Research Article

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# Survey on Various Defect Detection and Classification Methods in Fabric Images

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## ABSTRACT

Fabric defect detection is a necessary and essential step of quality control in the textile manufacturing industry. This paper has been reviewed the various fabric defect detection and classification methods of statistical, spectral, model based and structural approaches. This paper has been presented the survey on types of defects, detection accuracy, performance metric and inference from recent publications. It will benefit researchers and practitioners in image processing and computer vision fields in understanding the characteristics of the different defect detection approaches. It concludes that the pulse coupled neural network (PCNN) approach is better detection accuracy than the other methods and is suggested for further research.

**Keywords:** Computer vision; Defect classification; Fabric inspection.

## 1. INTRODUCTION

Fabric texture refers to the feel of the fabric. It is rough, velvety, smooth, soft, silky, lustrous, etc. The different textures of the fabric depend upon the types of weaves used. Textures are given to all types of fabrics. Textile fabric materials are used to prepare different categories and types of fabric products in the textile industry. Environment friendly natural fabric and synthetic fabric are the two different classifications of textile fabric. The deformed regions which damage the appearance and the fabric performance known as fabric defect. In a fabric, defects occur due to machine faults, yarn problems, poor finishing, excessive stretching and color bleeding.

Fabric defect detection is a process of identifying and locating defects. Fabric inspection is important for maintaining the quality of fabric. Traditional inspection process for fabric defects is human visual inspection which is insufficient and costly. The quality inspection process for textile fabrics is mainly performed manually. About70% of fabric defects could be detected by the most highly trained inspectors. In textile industry improved performance in the inspection of fabrics leads to good product quality and contributes to increased profitability and customer satisfaction. Hence automatic fabric defect inspection is required to reduce the cost and time waste caused by defects.

Image processing methods, artificial intelligence methods are used for automatic defect detection. Different types of image acquisition devices such as digital camera, CCD line scan camera, area scan camera and scanner are used for capturing the fabric images.

## 2. DIFFERENT APPROACHES OF FABRIC DEFECT DETECTION AND CLASSIFICATION

### 2.1. Statistical Approaches

The objective of this method is to separate inspection image into the regions of distinct statistical behavior. An important assumption in this process is that the statistics of defect free regions are stationary and these regions extend over a significant portion of inspection images. Based on the number of pixels defining the local features, these approaches classified into higher order and lower order statistics. Higher order statistics (HOS) used the term skeweness and kurtosis whereas the low order statistics (LOS) used the term mean and variance. Due to the higher powers, HOS are significantly less robust than lower order statistics. The use of statistical approaches is well distinguished in the field of computer vision and has been extensively applied to various tasks, and this method was reviewed in serial no of [1], [2], [3], [4], [9], [10], [11], [12], [13], [14], [17], [20], [21], [25], [29], [30] and [34] in Table 1.

## 2.2. Spectral Approaches

The primary objectives of these approaches are firstly to extract texture primitives, and secondly to model or generalize the spatial placement rules. Spectral approaches require a high degree of periodicity thus, it is recommended to be applied only for computer vision of uniform textured materials like fabrics. Spectral approach enabled to capture the most outstanding features of all defects and provide multi resolution of image. This method was used for image quality enhancement, noise reduction and feature extraction. For automated defect detection, Spectral approaches occupy a big part of the latest computer vision research work and this method was reviewed in serial no of [7], [19], [23], [24], [26] and [35] in Table 1.

## 2.3. Model Based Approaches

In this approach, the texture is regarded as a complex pictorial pattern and can be defined by a deterministic model. Model-based texture analysis methods try to generate the texture. Here model the texture by determining the parameters of a pre-defined model. Particularly, model-based approaches are suitable for fabric inspection when the statistical and spectral approaches have not yet shown their utility. The advantage of the modeling is that it can produce textures that can match the observed textures. Model based approaches are particularly suitable for fabric images with stochastic surface variations and this method was reviewed in serial no of [21], [27] and [32] in Table 1.

## 2.4. Structural Approaches

In structural approaches, texture is characterized by texture primitives or texture elements, and the spatial arrangement of these 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 generalize the spatial placement rules. The Placement rules can be obtained through modeling 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.) and this method was reviewed in serial no of [22] and [23] in Table 1.

