International Journal of Scientific & Engineering Research, Volume 5, Issue 3, March-2014 
ISSN 2229-5518

# Review of Defect Detection and Classification Methods for Fabric

Gaidhani Kavita Gajanan

**Abstract—** In recent years, it is a newer research hotspot using digital image processing technology to identify the sources of fabric defect in textile enterprises. Adopting image-recognition technology, through the fabric digital image preprocessing and recognition using feature detection and extraction of the fabric. Then the defect related information is stored in order to achieve automatic fabric defect detection which ultimately improves the efficiency of defect detection. Fabric defect detection system mainly includes three parts: The first, the fabric image acquisition, pre-processing part. The second, the identifier, for measurement and storage defect of fabric defect. The third, control mechanism automatically accomplished defect location and identifier. The proposed approaches have been characterized into three categories; statistical, spectral and model-based. In order to evaluate the state-of-the-art, the limitations of several promising techniques are identified and performances are analyzed in the context of their demonstrated results and intended application.

**Index Terms—** Segmentation, Thresholding, Neural Network, Histogram Equilization, Morphological operations, Spatial Frequency Domain, Image Resolution

## 1 INTRODUCTION

THE automatic fabric defect detection should be economical when reduction in labor cost and associated benefits are considered. The inspection system must also be robust and efficient. The advantage for the manufacturer here is to get a warning when a certain amount of defect or imperfection occurs during the production of the fabric so that precautionary measures can be taken before the product hits the market, because defects in fabrics can reduce the price of a product by 45% to 65%. The inspection of real fabric defects is particularly challenging due to the large number of fabric defect classes which are characterized by their vagueness and ambiguity.

Automated inspection of plain fabrics can detect 90% of the defects simply by thresholding.

The aim of this research is to study an effective way to detect and classify defects of textile for various defect types in different woven fabrics.

## 2 FABRIC DEFECTS

In order to identify the defect types in textile fabrics, most frequently occurring defects and the most costly defects are considered which are classified as follows.

### 2.1 Yarn Defects

The defects that originates from the spinning stage or winding stage. Different types of yarn defects are shown in Figure 1

**Broken Filaments-**Occurs when the individual filaments constituting the main yarn are broken.

**Knots-**Occurs when broken threads are pieced together by improper knotting.

**Slub-**A Slub is a bunch of fibers having less twist or no twist and has a wider diameter compared to normal spun yarn.

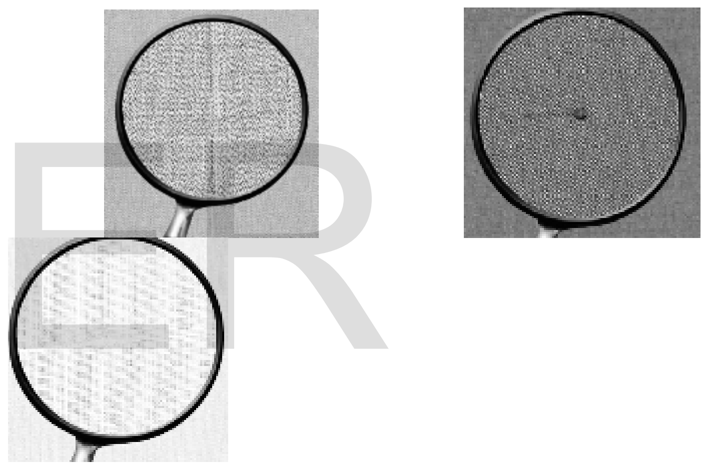


Figure 1: Yarn Defects: Broken Filament, Knots, Slub

### 2.2 Weaving Defects

The defects which originate during the process of weaving. Some of the various types of weaving defects are shown in Figure 2.

