Research Article

Journal of Environmental Nanotechnology

An Effective Automatic Fabric Defect Detection System using Digital Image Processing

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Received: 23.12.2016 Accepted: 01.01.2017 Published: 30-03-2017

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ABSTRACT

For a long time fabric defect detection is carried out manually with human visual inspection. Automatic fabric inspection is important to maintain the quality of fabric. Fabric analysis is performed on the basis of digital images of the fabric. The recognizer acquires digital fabric images by image acquisition device and sends it to a computer system to processes the received image. The computer system makes a fabric analysis to find out whether the fabric is defect free or defected using Digital image processing techniques. In spite of innumerable algorithms available, the research is still challenging one. This paper presents the need, challenges and the processes of automatic fabric defect detection system. And more over the paper presents all the possible available technologies involved in the automatic fabric defect detection system.

Keywords: Fabric defect; Computer vision; Defect classification; Statistical approaches; Structural approaches; Feature Extraction; Segmentation; Model based approaches; Performance metrics; Artificial Neural Network (ANN); Particle Swarm Optimization (PSO).

1. INTRODUCTION

Automatic fabric inspection is important to maintain the quality of fabric. It is desirable to produce the highest quality goods in the shortest amount of time possible. Fabric faults or defects are responsible for nearly 85% of the defects found by the garment industry. Manufacturers recover only 45-65 % of their profits from seconds or off-quality goods. It is imperative, therefore, to detect, to identify, and to prevent these defects from reoccurring. An automated inspection system usually consists of a computer-based vision system. Because they are computer-based, these systems do not suffer the drawbacks of human visual inspection.

1.1 Fabric Inspection

Product inspection is an important aspect in modern manufacturing industries such as in case of electronics, automotive and medical industries. Mainly, fabric defect detection has two distinct possibilities. The first one is the product or end (offline) inspection in which the manufactured fabric has to be inspected through fabric inspection machines. The second possibility is the process inspection (online) in which the weaving process (or its parameters) can be constantly monitored for the occurrence of defects.

1.1.1 Drawbacks of Manual Inspection

1. It is difficult to find the defects by even human experts.
2. Human require training and they take time to develop such skill.
3. Visual inspection tends to be tedious or difficult, even for the best trained experts.
4. Human is slower than the machines.
5. Human inspectors fatigue over time (get tired quickly).

1.2 Automated Fabric Inspection

Automatic inspection systems are designed to increase the accuracy, consistency and speed of defect detection in fabric manufacturing process to reduce labour costs, improve product quality and increase manufacturing efficiency.

This paper is structured as follows.

In Section 2, the need and challenges of an online automatic fabric inspection system has been discussed.

In Section 3, an overview of Automatic fabric inspection system explaining the key stages of it is presented.

In Section 4, Classification of all possible approaches available for an automatic fabric inspection system has been briefly discussed.

In section 5, the results of the implementation of various key stages of an automatic fabric inspection system are presented.

Finally, a conclusion is drawn in Section 6.

2. ONLINE FABRIC DEFECT DETECTION SYSTEM

The online fabric inspection is called as real-time fabric inspection where production and production control work are together in real time. The need for this vision system stems from the fact that the present fabric inspection method (offline) is an inadequate task.

The essential requirements for an online automated inspection system are as follows:

1. The system must operate in real-time with good results.
2. It must reduce escape rates.
3. It must reduce false alarms.
4. It must be robust and flexible.
5. It must be fast and cost efficient.

2.1 Challenges and Difficulties

1. The task is particularly challenging due to the large number of fabric defect classes.
2. There are inter-lass similarity and inter-class diversity of defects.
3. Also, the characterization of defects in textured materials is generally not clearly defined.
4. There is enormous variety of fabric patterns.
5. There are stochastic (random) variations in scale.
6. The problem of quantifying visual impressions in complex situations.
7. This task has extremely high data flow.
8. It suffers from noise influence.

