An Extended Review on Fabric Defects and Its Detection Techniques

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Abstract: In Textile Industry, Quality of the Fabric is the main important factor. At the initial stage, it is very essential to identify and avoid the fabrics faults/defects and hence human perception consumes lot of time and cost to reveal the fabrics faults. Now-a-days Automated Inspection Systems are very useful to decrease the fault prediction time and gives best visualizing clarity- based on computer vision and image processing techniques. This paper made an extended review about the quality parameters in the fiber-to-fabric process, fabrics defects detection terminologies applied on major three clusters of fabric defects knitting, woven and sewing fabric defects. And this paper also explains about the statistical performance measures which are used to analyze the defect detection process. Also, comparison among the methods proposed in the field of fabric defect detection.

***Keywords**: Fabrics Defects; Fabric faults; Fabric defects terminology; Thresholding; fabric defect identification system*

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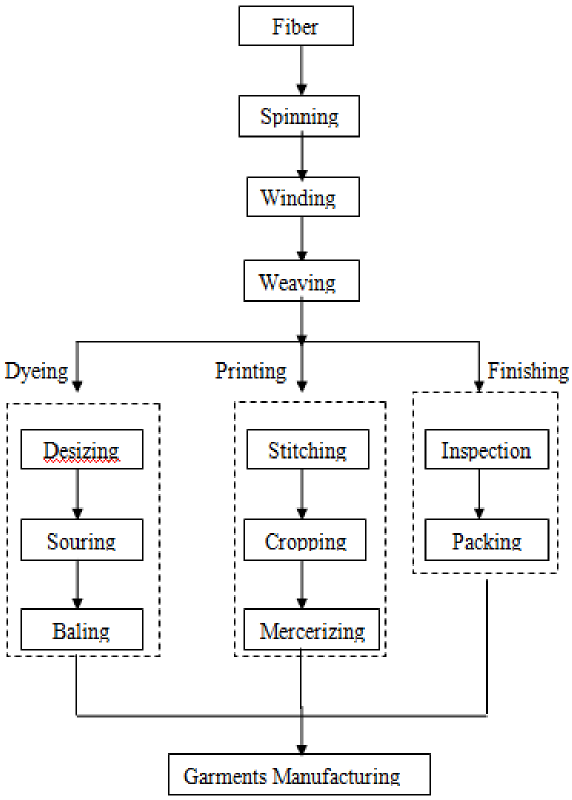
I. INTRODUCTION

The textile industry is vertically-integrated across the value chain and extends from fiber to fabric to garments. At the same time, it is a highly-fragmented sector, and comprises small-scale, non-integrated spinning, weaving, processing and cloth manufacturing enterprises.

Some of the Faults that commonly identified in the fabric types are skewed or Bias, Back Fabric Seam Impression ,Birdseye, Bowing ,Color Out, Color Smear, Crease Mark, Crease Streak, Drop Stitches, Dye Streak In Printing, End Out ,Jerk-in, Knots ,Missing Yarn ,Mixed End (yarn) Mottled, Needle Line, Open Reed ,Pin ,Press-Off , Printing Machine Stop ,Print Out of Repair ,Puckered Selvage and Runner Sanforized Pucker Scrimp. The purposes of visual inspection and decision making schemes that are able to discriminate the features are extracted from normal and defective regions. On the basis of nature of features from the fabric surfaces, the proposed approaches have been characterized into three categories: knitting, woven and sewing defects.

These defects are occurred in any one of the stage of fabric production process. The entire process of fabric production is described in Figure-1. Any fault occurs in between this flow of process will leads to faulty production result. So keep track the entire process is the best way to deliver the perfect material. While analyzing the fault prediction method available in the context one should gives the deep review on the all the methods which is applicable in all the stages of fabric production process.



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II. A REVIEW ON DEFECT DETECTION METHODS IN KNITTED FABRICS

The author of the paper [1] attempts to present the first survey on categorization of fabric defect detection techniques in evaluating the qualities of identified features. In order to evaluate the state-of-the-art, the limitations of several promising techniques are identified and performances are analyzed. In paper [2], the author proposed a gray level co-occurrence that can be specified in a matrix of the relative frequencies with which two neighboring pixels separated by a distance occur on the image. By applying the co-occurrence matrix and gray relational analysis of the gray theory, we can extract characteristic values of a fabric defect image and classify defects to recognize common problems, including broken warps, broken wefts, holes, and oil stains. Gray relational analysis is also used to investigate correlations of the analyzed factors among the selected characteristic indicators in a randomized factor sequence through data processing. In paper[3], fabric defects have been detected and classified from a video recording captured during the quality control process. The defective areas on the fabric surface were detected using the heat difference occurring between the defective and defect-free zones. Gray level co-occurrence matrix is used for feature extraction for defective images. The defective images are classified by k-nearest neighbor algorithm. The image processing stage consists of wavelet, threshold, and morphological operations.