**Broken Ends-**This defect is caused by a bunch of broken ends woven in the fabric.

**Float-**A float is the improper interlacement of warp and weft threads in the fabric over a certain area.

**Gout-**A gout is a foreign matter usually lint or waste accidentally woven into the fabric.

**Hole, Cut or Tear-**The occurrence of hole, cut or tear which is self-explanatory.

**Oil or Other Stain-**These are spot defects of oil, rust, grease or other stains found in the fabric.

ISSN 2229-5518

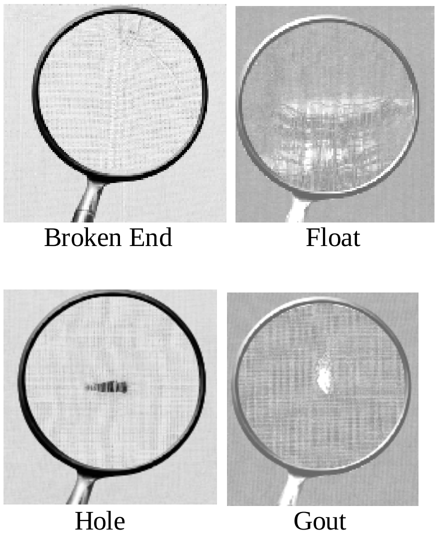


Figure 2: Weaving defects

The fabric quality is affected by yarn quality and/or loom defects. The poor quality of raw materials and improper conditioning of yarn result in yarn quality defects and effects such as color or width inconsistencies, hairiness, slubs, broken ends, etc.. There are numerous quality tests for yarns, such as ASTM D2255-96, for predicting the quality of fabric to be produced from the entire lots of sampled yarns. The tests on the quality of yarns are usually performed at the output of spinning-mills.

Numerous techniques have been developed to detect fabric defects and the purpose of this paper is to categorize and/or describe these algorithms. Categorization of fabric defect detection techniques is useful in evaluating the qualities of identified features.

## 3 Fabric Defect Detection And Classification Flow For Automatic Inspection System

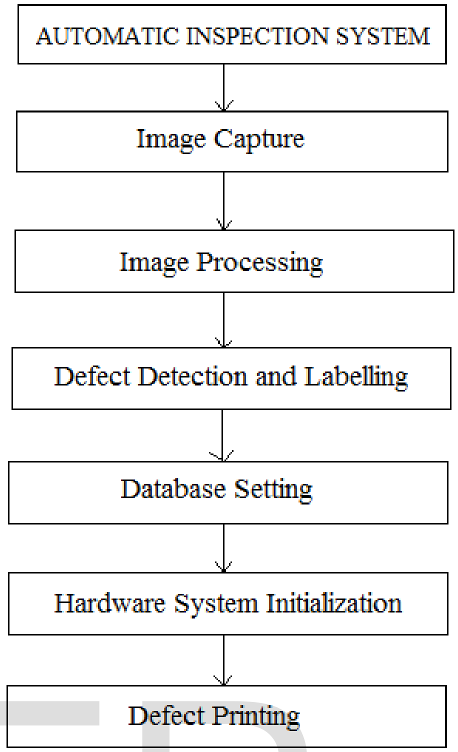


**Figure 3: Automated Inspection System Flow**

**Image Capture:** Image uptake generally consists of camera and image acquisition system and uniform lighting system. In software based system, the acquired image to the MATLAB is to be processed. The image formats are .tif, .Jpeg, and .png.

**Image Processing:** it consists of Contrast Enhancement, Equalization, Noise Removal, Image segmentation, etc. to capture the defect from the original image.

**Defect Detection and Labelling:** When the input data to an algorithm is too large to be processed and it is suspected to be notoriously redundant then the input data will be transformed into a reduced representation set of features. Transforming the input data into the set of features is called feature extraction.

**Database Setting:** It is used for classification of defects due to their non-parametric nature and ability to describe complex decision regions.

**Hardware System Initialization:** After the defect is detected, the system sets the yarn as defected and separates the defected one by sending it to another belt. After that the signal is given to the weaving machine as a feedback so that the defect can be known to the system and to be corrected.