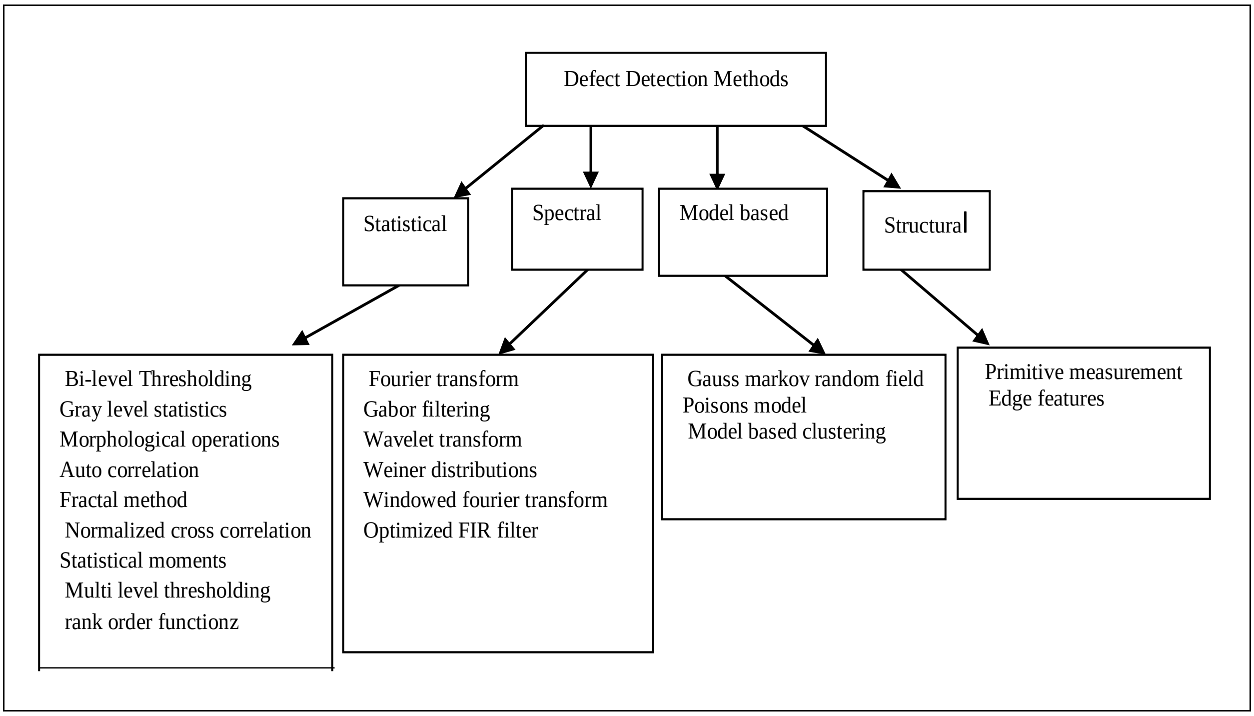


**Fig. 1: Different defect detection and classification methods.**

**Table 1. Different defect detection and classification methods.**

| S. No. | Detection and classification technique | Input image | Type of defects detected | Detection accuracy | Performance metric | Inference |
|---|---|---|---|---|---|---|
| 1. | Fisher criterion based stacked denoising auto encoding (FCSDA) (Yundong le *et al.* 2016) | Plain , twill fabric | Broken end, hole, netting multiple, thick bar, thin bar | 98% | Learning rate, scaling factor, network depth, number of hidden layer units | High detection accuracy provided by this method even the negative samples are insufficient, Training process is time consuming. |
| 2. | Genetic algorithm (Y.Kumbhar *et al.* 2016) | Textile color fabric | Threading defect, oil spot, color fading | 90% | Homogeneity, contrast, correlation, hue, saturation, | This method used to detect the defects for a sample of a very large number of high quality images. |
| 3. | Kernel principal component analysis (KPCA) (Junfeng Jing *et al.* 2016) | Uniform & Structured fabric | Hole, oil spot, thread error, objects on the surfaces | 96% | Detection success rate, specificity, sensitivity | This method achieved high true detection rate and low cost for online fabric inspection. |
| 4. | Pulse coupled neural network (PCNN) (Yundong Li *et al.* 2016) | Warp Knitted fabric | broken ends, loom fly, thin bar | 98.6% | Mean, standard deviation | This hybrid method is suitable to run on an embedded system because of the low computation. The system applied in defect inspection for warp knitting machine. |
| 5. | GIMP Retinex filtering (Amelio Carolina Sparavigana *et al.* 2016) | Textile woven fabric | Mispick | 92% | Image size, scale division, dynamic slider | This method is used to help human vision for instance detecting tiny flaws of the fabric. |
| 6. | Feature extraction technique, graph based segmentation (Prasad dakhole *et al.* 2016) | Color fabric image | Needle cutting, oil stain | 89% | Form factor, rectangularity factor, location, orientation, intensity based features, moment based features | This method not required any adjustment, finding the better accuracy and less time consumption in the industry. |
| 7. | 2D Fast fourier transforms (FFT) (George bardi *et al.* 2016) | Woven fabric | Hole, excessive margin | 78% | Yarn distance, energy distribution parameter, maximum energy parameter, displacement, speed | This method determined yarn paths even in highly draped border regions of the surface. So the influence of different settings on fiber orientation is easily evaluated. |