Table 1.1: Difference of Manual and Automated inspection

Inspection types	Manual Inspection	Automated Inspection
Defect detection	70%	85%
Statistics ability	0%	90%
Response type	50%	80%
Inspection speed	30m/min	120m/min
Reproducibility	50%	90%
Information exchange	20%	87%

2.2 Defects in Fabric

Most defects in fabric occur during weaving. Some of these fabric defects are visible, while others are not. However, some fabric defects may be rectified during weaving and after weaving while others are not. Texture of fabric is based on feel of the fabric. They can be classified as rough, velvety, smooth, soft, silky, lustrous, etc. The different textures of the fabric depend upon the types of weaves used. Textile Fabric materials are used to prepare different categories and types of fabric products in the textile industry viz. cotton, silk, wool, leather, and linen. Natural fabric and synthetic fabric are the two different classifications of textile fabric (Priyanka Vyas and Manish Kakhani, 2015).

In a fabric, defects can occur due to:

- machine faults
- hole
- Color bleeding
- yarn problems
- scratch
- poor finishing
- dirt spot
- excessive stretching
- crack point

In automated fabric defect inspection, as and when the fabric is produced during weaving, fabric inspection is automatically done. There are a large number of types of fabric defects available out of which color yarn, missing yarn, hole, slub, crease mark and spot are the frequently occurred defects, which are shown in fig.1.

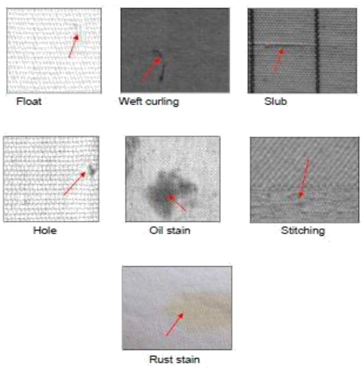

Fig. 1: Examples of different types of fabric defects

3. AUTOMATIC FABRIC INSPECTION SYSTEM

The development of an automated, i.e. computer vision based system for fabric defect inspection involves several steps as shown in fig.2.

3.1 Image Acquisition

The first stage of any vision system is Image acquisition. There can be different types of camera used for this application such as CCD (Charged Coupled Device) camera, CMOS (Complementary Metal Oxide Semiconductor) camera, Digital camera, etc. The pixel value of these cameras is around 320 × 420 pixels (Banumathi and Nasira, 2012; 2013).

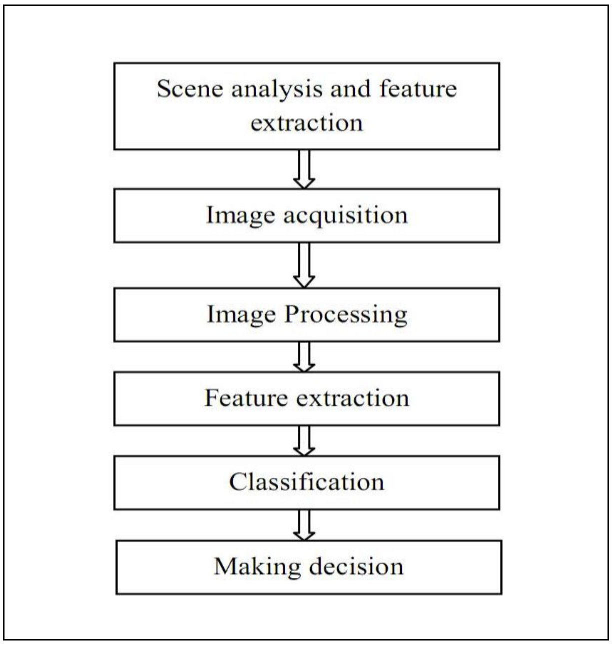

Fig. 2: Block diagram of various stages in an automatic fabric inspection system

3.2 Image preprocessing

Image preprocessing stage consist of collection of techniques that are used to improve the visual appearance of an image or used to convert the image to a form, which can be better suited for further analysis in the subsequent stages by a human or a machine (Kumar *et al.* 2011).

3.3 Feature Extraction

Feature Extraction is a stage in which various methods can be employed for capturing visual content of images for indexing & retrieval purpose. There can be number of features defined from an image ***and*** there are methods for calculating each of these features. The features which are better suited for a particular application are selected for further analysis (Nasira and Banumathi, 2014).