**Defect Printing:** The defect is then printed with its type.

## 4 Review Of Few Defect Detection And Classification Techniques

We can classify the most commonly used texture analysis techniques mainly into two categories: statistical and structural approaches.

**Structural Approach:** The pure structural models of image patterns are based on some primitives and placement rules, etc. Broadly speaking all the defect detection techniques presently used are statistical in nature because they employ some form of statistical calculations to declare the defects.

**Statistical Approach:** The objective of defect detection 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. The defect detection methods under this approach are given below.

**Model Based Approach:** Texture is usually regarded as a complex pictorial pattern and can be defined by a stochastic or a deterministic model. However, the real textures, such as fabrics, are often mixed with stochastic and deterministic components. The advantage of this 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.

There are several approaches under which different methods are proposed by various authors of which every method has its advantages and disadvantages for number of fabric types and textures.

### A. Statistical Approach:
1. Histogram properties,
2. Co-occurrence matrix,
3. Local binary pattern,
4. Other gray level statistics,
5. Autocorrelation

### B. Structural Approach:
1. Primitive measurement,
2. Edge Features,
3. Morphological operations

### C. Filter Based:
1. Spatial domain filtering,
2. Frequency domain analysis,
3. Joint spatial/spatial-frequency

### D. Model Based:
1. Fractal models,
2. Random field model

### E. Color texture analysis for defect detection
1. Neural network,
2. Artificial Intelligence

As a part of review, it is not possible to describe each and every method from the above approaches in detail in this paper. Since, some common and important techniques are explained below as a review study.

## 5 Some Common Techniques for Fabric Defect Detection

### 5.1 Regular Band-based Methodology
This methodology helps in identifying defects with the help of change in pixel intensities. This technique uses only one parameter i.e. the duration of a period. And this methodology also outlines the defective portion of fabric in the final image. The regular band methodology consists of two sub-bands;

Light Regular Band:

At the defective region the original moving average (Avg) is greater than zero and standard deviation (SD) is smaller. Avg >0, and SD is smaller

Dark Regular Band:

At the defective region the original moving average (Avg) is less than zero and standard deviation (SD) is smaller. Avg <0, and SD is smaller

Regular band is separated into two phases;
a) Training Phase, b) Testing Phase

Training Phase:

Here firstly, input image is taken which is then Histogram Equalized so as to filter the Guassian noise present in the image. This process also provides constant distribution of intensity all over the image to obtain the better contrast. For down shifting apply two lemmas such as for LRB and DRB. In the third phase find out LRB and DRB for both rows and columns. This produces overall two LRB's and DRB's for row and columns. Obtain threshold value for each regular band. This gives 8 threshold values in total that has upper and lower values of threshold and ultimately detects the defect and its location too.

Testing Phase:

In this stage the resultant images obtained from training phase and apply zero padding for row and column LRB and DRB as shown in figure. Combining the result of row and column LRB and DRB, we get optimized threshold values.

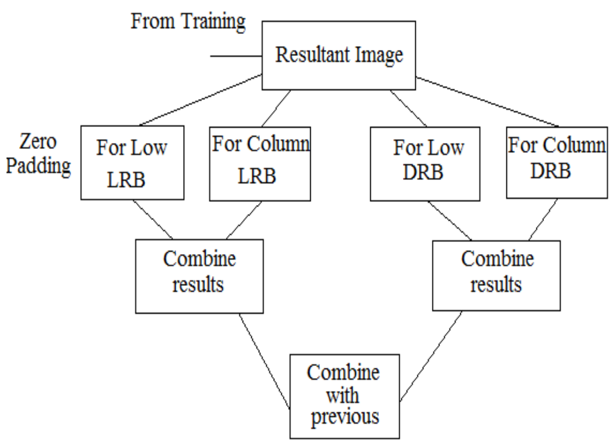
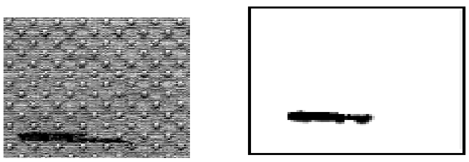