In paper [4] the author addresses issues concerning image analysis algorithms for the visual quality inspection of textile fabrics. An overview of a number of flaw detection techniques and analysis of their suitability for detecting the presence of weaving defects is presented. The flaw detection algorithms are based on a local analysis of spatial and spatial-frequency domain features, exploring both the statistical and structural texture analysis of the defective image samples. The methods that are applied to the flaw detection problem are spatial grey level co-occurrence; normalized cross-correlation; texture blob detection; and spectral approaches. The relations between energy and the local binary pattern as a new concept called energy-based local binary patterns (ELBPs) are defined by the author in paper[5]. The defects can be detected, using ELBPs rather than grayscale-based local binary patterns. The proposed method can detect chromatic and structural defects.

The author introduce an efficient algorithm in paper[6], which combines concepts from wavelet theory and co-occurrence matrices for detection of defects encountered in textile images. Detection of defects within the inspected texture is performed first by decomposing the gray level images into sub-bands, then by partitioning the textured image into non-overlapping sub windows and extracting the co-occurrence features and finally by classifying each sub-window as defective or non-defective with a Mahalanobis distance classifier being trained on defect free samples a priori. There arises a problem of automated defect detection in textured materials is investigated. The author introduces a new approach for defect detection using linear FIR filters with optimized energy separation is proposed. The issues relating to the design of optimal filters for supervised and unsupervised web inspection are addressed. A general web inspection system based on the optimal filters is proposed. The low computational requirement confirms the usefulness of the approach for industrial inspection. The author in paper [7] proposed a real time fabric defect detection system (FDDS), implemented on an embedded DSP platform. Textural features of fabric image are extracted based on gray level co-occurrence matrix (GLCM). A sliding window technique is used for defect detection where window moves over the whole image computing a textural energy from the GLCM of the fabric image. The implementation is carried out on a TI TMS320DM642 platform and programmed using code composer studio software. The authors presented a multi-resolution approach for the inspection of local defects embedded in homogeneously textured surfaces in paper [8]. It is based on an efficient image restoration scheme using the wavelet transforms. By properly selecting the smooth sub-image or the combination of detail sub-images at different resolution levels for image reconstruction, the global repetitive texture pattern can be effectively removed and only local anomalies are preserved in the restored image. A wavelet band selection procedure is developed to automatically determine the best reconstruction parameters based on the energy distribution of wavelet coefficients. The defects in a variety of real textures including machined surfaces, natural wood, sand paper and textile fabrics are well detected.

Comparison of six wavelet transform-based classification methods are compared in paper [9], using different discriminative training approaches to the design of the feature extractor and classifier are compared. These six classification methods are: methods of using an Euclidean distance classifier and a neural network classifier trained by maximum likelihood method and back propagation algorithm, respectively; methods of using an Euclidean distance classifier and a neural network classifier trained by minimum classification error method, respectively; method of using a linear transformation matrix-based feature extractor and an Euclidean distance classifier, designed by discriminative feature extraction (DFE) method; method of

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using an adaptive wavelet-based feature extractor and an Euclidean distance classifier, designed by the DFE method. In paper [10] the author presents a novel approach for defect detection of fabric textile. For this purpose, all wavelet coefficients were extracted from the perfect fabric. These coefficients can delete main fabric of image and indicate defects of fabric textile and so the authors were using the Genetic Algorithm for finding a suitable subset. The evaluation function in GA was Shannon entropy. Finally, it was shown that we can gain better results for defect detection, by using two separable sets of wavelet coefficients for horizontal and vertical defects. This approach, not only increases accuracy of fabric defect detection, but also, decreases computation time. A simulated fabric model is used by author in paper [11] to understand the relationship between the fabric structure in the image space and in the frequency space. Based on the three-dimensional frequency spectrum, two significant spectral diagrams are defined and used for analyzing the fabric defect. The author in paper [12] introduces a global approach for automatic inspection of defects in randomly textured surfaces like sandpaper, castings, leather, and many industrial materials. The proposed method is based on a global image reconstruction scheme using the Fourier transform (FT) but does not rely on local features of the textures. Since a statistical texture has the surface of random pattern, the spread of frequency components in the power spectrum space is isotropic. The author makes use of inverse FT to remove the periodic, repetitive patterns of any statistical textures.

A new method for fabric defect detection by incorporating the design of an adaptive wavelet-based feature extractor with the design of an Euclidean distance-based detector is introduced by the author in paper [13]. The proposed method characterizes the fabric image with multiscale wavelet features by using undecimated discrete wavelet transforms. Each non overlapping window of the fabric image is then detected as defect or non defect with an Euclidean distance-based detector. An adaptive wavelet basis is designed for the detection of fabric defects instead of using the standard wavelet. Minimization of the detection error is achieved by incorporating the design of the adaptive wavelet with the design of the detector parameters using a discriminative feature extraction (DFE) training method. In paper [14], the author extends the adaptive wavelet-based methodology from the use of a single adaptive wavelet to multiple adaptive wavelets. Defect-specific adaptive wavelet was designed to enhance the defect region at one channel of the wavelet transform, where the defect region can be detected by using a simple threshold classifier. Corresponding to the multiple defect-specific adaptive wavelets, the multi-scale edge responses to defect regions have been shown to be more efficient in characterising defects, which leads to a new approach to the classification of defects.