3.4 Classification

Artificial Neural Network(ANN), support vector machines (SVMs), clustering and statistical inference are to name some effective classifiers. The classification stage gives the end result of the entire fabric defect detection process by reporting whether the fabric is defected or defect free. Using neural networks as a classifier requires two phases namely, a training phase and a testing phase. In the training phase, the neural network makes the proper adjustment for its weights (W) to produce the desired results (Srinivasan *et al.* 1992).

4. CLASIFICATION OF AUTOMATED FABRIC DEFECT INSPECTION

Structural approaches are classified into Statistical, spectral, model based approaches.

Structural approaches assume that the textures are composed of primitives. These primitives can be as simple as individual pixels, a region with uniform gray levels, or line segments. Consequently, the main objectives 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.).

4.1 Stastical Approaches

They measure the spatial distribution of pixel values while their main object is to separate the image of the inspected fabric into the regions of distinct statistical behaviour. An important assumption in this process is that the statistics of defect-free regions are stationary, and that these regions extend over a significant portion of inspection images. Based on the number of pixels defining the local features, they are classified these approaches into first order, second order and higher order statistics. The first order statistics estimate properties like the average and variance of individual pixel values, ignoring the spatial interaction between image pixels, second and higher order statistics on the other hand estimate properties of two or more pixel values occurring at specific locations relative to each other.

The most used approaches are:

4.1.1 Gray Level Thresholding Approach

These approaches are direct and simple mean to detect high contrast fabric defects. The principle depends on the signal variation (peak or trough) due to the presence of high contrast defect.

4.1.2 Normalized Cross-correlation Approach

Correlation is used to locate features in one image that appear in another one and the correlation coefficient can generate a correlation map for defect declaration. The cross-correlation function provides a direct and accurate measure of similarity between two images. Any significant variation in the value of this measure indicates the presence of a defect.

4.1.3 Statistical Moments Approach

Mean, standard deviation, skewness and kurtosis provide statistical information over a region while the values are used for image segmentation.

4.1.4 Rank-order Functions Approach

An image rank-function is a simple statistical approach for defect detection based on histogram analysis. It is given by the sequence of gray levels in the histogram when this sequence is sorted in the ascending order. The histogram and the rank function provide exactly the same information.

4.1.5 Edge Detection Approach

Edge detection is a traditional technique for image analysis. The distribution of edge amount per unit area is an important feature in the textured images. The amount of gray level transitions in the fabric image can represent lines, edges, point defects and other spatial discontinuities. Thus these features have been largely employed for conformity testing, assembly inspection and fabric defect detection.

4.1.6 Morphological Operations Approach

The mathematical morphology helps describing the geometrical and structural properties of an image. Morphological image processing has relevance to conditioning, labeling, grouping, extracting, and matching operations on images. The morphological operations are one of the ideal tools for removing noise, in spatially filtered images of fabrics.

4.1.7 Local linear Transforms Approach

This approach is closely related to filter bank analysis methods. It gives a statistical justification for the extraction of texture properties by means of convolution operators (masks). These masks may be considered as local detectors elementary structures such as defects.

4.1.8 Artificial Neural-networks Approach

The Artificial neural-networks are among the fastest and most flexible classifiers used for fault detection due to their non- parametric nature and ability to describe complex decision transform. If the window function is Gaussian, the windowed regions composed of a number of similar elementary processing units (neurons) connected together into a network. These neurons are arranged in layers with the input data initializing the processing at the input layer.

4.2 Structural Approaches

Based on spatial-Frequency domain features which are less sensitive to noise and intensity variations than the features extracted from spatial domain, spectral approaches occupy a big part of the latest computer vision research work. 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.

4.2.1 Fourier Analysis Approach

The Fourier analysis is a global approach that characterizes the textured image in terms of frequency components. Fourier techniques have desirable properties of noise immunity, translation invariance and the optimal characterization (enhancement) of the periodic features. To implement Fourier analysis for fabric defect detection, various methods are available; Optical Fourier Transforms (OFT) obtained in optical domain by using lenses and spatial filters can be used, but most techniques, digitally implemented, are derived from Discrete Fourier Transforms (DFT) and/or its Inverse (IDFT) which recovers the images in the spatial domain.