Figure 4: Block diagram of Regular base-band method

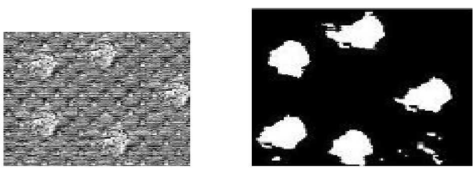
### 5.2 GaborWavelet Filter Methodology

This methodology consists of morphological analysis and Gabor filter wavelet responses. In this methodology defects appeared as basins on domes. 2-D Gabor filters have been successfully used in a large number of image analysis and computer vision applications.

Here the optimal Gabor wavelet filter is used to generate feature image. The threshold of this image produces a binary image of defect under inspection. To determine the threshold value in an adaptive way, the morphological analysis is used.



Dark-color defect



Bright color defect

Figure 5: Types of color defect

Gabor filters can decompose the image into components corresponding to different scales and orientations. Gabor filters achieve optimal joint localization in spatial and spatial frequency domain and, therefore, have been used extensively for texture analysis. For defect detection, two types of color defects are taken. First class defects appear in black areas with increasing the threshold value gradually whereas in second class defects appear in white areas with black background.

The method doesn't use Histogram Equalization because it requires limited contrast images to segment the defect correctly.

This method identifies the material for defect and defect free classes correctly with false alarm rate of 3.2.

Again the selection of filter parameter is a function of texture characteristics and size of image, therefore this method might not work very well for every individual image and so not a standard method.

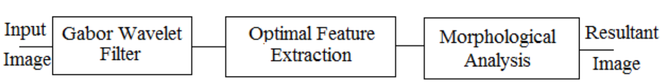



Figure 6: Gabor Filter Methodology

### 5.3 Usage of Computer-Vision and Artificial Neural Network

This approach is a combination of computer vision and artificial neural networks. Firstly any image capturing device captures the images of fabric through. After acquisition phase convert the RGB image into binary image through image restoration and threshold process [14]. This output image contains the defected portion along with the other objects. The neural network classifies the defected portion out of the fabric material [15].

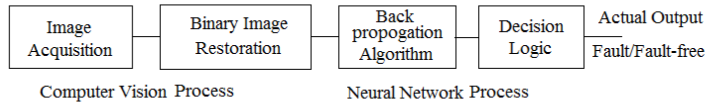



Figure 7: Process flow for ANN

### 5.4 Using Digital Signal Processing

The mathematical Morphology is presented in this paper which removes the details smaller than certain reference shape known as Structuring Element (SE), that ultimately highlights the defect, its type, its shape and location as well. It uses morphological operations over the binary image also called as bit plane image which carries the most significant information.

Here, the original image is first converted into grayscale image before further processing is done. Then bit plane slicing is performed to obtain two different bit planes. The lower order decomposed image preserves the information and therefore it is suitable to process whereas higher order ones are discarded.The Morphological Operations such as Dilation, Erosion, Open, Close are applied to detect the defect and to extract the defect by marking outline carefully.

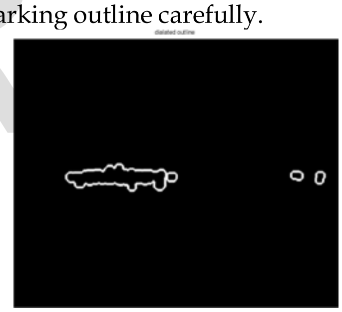


Figure 8: Dilated Outline

In this paper, only uniformly colored materials are usually considered because, the existence of hierarchical structures given by bands, squares, circles, or drawings of varied colors along with the basic woven structure makes the inspection more difficult.