The authors introduced an ultrasonic method in paper [15] and system are provided for monitoring a fabric to identify a defect. A plurality of ultrasonic transmitters generate ultrasonic waves relative to the fabric. An ultrasonic receiver means responsive to the generated ultrasonic waves from the transmitters receives ultrasonic waves coupled through the fabric and generates a signal. The digitized signal is processed to identify a defect in the fabric. The digitized signal processing includes a median value filtering step to filter out high frequency noise. Then a mean value and standard deviation of the median value filtered signal is calculated. The calculated mean value and standard deviation are compared with predetermined threshold values to identify a defect in the fabric. The authors in paper[16] proposed a novel defect detection scheme for fabric inspection based on bi-dimensional empirical mode decomposition. The stopping criterion for sifting and the intrinsic mode functions (IMFs) are adapted for this specific application. Appropriate IMFs are selected to eliminate influences of fabric textures and lighting in defect segmentation. The proposed method is a robust and accurate approach for fabric defect inspection. A pilot system for defect detection and classification of web textile fabric in real-time are introduced by the author in paper [17]. The general hardware and software platform, developed for solving this problem, is presented while a powerful novel method for defect detection after multi resolution decomposition of the fabric images is proposed. An artificial neural network, trained by a back-propagation algorithm, performs the defect classification in categories.

In paper [18], the authors introduce an intelligent color-textured fabric defect detection and classification model using genetic algorithms and the Elman neural network. A color ring projection is used for image processing, and the solution for optimization of parameters is based on the genetic algorithm method. The new modified Elman network is proposed which is more feasible to classify the type of fabric defects, which have proportional, integral, and derivative properties. The authors proposed an approach of using local contrast deviation (LCD) based on the characteristics of fabric structure in paper [19] for fabric defect detection. LCD is a parameter used to describe features of the contrast difference in four directions between the analyzed image and a defect-free image of the same fabric, and is used with a bi level threshold function for defect segmentation. The validation tests on the developed algorithms were performed with fabric images from

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TILDA's Textile Texture Database and captured by a line-scan camera on an inspection machine. In paper[20], the authors presented a new defect detection algorithm for textured images where proposed by the author in paper [20] based on the sub-band decomposition of gray level images through wavelet filters and extraction of the co-occurrence features from the sub-band images. Detection of defects within the inspected texture is performed by partitioning the textured image into non-overlapping sub-windows and classifying each sub-window as defective or non-defective with a mahalanobis distance classifier being trained on defect free samples a priori.

The author in paper [21] describes a computer vision-based fabric inspection system implemented on a circular knitting machine to inspect the fabric under construction. The first part is the detection of defects in knitted fabric was performed and the performance of three different spectral methods, namely the discrete Fourier transform, the wavelet and the Gabor transforms were evaluated off-line. The second part is the knitted fabric defect-detection and classification was implemented on-line. The captured images were subjected to a defect-detection algorithm, which was based on the concepts of the Gabor wavelet transform, and a neural network (as a classifier). The fabric images were broadly classified into seven main categories as well as seven combined defects. A new method is proposed by author in paper [22] for knitted fabric defect detection and classification using image analysis and neural networks. Images of six different induced defects were obtained and used in the analysis. Statistical procedures and Fourier Transforms were utilized as two different approaches in the feature extraction effort and neural networks were used to detect and classify the defects. The study [23] has shown that image analysis has great potential to provide reliable measurements for detecting defects in knitted fabrics. An automatic fabric evaluation system, which enables automatic computerized defect detection (analysis of knitted fabrics) was developed. This analysis system is capable of on-line detection of fabric defects and full control in the knitting machine by the way of stopping the circular knitting machine as soon as a defect is acquired by the digital camera. The author introduces a new approach in paper [24] for classification of circular knitted fabric defect is proposed which is based on accepting uncertainty in labels of the learning data. There are some classification problems in which a considerable amount of uncertainty exists in the labels of samples. The main core of this research has been usage of the uncertain information of labeling and their combination with the Dempster–Shafer theory of evidence. In paper [25], the authors introduce the system which combines the fuzzification technique with fuzzy logic and a back-propagation learning algorithm with neural networks. Four input features—the ratio of projection lengths in the horizontal and vertical directions, the gray-level mean and standard deviation of the image, and the large number emphasis (LNE) based on the neighboring gray level dependence matrix for the defect area—are selected and their usefulness is justified. The neural network is also implemented and compared with the neural-fuzzy system.

