresolution of human vision. Shu-Guang and PingGe [19] used wavelet transform with BP neural network for plain white fabric. The multiscale wavelet representation has the property of shift invariance and can be used for fabric defect identification. The authors [20] have used lifting wavelet constructed by minimum texture entropy of DB wavelets and lifting scheme and were given the result over 95%. Guan, Yuan and Ke Ma [21] have developed a fabric defect detection system based on wavelet reconstruction with morphological filtering.

C) Gabor filter transform based Approach

Gabor filters are a joint or spatial-frequency representation for analyzing textured images. Escofet et al. [22] described the fabric defect detection system based on asset of multiscale and multi-orientation Gabor filters. Bodnarova et al. [23] invented a fabric defect detection method in which a set of optimal 2D Gabor filters based on Fisher cost function is used. Zhang and Wong [24] applied a system based on 2D Gabor wavelet transform and Elman neural network. In this system, the texture features of the textile fabric are extracted by using an optimal 2D Gabor filter. The recognition rate was 100%. Shu and Tan [25] proposed an algorithm based on multichannel and multiscale Gabor filtering. It was based on the energy response from the convolution of Gabor filter banks in different frequency and orientation domains. The imaginary part of Gabor filter is odd symmetric, which is used to derive edge detectors and the real part is even symmetric which is used to derive blob detectors.

2.3 Model-Based approaches

Texture can be defined by a stochastic or a deterministic model [6]. Model-based approaches are suitable for fabric images with stochastic surface variation. Autoregressive (AR) model belongs to 1-D class of stochastic modeling. Serafim [26] applied a 2D AR model for texture representation. For real time defect detection a 1D AR model is used in [27]. Cohen et al. [28] used Gaussian Markov Random Field (GMRF) to model defect free texture of fabric images, whose parameters are estimated from the training samples observed at a given orientation and scale. Campbell et al. [28] proposed model-based clustering to detect the defects on denim fabric. Kong et al. [29] have applied a new color-clustering scheme for the detection of defects on colored random textured images.

III. CONCLUSION

Fully automated vision inspection system is necessary to ensure the best quality output. A brief review of the of the automated fabric defect detection approaches is presented in this work. These techniques are categorized into three approaches: statistical, spectral and model-based. The classifications for the automated fabric inspection methods are improved as the available material is sufficient enough as well as diverse. The fundamental concepts and principles of these approaches with their demerits were discussed whenever known. It is important to be able to accurately identify and locate the defective regions,to understand the formation and nature of the defects. Unfortunately, with these large numbers of implemented approaches, the perfect approach does not exist yet as each of them have some advantages and disadvantages. The combination of several approaches can give the better results than individually.

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Girish G. Patil,et.al. "A Systematic Review of Fabric Defect Detection Approaches." *IOSR Journal of Engineering (IOSRJEN),* 10(1), 2020, pp. 61-65.