The proposed algorithm is simple and more efficient for automation.

Moreover, this method does not just detect the defect but the shape and size of the defect also. The advantages of the proposed method are its simplicity, accuracy and computational time. It extracts most defect pixels accurately.

The false alarm rate is found to be less than 5% even in low contrast images with multiple defects. This algorithm has an average accuracy of 90.8%. This algorithm demonstrates its strong ability to differentiate defects

ISSN 2229-5518

from other regions in the image. The method works pretty well even when the input image is a low-contrast one. The experimental results demonstrate that the proposed algorithm is fast and robust.

The method is not suitable when the patterned and multi-colored fabrics are taken.

### 5.5 Using CNN

The input to the CNN system is taken from two images of surface whose defect/ defects are to be known. Each pixel of an image is locally connected with one cell of an array.

Here three cell variables are comprises with the required information to be processed-

1. Cell State- conveys cell energy information as a function of time
2. Cell Output- obtained from cell state through the non-linear transformation
3. Cell Input- representing external excitation signal

To extract the features of defect and to determine its depth, two images of the surface are projected onto two different locations from two different cameras. Both the images are used as an input to the detection algorithm which finds the presence of defect. If the

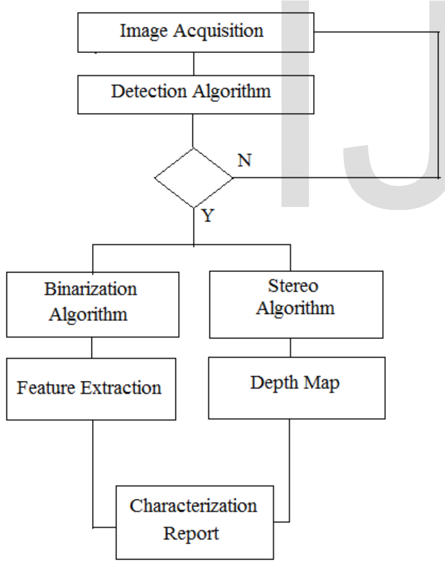


Figure 9: Methodology Flow

defect is found, then the surface features are extracted otherwise system continues with the next input image.

The system uses two algorithms. One is Binarization algorithm to locate the defect by means of some templates which isolates the defect from background and then feature extraction is done to provide the details of defect. Another is Stereoscopic algorithm to obtain the information about the defect depth.

The main advantages of this are system-on-chip and real time system. But the system is not economical for the application point of view when considered for textile industry. In military application such as aeronautical material analysis, the system works efficiently and effectively with proper expense management.

### 5.6 Detection by Fourier Analysis

To identify small and undistinguishable faults, only monitoring the intensity change is difficult and insufficient. This problem can be resolved by the use of Fourier Transform for the repetitive and regular global texture. Here, the spatial frequency spectrum is analyzed and center frequency is observed for the fault when intensity at specific position changes.

The system is less sensitive to the background noise and it is more effective for revealing a defect due to dimensional changes in the structure of the fabric.

The computational time for Fourier transform is generally long. For two-dimensional discrete Fourier transform, it is proportional to the second order of the image size. In order to reduce

the computation time, fast Fourier transform (FFT) is used.

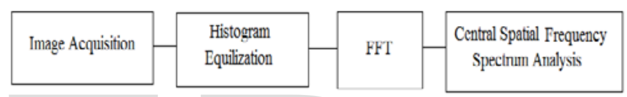


Figure 10: Defect Detection System Flow

In this study, plain white fabrics are used. Defects with double yarn, missing yarn, web and fabric density variation were inspected and compared with the faultless fabric.

The system efficiency is good. It is difficult to identify the defect for irregular texture by this method.

### 5.7 Using Gabor Filter Bank and Thresholding

The modification of multichannel filtering algorithm for defect detection should lead to a reduction in computational complexity and, false alarm, and offer high rate of detection. Multichannel filtering approach allows multi-resolution analysis of fabric texture.