4.2.2 Gabor Filters Approach

The classical way of introducing spatial dependency into Fourier analysis is through the windowed Fourier transform. If the window function is Gaussian, the windowed Fourier transform becomes the well-known Gabor transform, which can arguably achieve optimal localization in the spatial and frequency domains.

4.3 Model based Approaches

The problem of locating possible clusters in a data set (image) is a recurrent one with a long history. Campbell et al combined image-processing techniques with a powerful new statistical technique to inspect denim fabrics. The approach employs model based clustering to detect relatively faint aligned defects. In order to assess the evidence for the presence of a defect, Bayesian information criterion (BIC) is used.

4.3.1 Gauss Markov Random Field (GMRF) Model Approach

The image is simply random noise, Markov random fields use a precise model of this dependence. They are able to capture the local (spatial) contextual information in an image. These models assume that the intensity at each pixel in the image depends on the intensities of only the neighboring pixels. The theory provides a convenient and consistent way for modeling context dependent entities such as pixels, through characterizing mutual influences among such entities using condition MRF distribution.

4.3.2 Poisson's Model Approach

The stochastic models of some randomly industrial textured materials are based on the nature of the manufacturing process. One example of such material is the fibrous, non-woven material used for air filtration that is manufactured through adhesive technology.

5. RESULTS & DISCUSSIONS

Even though there are huge number of fabric defect detection algorithms and techniques, the need to identify effective methods among these approaches is very important. The comparative study is very important and can be of a research guide as it enables the researchers to learn and understand the differences between the various approaches based on its feasibility and reliability.

It has been evaluated in Fatemi-Ghomi *et al.* (1996) that there are number of different methods for wavelet based texture segmentation. The two-point correlation function has been used as performance measure. It is been found that, the function can be appropriate tool for both the visualization of the presence of structure in any feature space of high dimensionality and can be used as a tool for choosing the best features to be used in the detection process.

Also, Zhang and Bresee (1995) has compared two approaches for detecting and classifying knot and slub defects in woven solid-shade, un-patterned fabrics. The autocorrelation function was used for both methods to identify fabric structural repeat units, based on statistical or morphological computations. It has been found and concluded that, both methods exhibit similar performance.