A new approach for fabric defect classification using radial basis function (RBF) network improved by Gaussian mixture model (GMM) is investigated by the author in study [26]. First, the gray level arrangement in the neighborhood of each pixel is extracted as the feature. This raw feature is subject to principal component analysis (PCA) which adopts the between class scatter matrix as the generation matrix to eliminate the variance within the same class. Second, the RBF network with Gaussian kernel is used as the classifier because of the nonlinear discrimination ability and support for multi-output. A novel method for texture defect detection is presented in paper [27], there this method makes use of Independent Component Analysis (ICA) for feature extraction from the non-overlapping sub-windows of texture images and classifies a sub-window as defective or non-defective according to Euclidean distance between the feature obtained from average value of the features of a defect free sample and the feature obtained from one sub-window of a test image. The authors proposed a new approach in paper[28] for the segmentation of local textile defects using feed-forward neural network. Every fabric defect alters the gray-level arrangement of neighboring pixels, and this change is used to segment the defects. Principal component analysis using singular value decomposition is used to reduce the dimension of feature vectors. The acceptance of a visual inspection system depends on economical aspects as well. Therefore, a new low-cost solution for the fast web inspection using linear neural network is also presented.

III. A REVIEW ON DEFECT DETECTION METHODS IN WOVEN FABRICS

A new algorithm based on multichannel filtering is presented in paper [29]. The texture features are extracted by filtering the acquired image using a filter bank consisting of a number of real Gabor functions, with multiple narrow spatial frequency and orientation channels. For each image, the authors propose the use of image fusion to multiplex the information from sixteen different channels obtained in four orientations. This algorithm realizes large computational savings over the previous approaches and enables high quality real-time defect detection. In study [30], a new method based on the use of thermal camera for detecting

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these defects from the textile fabric images is presented. For identification process of defective area, fabric images were obtained by a thermal camera during the fabric flow in quality control machine that was specially designed for this experiment. Defective and defect-free regions on fabric surface were determined by thermal camera due to the thermal differences. The mentioned thermal defect detection system will eliminate the worker usage for fabric quality control process, thus it will provide a cost-effective and competitive manufacturing. A novel defect detection scheme based on morphological filters is proposed by the author to tackle the problem of automated defect detection for woven fabrics in paper [31]. In that scheme, important texture features of the textile fabric are extracted using a pre-trained Gabor wavelet network. These texture features are then used to facilitate the construction of structuring elements in subsequent morphological processing to remove the fabric background and isolate the defects.

The author presents a new scheme in paper [32] for automated FDDS implementation using GLCM and also compares it with Gabor filter approach. GLCM texture statistics are extracted and plotted against the inter-pixel distance of GLCM as signal graph. The non-defective fabric image information is compared with the test fabric image. In Gabor filter based approach, a bank of Gabor filter with different scales and orientations is generated and fabric images are filtered with convolution mask. In paper [33], the author investigated the problem of automated defect detection in textured materials. The authors introduce a new approach for defect detection using linear FIR filters with optimized energy separation is proposed. Performance of different feature separation criterion with reference to fabric defects has been evaluated. The issues relating to the design of optimal filters for supervised and unsupervised web inspection are addressed. A general web inspection system based on the optimal filters is proposed. The paper [34], explains the investigation of the problem of automated defect detection for textile fabrics and proposes a new optimal morphological filter design method for solving this problem. Gabor Wavelet Network (GWN) is adopted as a major technique to extract the texture features of textile fabrics. An optimal morphological filter can be constructed based on the texture features extracted. In view of this optimal filter, a new semi-supervised segmentation algorithm was then proposed.

A fabric defect detection method based on Gabor filter masks is proposed in paper [35] on one even symmetric Gabor filter mask and one odd symmetric Gabor filter mask derived from the impulse response of the optimal Gabor filter are used. The optimal Gabor filter is designed to match with the texture features of defect-free fabric image, whose parameters are obtained by using the genetic algorithm. The author investigates the problem of automatic and robust fabric defect detection and classification which are more essential and important in assuring the fabric quality in paper [36]. Two characteristics of this work are: a new scheme combining Gabor filters and Gaussian mixture model (GMM) is proposed for fabric defect detection and classification , the test data is actually collected from Qinfeng textile factory, China, including nine different fabric defects with more than 1000 samples. The author aims at investigating methods in paper [37] for solving the problem of automated fabric defect detection and classification, which are more essential and important in assuring the fabric quality. The author focuses the work on two aspects: fabric defect detection and classification. First the detection texture features for texture defect are extracted using Gabor filters. The method would automatically segment defects from the regular texture. Second, texture features for classification use local binary patterns and Tamura method.