The block diagram of this approach is shown in Fig. Every acquired image from the imaging system is filtered with a bank of self-similar Gabor filters. Each of these Gabor filters is selectively tuned to a narrow range of frequency and orientation. Every inspection image is filtered with each of the 18 Gabor filters and the magnitude of every filtered image is computed.

Next, a local nonlinear function is used to rectify multichannel filter response. This nonlinear function transforms both negative and positive amplitudes to positive amplitudes. This nonlinearity is inherent while computing the magnitude of Gabor filter images, therefore, no extra computational burden is added. The 18 images represent the features of image under inspection.

ISSN 2229-5518

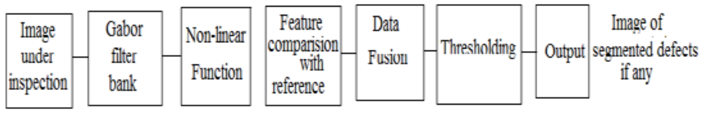



Figure 11: Block diagram of Proposed system

The defect-free images are also computed as a reference images at the beginning of inspection for calibration. The mean and standard deviation from each of these images is used to locate defects. Then the decision rule is chosen to differentiate the features of inspecting image from the reference one.

The information is then gathered from the different knowledge sources from same image to detail the defect pattern. It is referred as 'data fusion'. This data fusion method is less noisy. The fused image is thresholded afterword so as to eliminate the non-belonging pixel element.

Defect segmentation is more accurate. This scheme also reduces false alarms. The defect segmentation is accurate for varying size, orientation, and resolution and therefore is robust, too.

### 5.8 Detection by Neuro-Fuzzy Logic

It can be of two types, first is based on fuzzy clustering using C means clustering (FCM) and second is Adaptive Neuro-uzzy Inference System (ASIC). The defects considered here are Vertical stripes, Horizontal stripes, Hole, Dropped stitch defect, Thick place defects, etc.

The image is first acquired randomly from inspection department.

It is then given to processing system where it is made to a fixed desired size so as to be suitable for all defect types. Preprocessing also includes the intensity adjustment.

The feature extraction is applied after the images are adjusted. Here two types of features have selected are first order statistical (Tonal features) and second order statistical (Texture features) for both the systems to be classified.

It gives correct detection and classification as well. Both systems have high degree of performance and efficiency with very less false alarm is observed with high accuracy, separately and collectively.

The drawback of the system is that it requires large number of training samples and therefore need of memory is also more for the system which affects the development time and overall manufacturing cost. The performance of system slows down as we expect more samples to improve accuracy.

### 5.9 Defect detection using edge detection

The distribution of the amount of edge per unit area is an important feature in the textured images. The amount of gray level transitions in the fabric image can represents lines, edges, point defects and other spatial discontinuities. The image under inspection is transformed into a gradient image using a set of masks. This gradient image is thresholded to separate possible defect pixels from the non-defect pixels. The resultant image is dilated with the SE to further segregate the defect pixels from the noise. The last step is the blob analysis, which labels the connected pixels as objects. The edge detection is suitable for plain weave fabrics imaged at low-resolution. The difficulty in isolating fabric defects with the noise generated from the fabric structure results in high false alarm rate and therefore makes them less attractive for textile inspection.

### 5.10 Defect detection using Gauss Markov Random Field model

The stochastic models based on the Gauss Markov Random Field (GMRF) have been successfully shown to model many natural and man-made textures. The defect-free fabric is modeled by GMRF, whose parameters are estimated from the training samples observed at a given orientation and scale. Authors classify each of the textile blocks into defective or defect-free class using $\chi$ 2 test on maximum likelihood estimate (MLE) of the GMRF model parameters obtained from defect-free fabric. Attali and Cohen [129] have discussed stochastic modeling of textured images using Markov random field (MRF) and fractal models.

They have suggested that the MRF based models are useful for modeling fabric textures while fractal models are suitable for modeling perceptual surface roughness.