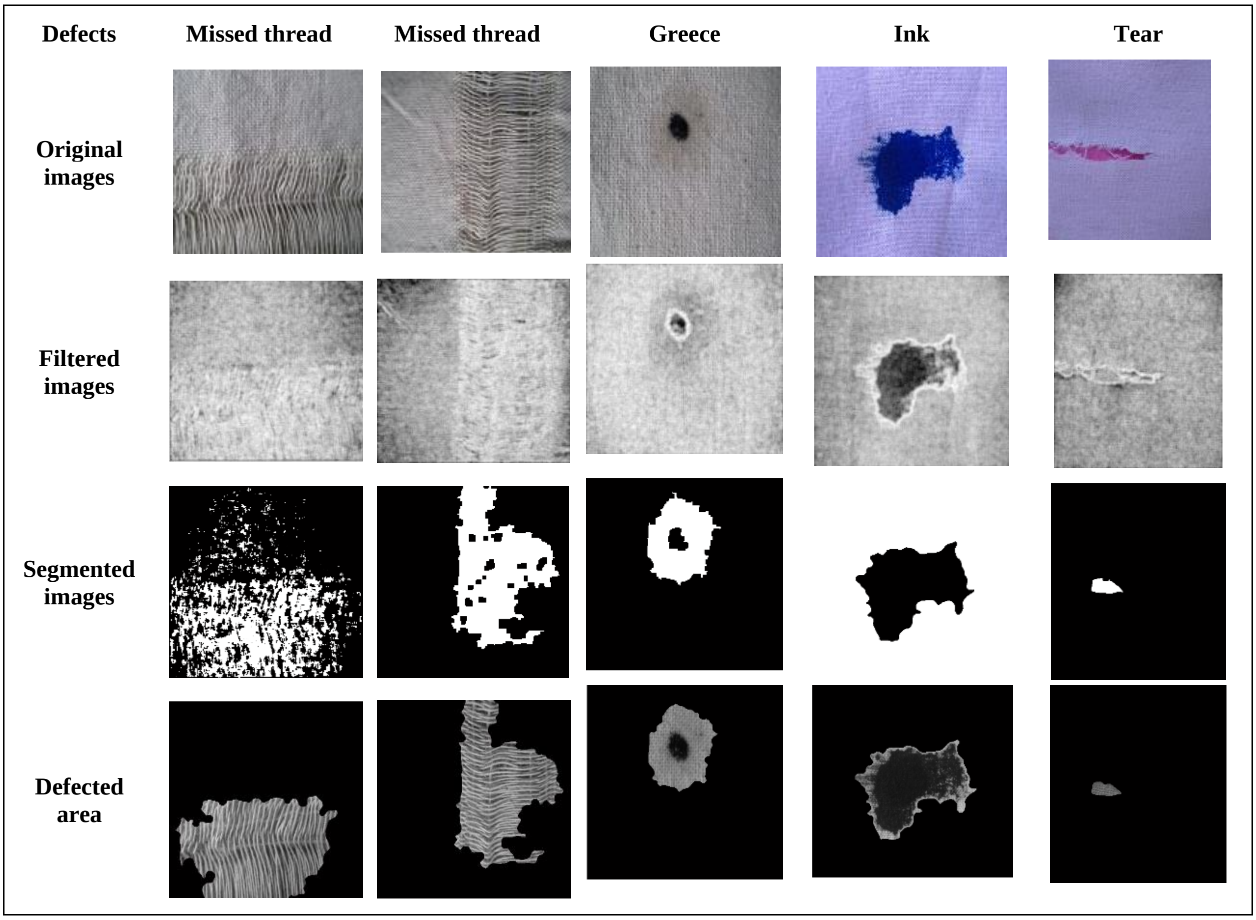

Fig. 3: Resulted images after applying various filtering techniques on original images

In Bodnarova *et al.* (2000), a comparative study has been developed to examine the suitability of four different detecting algorithms. Gray level co-occurrence, normalized cross-correlation, texture-blob detection and spectral approaches were applied in this study. The correlation approach appeared to be the most promising method for a real time, high accuracy defect detection algorithm.

Comparing the Sobel edge detection with those based on thresholding and fractal dimension in Conci and Proença (2000), it has been found that they are robust and fast methods to detect fabric defects. It has been effectively concluded that use of fractal dimension method can be the most reliable results because it is able to correctly detect all types of defects with only 2% false alarms while it is faster than the other approaches.

The basic algorithms and technique require robust strategy to be implemented. In the proposed algorithm, based on the Automatic fabric inspection system defined in Section III , the digital images of both defected and defect- free were acquired by a digital camera as shown in fig. 3.

These images are preprocessed so that they become noise free images by applying PSO based median filtering technique. The resultant images are shown in fig. 3.

In the process of locating the defects occurred in the fabric images, entropy based segmentation is applied on the filtered images which results in exactly segmenting out the defected area, if any in the image.

These images are then sent to the Artificial Neural Network classifier which classifies the images to be defected or defect – free. To improve the credibility of the technique, a second step is implemented using a PSO based feature selection, the classifier is enabled to exactly identifying what kind of defect it is. Here, in the proposed system five kind of defects has been tested to identify exactly viz. as Tear, Ink stain, Oil stain and missed thread (both warp and weft thread miss). The objective here is to prove the utility of the technique to detect defects in case of a real fabric and in case of a simulated one.

6. CONCLUSION

In this paper, various defects which may occur in a fabric, their causes, The need and challenges of an online automated fabric inspection system, an overview of an automated fabric inspection system has been clearly discussed. A proposed system and the resultant output has been given. This method classifies 85% of defect in fabric and locates the defect in the normal fabric at an acceptable rate and provides 80% classification accuracy. We have presented promising results for an effective automated fabric inspection system for multi-class defect detection and classification in fabrics using both geometric and texture features to capture the visual properties.

ACKNOWLEDGEMENT

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FUNDING

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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