In paper [38], the author carries an extensive evaluation on the performance of a generalized motif-based method for detecting defects .The motif-based method evolves from the concept that every wallpaper group is defined by a lattice, which contains a further constituent motif. Decision boundaries are determined by learning the distribution of those values among the defect-free and defective patterns in the energy-variance space. The authors presented a novel approach in paper [39] to the fast detection and extraction of fabric defects from the images of textile fabric. Automated visual inspection systems are much needed in the textile industry, especially when the quality control of products in textile industry is a significant problem. For the detection of fabric defects, we first decompose the image into its bit planes. The lower order bit planes are found to carry important information of the location and shape of defects. A method of detecting the fabric defects automatically based on Gabor filters is introduced in paper [40]. The proposed method is based on the energy response from the convolution of Gabor filter banks in different frequency and orientation domains. Using the image fusion to combine all response feature images and finally the threshold of this fused image produces a simple binary image of defects. The authors in paper [41] proposed a method of fabric defect detection online based on Gabor filter bank is proposed. First, optimal Gabor filter bank is designed to match texture features of normal fabric image and built adopting the half-peak tangent method. The fabric defect image is treated using this filter bank, and filtered sub-images are obtained which characterize the fabric defect in different orientations and frequencies. Finally, these sub-images are fused to

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reconstruct a binary defect image. And the binary defect image is output to finish the detection.

The theoretical basis of a technique is presented in paper [42] for real time defect detection in fabrics using a joint transform correlator. This correlation technique is an extension of Fourier transform analysis and is extremely useful for real time pattern recognition. The regular periodic nature of a woven fabric makes it possible to use the Fourier transform technique to detect defects.. Cross- and auto-correlation peaks, generated after the execution of the second Fourier transform on the filtered joint power spectrum, indicate the existence of a particular defect type. A fractional power fringe adjusted filter is used for efficient detection of defects. The author introduces a simulated fabric model in paper [43] which is used to understand the relationship between the fabric structure in the image space and in the frequency space. The author uses two significant spectral diagrams called the central spatial frequency spectrums which is mainly used for analyzing the fabric defect. The fabric defects are broadly classified into four classes: 1) double yarn; 2) missing yarn; 3) webs or broken fabric; and 4) yarn densities variation. After evaluating these four classes of defects using some simulated models and real samples, seven characteristic parameters for a central spatial frequency spectrum are extracted for defect classification. In paper [44], the method of wavelet preprocessed golden image subtraction (WGIS) has been developed for defect detection on patterned fabric or repetitive patterned texture. This paper also presents a comparison of the three methods. The author presents a new method in study [45] to capture the texture information using adaptive wavelet bases. Wavelets are compact functions which can be used to generate a multi resolution analysis. Texture constraints are used to adapt the wavelets to better characterize specific textures. This paper demonstrates how adaptive wavelet basis can be used to locate defects in woven fabrics. A wavelet-filter method that minimizes entropy in the wavelet transform of images of woven fabrics is designed in paper [46]. Filters that minimize entropy in images tend to filter out fabric texture while highlighting fabric defects. The design of the wavelet filter is couched as a non-convex optimization problem which is solved using a hybridized Genetic Algorithm. Three distinct filters are tuned to detect horizontal, vertical and blob defects in woven fabrics. In addition to texture filtering, defect segmentation, noise removal, and object extraction are presented.

The author introduced a vision-based online fabric inspection methodology in study [47] for woven textile fabrics. The proposed inspection system consists of hardware components consist of CCD array cameras, a frame grabber and appropriate illumination and software components routines capitalize upon vertical and horizontal scanning algorithms to reduce the 2-D image into a stream of 1-D data. The wavelet transform is used next to extract features that are characteristic of a particular defect. The defect declaration is carried out by employing SNRs and scanning methods. Learning routines are called upon to optimize the wavelet coefficients. In paper [48], the authors introduce a prototype system for automatic in-line flaw detection in industrial woven fabrics. The authors describe the process flow to segment single yarns in high-resolved (≈ 1000 ppi) textile images. This work is partitioned into two parts: First, mechanics, machine integration, vibration cancelling and illumination scenarios are discussed based on the integration into a real loom. Subsequently, the software framework for high precision fabric defect detection is presented. A new method based on using features is proposed for defect detection in paper [49] for patterned fabrics. In the training stage, at first step LBP operator is applied to an image of defect free fabric, pixel by pixel, and the reference feature vector is computed. Then this image is divided into windows and LBP operator is applied to each of these windows. In the detection stage, a test image is divided into windows and using the threshold, defective windows can be detected. The authors discussed computer-vision-based automatic detection of fabric defects in paper [50] which is one of the difficult one-class classification tasks in the real world. To overcome the incapacity of a single fractal feature in dealing with this task, multiple fractal features have been extracted in the light of the theory of and problems present in the box-counting method as well as the inherent characteristics of woven fabrics. A robust new scheme is presented in this paper for optimally selecting values of the parameters especially that of the scale parameter of the Gaussian kernel function involved in the training of the SVDD model.