## 6 Comparative Studies

The comparative study of above mentioned techniques is not easy enough, as all the techniques use different parameters. Different techniques use different dataset of information. The resolution of the images used for the detection process also matters a lot. Regular Band based Methodology is used to detect small defects with box, star or dot patterns. This is observed 99.4% accurate. Gabor Wavelet Filter Methodology is used to detect with almost 30 types of different defects. Its accuracy is about 96 %. Wavelet-Texture Analysis technique is studied and its accuracy turns to be 95% with 7 different types of defects tried. Computer vision and neural networks techniques gives accuracy about 77 % overall for 4 types of defects. Here the size of the image also affects the efficiency of the algorithm devised. Digital Image Analysis techniques gives about 83 %.

## 7 Conclusions and Future Work

This paper has provided a survey of fabric defect detection methodologies reported in about 30 references as shown. These available techniques were classified into three categories: statistical, spectral and model-based. The core ideas of these methodologies along with their drawbacks/ critics were discussed whenever known.

The effective performance evaluation requires careful selection of data sets along with its clear definition of scope. This will remove any subjective judgment of results and allow the users to know which algorithms are competitive in which domain. Despite the significant progress in last decade, the problem of fabric defect detection still remains challenging and requires further attention. The statistical, spectral and model-based approaches give different results and therefore the combination of these approaches can give better results, than either one individually, and is suggested for future research.

If neural Networks are trained well for large number of samples, they can provide 99.5% accuracy for different classes of defects. This classification algorithm has less false alarm values. Also the system performance is good enough to work as for online defect detection and classification, there is a large scope for future research.

## 8 REFERENCES

[1] Kang T.J. et al. "Automatic Structure Analysis and Objective Evaluation of Woven Fabric Using Image Analysis", Textile Res. J. 71(3), 261-270 (2001)

[2]. A. D. H. Thomas, M. G. Rodd, J. D. Holt, and C.J. Neill, "Real-time Industrial Inspection: A Review," Real- Time Imaging, vol. 1, pp. 139-158, 1995

[3] Wang D.,Liu H.,"Edge Detection of Cord Fabric Defects Image based on an Improved Morphological Erosion Detection Methods", Sixth International Conference on Natural Computation (ICNC 2010) IEEE,978-1-4244-5961-2/10

[4] Cohen, F. S., Fan, Z., & Attai, S. (1991). Automated inspection of textile fabrics using textural models. IEEE Transactions on Pattern Analysis Machine Intelligence, 13(8), 803–808

[5] Xie Xianghua "A Review of Recent Advances in Surface Defect Detection using Texture analysis Techniques" Electronic Letters on Computer Vision and Image Analysis 7(3):1-22, 2008

[6] S. Priya, T. Ashok Kumar, Dr. Paul Varghese "A Novel Approach to Fabric Defect Detection Using Digital Image Processing" Proceedings of International Conference on Signal Processing, communication, Computing and Networking Technologies (ICSCCN 2011), 2011

[7] Mahajan P.M., Kolhe S.R. and Patil P.M. "A Review of Automatic Fabric Defect Detection Techniques" Advances in Computational Research, ISSN: 0975–3273, Volume 1, Issue 2,pp-18-29. 2009

[8] Jagrti Patel, Meghna Jain, PapiyaDutta, "Location of Defects in Fabrics Using Feature Extraction Technique", International Journal of Research in Management, ISSN 2249-5908, Issue 3, Vol.5 (September2013)

[9] A. Kumar, "Neural network based detection of local textile defects," Pattern Recognition, vol. 36, pp. 1645-1659, 2003

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

[11] M. Zou, D. Wang, "Texture identification and image segmentation via Fourier transform", Proc. SPIE, Wuhan, China 4550 (2001) 34–39