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| 8. | Small scale over completed dictionary of sparse coding (SSOCD) (Feng *et al.* 2016) | Twill fabric | Mispick, Broken pick, buckling, tom selvedge, rough selvedge, fuzzy ball, bore, yarn, double flat, yarn evenness, pulled in selvedge, oil warp | 93.7% | Reconstruction error, sum of the absolute value of projection, largest absolute value of projection, distance between the image, average of trained samples, Size of image patches | The algorithm was run with high parallel efficiency. detection result was easily affected by noise through, illumination changing, fabric grain fluctuating, etc. |
| 9. | Back propagation algorithm (Akshay V.Nalawade *et al.* 2016) | Textile woven fabric | Oil spot, horizontal defect, vertical defect | 88% | Entropy, homogeneity, contrast, wavelets, fractals | This method was reliable for fabric inspection system in textile Industries. |
| 10. | Artificial neural network, back propagation pattern reorganization technique (Gangandeep singh *et al.* 2016) | Woven fabric | 3 types of defects | 93.3% | 5 features | The efficiency of this model was reliable to find the defects in fabrics. This algorithm is not appropriate for all types of defects. |
| 11. | Artificial neural network (ANN) (karunamoorthy *et al.* 2015) | Patterned fabric image – star pattern, dot pattern, box pattern | Oil stain, stab cut, hole, broken end, netting multiple, thin bar, | 95% | Divergence factor, mean standard deviation | Image decomposition with ANN classifier provided best defect detection result among all testing methods |
| 12. | Local binary pattern technique(LBP) (Lei zhang *et al.* 2015) | Textile fabric | 6 types of defects | 97.6% | Angular second moment, contrast, correlation, entropy | In this method, GLCM features and LBP features are combined. So accuracy is increased. |
| 13. | Morphological filtering (Vikrant tiwari *et al.* 2015) | Woven fabric | Shrinking, abrasion, holes, stain, broken ends | 93.2% | Average gray level, average contrast | Defects from other regions are differentiated in the image by this method even in the presence of certain prints in the fabric. |
| 14. | Auto correlation function (Dandan zhu *et al.* 2015) | Yarn dyed fabric | Holes, weft crackiness, broken weft, wrong weft, oil stain | 90% | Inter pixel distance, inter pixel orientation, euclidean distance, size of detection window, | High accuracy, better adaptability is provided by this method |
| 15. | Rough set classifier (Sudarshan Deshmukh *et al.* 2015) | Regular patterned fabric | Oil warp, oil weft, missing pick, thin bar, thick bar | 96% | Flaw area, dispersion, aspect ratio, euler number, maximum of | This method took 0.2 seconds to detect the flawed areas and classify the type of each flawed area. This system |

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| | | | | | gray value, minimum of gray value, mean of gray value, | suitable for on line real time application. |
| 16. | K–Nearest neighbor classification, (KNN) (Gede surya rahayuda *et al.* 2015) | Endek fabric bali - one form of craft woven fabric | Classification of different types endek bali fabrics | 57.50% | Contrast, correlation, energy, homogeneity | More data samples used in this method to improve the accuracy. |
| 17. | Gray level co-occurrence matrix(GLCM) (Pritpal Singh *et al.* 2015) | Design fabric | Deviated quality | 88% | Contrast , homogeneity, auto correlation, energy | Fabric quality can be estimated. Fine tuning used to accurately distinguish the minor offset in design pattern. |
| 18. | Rule based approach (Basavaraj *et al.* 2015) | Color fabric | Shades of basic color fabric | 97.6% | Mean , standard deviation | The work was applied in automation in apparel industry, namely, readymade garments, knitwear, formal ware, cotton dress materials, etc. |
| 19. | Radon signature and Discrete wave let transform (DWT) (Rakhil *et al.* 2015) | Plaid, striped patternless and irregular fabric | Gout , stain, hole broken filaments, float, drop Stitches | 90% | Variance, energy, uniformity, entropy | This method applied to patternless fabrics and patterned fabrics of different types. This method is adopted in the textile manufacturing units by combining with control and automation using microcontrollers. |
| 20. | Artificial neural network (ANN) (Banumathi *et al.* 2015) | Plain woven fabric | Hole , oil stain | 89% | Mean, energy, standard deviation, entropy, skewness, kurtosis, | High detection accuracy is provided by this method. |
| 21. | Fuzzy clustering (dorian Schneider *et al.* 2014) | Plain, twill, satin, fabric | weave error rate, weave class, | 97% | Weft density, warp density, random sampling, sensitivity | Detection is done without any prior knowledge of the fabric, so called as blind weave detection |
| 22. | Canny edge detection (Halimi Abdellah *et al.* 2014) | Textile fabric | Vertical missing yarn, horizontal missing yarn, hole, spot | 94.84% | Area of defective region, total area of window size, , centroid of defective parts | Fast detection and extraction of fabric defects from the images of textile fabric is done by this method |
| 23. | Discrete wavelet transform DWT)(Ibrahim Celik *et al.* 2014) | Un dyed denim fabric sample | Warp lacking, weft lacking, soiled yarn, hole, knot or yarn flow | 83% for off line<br>88% for real time | Average gray level, average contrast, smoothness, entropy, correlation | The defective areas of the fabric sample are detected successfully and the boundaries of them are labeled. |