IV. A REVIEW ON DEFECT DETECTION METHODS IN SEWING FABRICS

The author presents the theoretical foundation of the method in paper[51] and defines the relations between motifs and lattice, from which a new concept called energy of moving subtraction is derived using norm metric measurement between a collection of circular shift matrices of motif and itself. A fast normalized cross correlation computation for defect detection application in paper [52] is proposed by author. Given larger images of size M ´ N and the neighbourhood window of size m´ n , the computational complexity can be significantly reduced from $O(m \times n \times M \times N)$ with the traditional normalized correlation operation to only $O(M \times N)$ with the proposed sum-table scheme. In

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paper [53], the author presents a study of using ellipsoidal decision regions for motif-based patterned fabric defect detection to improve the original detection success using max–min decision region of the energy-variance values. In our previous research, max–min decision region was found to be effective in distinct cases but ill detect the ambiguous false-positive and false-negative cases. To alleviate this problem, we first assume that the energy-variance values can be described by a Gaussian mixture model. Second, we apply k-means clustering to roughly identify the various clusters that make up the entire data population. Third, convex hull of each cluster is employed as a basis for fitting an ellipsoidal decision region over it. Defect detection is then based on these ellipsoidal regions.

The adaptive wavelet design for fabric defect detection is used in paper[54] to achieve translation invariance and more flexible design. The authors design the wavelet filters under the constraints that the analysis filters are power complementary, and the wavelet has one vanishing moment, which corresponds to a multi-scale edge detector. Adaptive wavelets are designed for five kinds of fabric defects in the experiments. Comparing the proposed method with adaptive wavelet design for defect detection based on orthogonal wavelet transform, the author design has largely improve the ratio of wavelet transform energy between the defect area and the background. The authors introduce a visual inspection methods in paper [55] for defect detection on patterned fabrics. A review on some defect detection methods on patterned fabrics will be given. Then, a new method for patterned fabric inspection called Golden Image Subtraction (GIS) is introduced. GIS is an efficient and fast method, which can segment out the defective regions on patterned fabric effectively. An improved version of the GIS method using wavelet transform is also given. To develop an automated visual inspection method for defect detection on patterned fabric the author uses the wavelet transform in his study [56]. The authors introduce methods like direct thresholding (DT) based on WT detailed sub-images and the golden image subtraction method (GIS). GIS is an efficient and fast method, which can segment out the defective regions on patterned fabric effectively.

In study [57], the authors introduce a new technique called fractal scanning, is developed to scan the digitized image of textile fabrics. A fuzzificd wavelet transform algorithm with adaptive noise rejection and on-line learning is used to extract features and a knowledge based inference engine is called upon to declare the defect categories. Off-line learning is introduced to maximize the detachability and identifiability measures. The authors introduce a new method that combines the concepts of wavelet transformation and Independent Component Analysis (ICA) in paper [58] for defect detection problem in textile images. The authors aim is to find the independent components of the wavelet transform of textile fabric images for the purpose of defect detection. In paper [59], the authors introduce a stitching detection and classification technique, which combines the improved thresholding method based on the wavelet transform with the back propagation (BP) neural network. The author uses the direct thresholding method, which is based on wavelet transform smooth subimages from the use of a quadrant mean filtering method, to attenuate the texture background and preserve the anomalies. The images are then segmented by thresholding processing and noise filtering. Nine characteristic variables based on the spectral measure of the binary images were collected and input into a BP neural network to classify the sample images.

An implemention of a textile defect detector which uses computer vision methodology is done by the author in paper [60] with the combination of multi-layer neural networks to identify the classification of textile defects and detect it with a real time configured mechanical system containing a microcontroller. The recognizer, suitable for LDC countries, especially for Bangladesh where textile exports earns the maximum for the country's economy. In paper [61], the authors introduce a defect detection system which includes a video camera with defect detection circuits for detecting defects in video signals being outputted by corresponding sections of an array sensor such as a TDI CCD two-dimensional array sensor. Each defect detection circuit includes a subtraction circuit for subtracting a prior stored pixel from an incoming pixel to generate a difference. The prior stored pixel is updated to the succeeding pixel only when the difference value is acceptable. The memories are sequentially read up to their end of line bits, and the defect pixel values along with coordinates expanded to include section indicating bits are transferred from the camera to further processing facilities. The author in paper [62] uses the multiple line scan cameras and multiple computers for preprocessing and post processing provides detailed analysis. This system does not identify the specific defect or cause, but does save a picture of a portion of the defect which can be reviewed by an operator or quality assurance technician. The system is described and the defect detection/identification algorithms discussed.