[12] Yang, X. Z., Pang, G., & Yung, N. (2004). Training approaches to fabric defect classification based on wavelet transform. Pattern Recognition, 37(5), 889– 899

[13] Hao Liu and Jiuqiang Han, "Defect Detection in Textiles Using Optimal Gabor Wavelet Filter". Proceedings of the 6th World Congress on Intelligent Control and Automation, 10005-10007, 2006

[14] Jianli Liu and Baoqi Zuo, "The Recognition of Fabric Defects Using Wavelet Texture Analysis and LVQ Neural Network", 2nd International Congress on Image and Signal Processing, 2009

[15] Hamid Alimohamadi, Alireza Ahmadyfard and Esmaeil shojaee, "Defect Detection in Textiles Using Morphological Analysis of Optimal Gabor Wavelet Filter Response", International Conference on Computer and Automation Engineering, 2009

[16] C. Beirão and M. Figueiredo, "Defect detection in textile images using Gabor filters," Proc.

ICIAR'2004, Lecture Notes in Computer Science, Springer Verlag, vol. 3212, 2004

[17] A. Monadjemi, M. Mirmedhi,and B. Thomas, "Restructured eigenfilter matching for noveltydetection in random textures," Proc. 15th British Machine Vision Conf., pp. 637-646, Sep. 2004

[18] R. Cross and A. K. Jain, "Markov random field texture models," IEEE Trans. Patt. Anal. Machine

Intell., no. 5, Jan. 1983

[19] A. Kumar, "Neural network based detection of local textile defects," Pattern Recognition, vol. 36, pp. 1645-1659, 2003

[20] C.-C. Hung and I.-C. Chen, "Neural-Fuzzy classification for fabric defects," Text. Res. J., vol. 71(3), pp.220-224, (2001)

[21] T. Mäenpää, M. Turtinen, and M. Pietikäinen, "Real-time surface inspection by texture," Real-Time Imaging, vol. 9, pp. 289-296, 2003

[22] L. Occhipinti, G. Spoto, M. Branciforte, and F. Doddo, "Defects detection and characterization by using cellular neural networks," Proc. IEEE Conf. Circuts & Sys., ISCAS 2001, pp.481-484, 2001

[23] X. Yang, G. Pang and N. Yung, "Discriminative training approaches to fabric defect classification based on wavelet transform", Pattern Recognition, vol. 37, pp. 889-899, May 2004

[24] C.Chan and G. K. H Pang., "Fabric defect detection by Fourier analysis", IEEE Trans. on Ind. Appl, vol 36, no.5, ppI267-1276 Oct 2000

[25] Xie Xianghua "A Review of Recent Advances in Surface Defect Detection using Texture analysis Techniques" Electronic Letters on Computer Vision and Image Analysis 7(3):1-22, 2008

[26] Mahajan P.M., Kolhe S.R. and Patil P.M. "A Review of Automatic Fabric Defect Detection Techniques" Advances in Computational Research, ISSN: 0975–3273, Volume 1, Issue 2,pp-18-29. 2009

[27] Jianli Liu, Baoqi Zuo, "Identification of Fabric Defects based on Discrete Wavelet Transform and Back-propagation Neural Network", Journal of the Textile Institute, Taylor & Francis, UK, 2007, 98(4), pp. 355-362

[28] Ajay Kumar, G.K.H. Pang, "Defect Detection in Textured Materials Using Gabor Filters", IEEE Transactions on Industry Application, IEEE Industry Applications Society ,USA, 2002, 38(2), pp. 425-440

[29] Do M.N., Vetterli M., "Wavelet-based Texture Retrieval using Generalized Gaussian Density and Kullback-Leibler Distance", IEEE Transaction on Image Processing, IEEE Signal Processing Society, USA, 2002, 11(2), pp. 146-158

[30] Ali Javed, Ullah, Rehman, " Comparative Analysis of Different Fabric Defects Detection Techniques" I.J. Image, Graphics and Signal Processing, 2013, 1, 40-45