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| 24. | Discrete cosine transform (DCT) (Semiyaa *et al.* 2014) | Plain & Patterned fabric | No defect, weaving defect in weft direction, weaving defect in warp direction, holes, oil spot | 97% | Energy, contrast, correlation cluster prominence, horizontal, vertical, diagonal energy value | This method is simple to understand. This method was give good defect detection performance. |
| 25. | Artificial neural network (ANN) (Birdar *et al.* 2014) | Knitted fabric | Missing yarn, hole, spot, | 92% | Defective area, height to width ratio of defective window, | Size of defective window is calculated |
| 26. | Discrete cosine transform (DCT) (Ali Rabhi *et al.* 2014) | Woven fabric | Excessive margin, hole | 97.8% | Detection success rate, sensitivity, specificity | This work easily extended for color images by applying the different algorithm steps on the RGB image components. |
| 27. | Neuro fuzzy classifier (Mohamed eldessouki *et al.* 2014) | Plain woven fabric | Wrong draw, warp slub, stop mark, holes, blotch woven fabric | 95% | Spatial and spectral features | More data samples used in this method to improve the accuracy. |
| 28. | Bi dimensional empirical mode decomposition (Zhengxin li, *et al.* 2014) | Synthetic fabric | Broken end, broken pick, bars, stitches, foreign fiber, | 96.1% | Intrinsic mode function fusion | proposed method is a robust and accurate approach for fabric defect inspection. |
| 29. | Principal component analysis (PCA) (Lucia Bissi *et al.* 2013) | Uniform, structured fabric, wool | Hole, oil spot, thread error, objects on the surfaces | 98.1% | Gabor generating function, kernel size, correction gain | This method is reduced computational cost up to 33% e. |
| 30. | Feed forward neural network (FFNN) (Nasira *et al.* 2013) | Plain woven fabric | Stain, hole, weft float type fault, warp float type fault | 94.6% | Mean, standard deviation | In this method, inspection time was reduced, high accuracy than manual inspection system |
| 31. | Sliding window technique (Jagdish lal rahya *et al.* 2013) | Woven fabric | Holes, weft crackiness | 90.1% | Contrast , homogeneity, auto correlation, energy | The algorithm is simple, and its decision making process is modified for extension. The response time is quite good and easily implemented in industrial applications. |

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| 32. | Multi resolution combined statistical and spatial frequency (MRCSF) (.Sabeenian *et al.* 2012) | Hand loom silk fabric | Missing ends, float, shuttle smash, temple marks, stain hole | 96.6% | Mean, energy, variance, entropy, maximum probability | This method provide a good success rate of classification |
| 33. | Canny edge detection (Halimi Abdella *et al.* 2012) | Woven fabric | Hole | 89.2% | Area, perimeter, compactness | Type and shape of defect is calculated by this method. This work is useful for inspecting industrial materials |
| 34. | Histogram equalization (R.thilepa *et al.* 2010) | Textile color fabric (digital image) | Hole, scratch, dirt spot, fly, crack point, color bleeding , fading | 85% | Optimal threshold value | Computation time is less |
| 35. | Fast fourier transform (FFT) (Swati F, Bhope *et al.* 2010) | Textile fabric | Broken fabric, missing yarn, variation of yarn, double pick defect | 88% | Intensity difference | Structural defect is identified by this method, efficiency is increased. |

## 3. CONCLUSION

Various methods of defect detection and classification of fabrics and quality and quantity metrics are reviewed in Table 1. There are several comparative studies in the literature that evaluate texture analysis methods in application to defect detection. K-nearest neighbor classification, discrete wavelet transform techniques provide low detection accuracy while the principal component analysis, pulse coupled neural network, local binary pattern techniques provide high accuracy and less inspection time. It must be noted that different studies use different data sets and possible different performance parameter settings. The resolution of the images used for the detection process also important and are not are not affect the environment. Here the size of the image affects the efficiency of the algorithm. Although a solid conclusion cannot be drawn to determine the best method for defect detection, statistical and model based methods have been more popularly applied for fabric Inspection.

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## CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.



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