A fabric defect detecting system in paper [63] that uses an advanced method involving computer vision and image analysis is capable of defect classification. Image pre-processing techniques that enhance raw images are applied before defect classification by a *K*-means algorithm and statistical method. These generate a Bayes classifier from which a decision surface is created for a classification procedure that can categorize defective or non-defective regions. The advantages of using the decision surface are a reduction in the training step and the ability to rapidly classify fabric. The author introduces a fabric detect detection scheme in study [64] based on HOG and SVM is proposed. Histograms of orientated gradients (HOG) where the feature of the image is encoded and it is insensitive to various lightings and noises. The powerful feature selection algorithm, AdaBoost, is performed to automatically select a small set of discriminative HOG features in order to achieve robust detection results. In the end, support vector machine (SVM) is used to classify the fabric defects. A new approach to the problem of textile surface quality evaluation is presented in paper [65]. This new approach is based on the capture and analysis of the profile of protrusions. The specific methods of image processing for protrusion detection and parameterization have been elaborated. New algorithms for the grading of four types of fabric defect pilling, fuzziness, snagging, and hairiness which can be used to demonstrate a high level of coincidence between the obtained grades of all types of defect with expert grades.

V. QUANTITATIVE COMPARISON AND DISCUSSION

A quantitative comparison between the various defect detection in knitting, woven and sewing fabrics are surveyed in this paper. The performance of each methods applied to detect the defect in those types of fabrics have been assessed/reported on the fabric test images with varying resolution, background texture and defects is very difficult. Higher computational complexity can be justified with better performance on high resolution images but this also may not always hold good in various applications and overall cost of system. Some of approaches developed in [28], [6], [66], [67] have been in evaluated on image sample with various resolutions. The resolution of the images used for the detection process also matters a lot. Different techniques use different dataset of information. While examining on those techniques, Regular Band based Methodology is used to detect small defects with box, star or dot patterns. FDDS implemented on a Texas Instruments TMS320DM642 Evaluation Module, process one frame at a time. Moving window analysis is performed on each frame and the defects are marked with white squares on the input fabric image.

The high resolution images are highly suitable for detecting defects with very subtle intensity variations, but their use will require a high volume of online computations for unsupervised defect detection. Ozdemir et al. compared six texture features, consisting of MRF, KL transform, 2D lattice filters, Laws filters, Co-occurrence matrices, and a FFT - based method, for detecting textile defects. Also, by considering the results obtained with respect to speed and reliability, MRF approach seems feasible for a real-time factory implementation. Also Bodnarova et al. [68] have concluded that the optimal Gabor filters (optimized to detect five types of defects) perform better than gray level co-occurrence matrix, correlation or FFT based approaches. Lee Tin Chi [69], compares the performance of three methods which utilize matched masks, wavelet transform and neural network for fabric defect detection. The wavelet transform method was the least effective, because it was only able to detect effectively certain classes of fabric defects. Comparative studies performed by Randen et.al. [70, 71] and Chen et al. [72] indicate that the Gabor features in most of the cases outperform the other methods regarding the complexity and overall error rate. The online defect inspection system of mesh fabric was established by integrating the motor, encoder, linear CCD camera, capture card, industrial computer, converter, light source, and inspection system software. These operations took various duration for each steps. Some of authors have proposed improved systems with high real-time performance.

The performance are evaluated by visually assessing the quality of the binary output images. True detections (TP) are recorded when (1) the white areas of the binary output image only overlap the areas of the corresponding defects in the fabric image, and (2) no white area appears in the binary output image if the fabric image contains no defect. False alarms (FP) are recorded when the white areas appearing in the binary output image do not only overlap the areas of the corresponding defects in the fabric image, but also appear in some other areas significantly distant from the defect areas, or when white areas appear in the binary output image when the fabric image contains no defect. Overall detection (OD) is the sum of TP and FP. Missed detection (FD), which is the sum of True Negative (TN) and False Negative (FN) means that no white area appears in the binary output image even if the fabric image contains a defect. The Figure-2 confusion matrix is based on the above metrics and statistical performance measures are derived.

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		Condition	
		Condition Positive	Condition Negative
Test Outcome	Test Outcome Positive	True Positive(TP)	False Positive(FP) (Type I error)
	Test Outcome Negative	False Negative(FN) (Type II error)	True Negative(TN)

Figure 2: Confusion Matrix for Detection Performance Analysis

The Figure-3 explains the analysis of few methods and its examined defects based on the review papers.

