An Intelligent Scheme for Fault Detection in Textile Web Materials

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ABSTRACT
The Indian textile industry has a major impact on the world economy through millenniums. At present all the textile industries aim to produce competitive fabrics. The competition depends mainly on productivity and quality of the fabrics produced by industry. In the textile sector, there are huge losses due to faulty fabrics. Fault identification in the manufactured fabric is the most complicated process in the textile industry. Existing fabric inspection methods are carried out by human visual inspection, or by imported machines. But it is time consuming and costly. The proposed method of computational intelligence based fabric inspection method aims to produce a low cost method with higher efficiency. The video of the knitted fabric that is rolled is being captured and it is converted into individual frames. Then the extracted frames are processed to find its defects and those defects are classified using computational techniques.

Key Words
Computational Intelligence , Fabric Inspection ,Fault Identification, Feature Extraction, Frame Extraction.

1. INTRODUCTION
The global economic pressures have gradually led business to ask more of it in order to become more competitive. In textile industry, inspection of fabric defects plays an important role in quality control. An optimal solution would be to automatically inspect the faulty fabric to prevent defects in production of fabrics or to change process parameters automatically to improve the product quality.

This paper produces a computational technique based fabric fault inspection technique. The video of the moving fabric material is captured and it is processed into individual frames. These individual frames are preprocessed to improve the quality of the image and textural features are extracted from them. These extracted features are analysed using the designed fuzzy system to identify the faults in them. After analyzing the frames, the percentage of faults are determined and the inferences are listed.

2. FABRIC DEFECTS
The fabric quality is affected by yarn quality and/or loom defects. The poor quality of raw materials and improper conditioning of yarn results in yarn quality defects and effects such as color or width inconsistencies, slubs, broken ends, *etc.* The tests on the quality of yarns are usually performed at the output of spinning-mills. Quality test runs for looms and knitting machines require interruption of the weaving process. This interruption is not practically feasible for the machines that are intended for large production runs of fabric rolls. The quality test is carried out in weaving machines using existing methods which generally produces unacceptable results. These test runs tend to be smaller and may not register recurring fabric defects that are generated due to sinusoidally occurring inconstancies in the weaving machines. The weaving irregularities generated in the weaving machines due to the change in operating conditions (temperature, humidity, *etc*.) also results in various fabric defects independent of yarn quality.

Fig 1: Web Material with Missing Yarn, Hole, Oil Spot, Color Yarn

3.FABRIC DEFECT INSPECTION METHODS
3.1 Traditional Inspection
The traditional inspection of the fabric fault is carried out by Human inspections [5]. The fabric produced from the weaving machines is about 1.5-2 meters wide, and rolls out at the speed of 0.3-0.5 meters per minute. When a human inspector notices a defect on the moving fabric, he stops the motor that rotates the fabric roll, records the defect with its location and starts the motor again.

3.2 Automation For Inspection
The automated fabric inspection system is economically attractive when reduction in personnel cost and associated benefits are considered. The architecture of a typical automated textile web inspection system [3] is shown in Fig 2. The system consists of a bank of cameras arranged in parallel across the web to be scanned, a computer console hosting (single or an array of) processors, the frame grabber, a lighting system and the supporting electrical and mechanical interfaces for the inspection machine. The inspection system employs massive parallelism in image acquisition with a front-end algorithm. The Image acquisition is not real-time and doesn’t match with the speed of the process too. Even some of the frames are not processed and hence the result of this fault analysis is not accurate

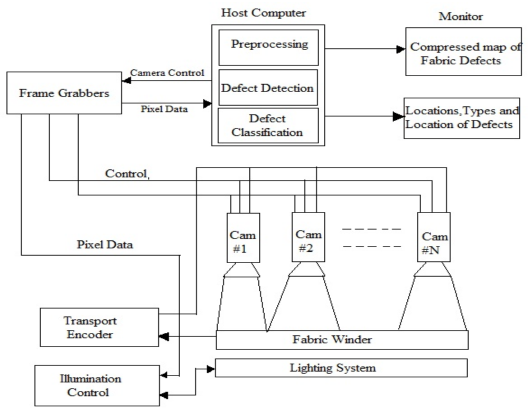

Fig 2 : Automated Textile Web Inspection

3.3 Classification of Inspection Methods

The automation of visual inspection process is a multifaceted problem and requires complex interaction among various system components. The prior techniques and models, which are already used for fabric defect detection, are discussed in some papers [1]. Based on the material of the fabric and other factors, the inspection method may differ. The flow chart about the classification of inspection methods is given in Fig 3.