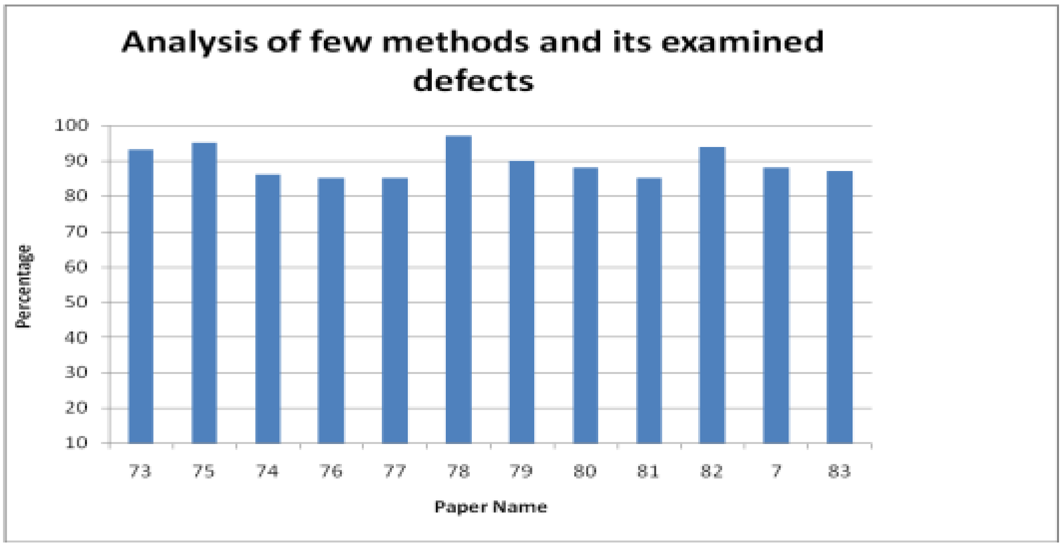

Figure 3: Graphical analysis of few methods and its examined defects

The equation listed in Table-1 is used to calculate the performance measure of the fabric detection system statistically. These statistical measures may be used to plot the results graphically and to evaluate the system and compression with other state-of-art systems. In Table-2 the detailed explanation about the publication, methods applied on it, which type of defects are experimented or identified and derived grading efficiency are given.

S. No	Performance Measure	Formula
1	Sensitivity	$\frac{TP}{TP+FN}$
2	Specificity	$\frac{TN}{FP+TN}$
3	Precision	$\frac{TP}{TP+FP}$

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4	Recall	$\frac{TP}{TP+FN}$
5	F-Score	$2*\frac{\Pr ecision.\text{Re}\,call}{\Pr ecision+\text{Re}\,call}$

Table – 1 Statistical Formula for Defect Detection Performance Analysis

S. No	Title & Year of Publication	Methods Applied	Defects Experimented	Grading Efficiency
1	Automated Fabric fault detection using Morpho logical operation on Bit plane,2015[73]	Bitplane decomposition & Weighted morphology	Woven fabric defects	93.2%
2	Automated patterned fabric fault detection ,2015	Novel image Decomposition method ANN classifier	Envision defective objects in patterned fabric image	95%
3	Fabric fault processing using image processing Techniques,2015[74]	Histrogram, Thresholding	machine faults, hole, Color bleed, problems ,scratch poor finishing ,dirt spot, excessive stretching ,crack point	86%
4	Automated patterned fabric fault detection, 2015[75]	Histrogram, Thresholding,Gray Scale	Patterned Fabric Defects	95%
5	Evaluation of yarn quality in fabric, 2014	IP-Mathematical (Stat)Model	Thickness of yarn	85%
6	Defect detection in fabric images using SVD techniques,2014[76]	SVD Technique	Hole,stain,miss-pick,miss-end,double-pick,double-end,weft-float,wrap-float,course-pick,course-end	D >=20-Defects
7	Fabric Fault processing perfections & imperfection,2014[77]	Histrogram, Thresholding	Hole,Sctrach,Fading,Broken ends,broken picks,float,gout,cut	85%
8	Texture defect detection using Local Homo -geneity & DCT,2014[78]	DCT/H-image method, Multivariate statistics method	Common fabric defects	96.01 to 97.8%
9	Yarn parameterization & fabric prediction 2013[79]	Artificial intelligence Method	Yarn faults-thin & thick places &neps	90%
10	Measuring the roughness of knitted fabrics by analysis of surface signals 2013[80]	Kawabata Method	Knitted fabric roughness	88%
11	Fabric fault processing using image processing technique 2013[81]	Global thresholding & Local or Adaptive Thresholding	Broken ends,broken picks,float,gout,hole,cut	85%
12	Fabric defect detection based on GLCM & Gabour filter 2013[82]	GLCM & Gabour filter	Blob shaped,edge shaped	94%
13	Real Time fabric defect	GLCM	Texture defect	88%

	detection system on Embedded DSP platform,2013			
14	Determination of diameter spectrogram & Neps for yarn parameterization, 2013[83]	Artificial Intelligence Method	Neps identification in yarn(Cotton &jute)	87%

Table – 2 Tabular analysis of few methods and its examined defects.

VI. CONCLUSION

In this paper, major defect detection techniques are surveyed based on three fabric defects namely knitting, woven and sewing fabrics. According to this survey we found that the system is fully automatic as well as defect is detected in all sort of steps in fabric production process is needed. The application methodology opted for each fabric type is dissimilar to one another. We hope that this paper would be useful for every newcomer to the area of automated fabric defect inspection. The comprehensive survey presented in this paper will be useful to develop and analyze a novel approach.

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