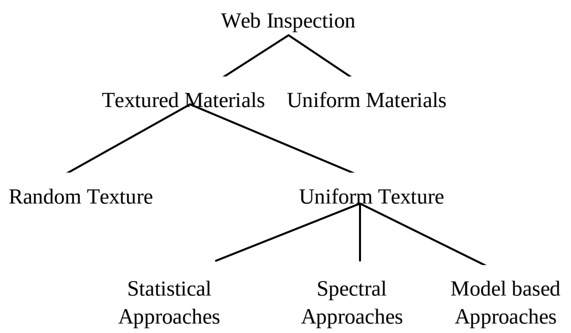

Fig 3 : Classification of Inspection Methods

Texture analysis [10] is the most common method of inspection of fabric faults.

The most commonly used texture analysis techniques are classified into three categories

- Statistical approaches
- Spectral approaches
- Model based approaches

3.3.1 Statistical Approaches

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 pure-statistical approaches [4] form the majority of work presented in the literature. The defect detection methods employing texture features extracted from fractal dimension, first-order statistics, cross correlation; edge detection, morphological operations, co-occurrence matrix, eigen filters, rank-order functions, and many local linear transforms have been categorized into this class.

3.3.2 Spectral Approaches

Many common low-level statistical approaches such as edge detection break down for several fabric defects that appear as subtle intensity transitions. Spectral approaches [7] are robust and efficient computer-vision approaches for fabric defect detection. In these approaches texture is characterized by texture primitives or texture elements, and the spatial arrangement of those primitives. Thus, the primary goals of these approaches are firstly to extract texture primitives, and secondly to model or generalize the spatial placement rules. However, random textured images cannot be described in terms of primitives and displacement rules as the distribution of gray levels in such images is rather stochastic. Therefore, spectral approaches are not suitable for the detection of defects in random texture materials.

3.3.3 Model-Based Approaches

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 real textures can be modeled as stochastic process, and textured images can be observed as the realizations or the samples from parametric probability distributions on the image space. The advantage of this modeling is that it can produce textures that can match the observed textures. The defect detection problem can be treated as a statistical hypothesis-testing problem on the statistics derived from this model. Model-based approaches [6] are particularly suitable for fabric images with stochastic surface variations (possibly due to fiber heap or noise) or for randomly textured fabrics for which the statistical and spectral approaches have not yet shown their utility.

4. Proposed Technique

The proposed fuzzy based technique aims at identifying and classifying the fabric faults effectively. The video of the knitted fabric, which is to be inspected for quality test, is captured. The captured video is converted into individual frames. These frames are preprocessed to improve to improve the quality of the image. Then the textural features are extracted from those images.

These extracted properties are given as the input for the fuzzy system. Based on the features, the faults in the fabrics are identified and they are classified. The block diagram of the proposed method is given in the Fig 4.

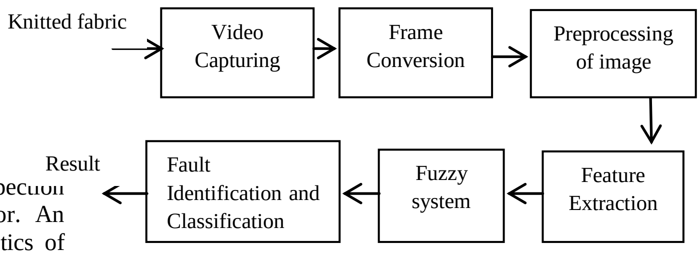

Fig 4 : Block Diagram of Proposed Fabric Fault Inspection method

4.1 Preprocessing of Image

The first step in the proposed method is to extract frames from the video of the knitted fabric for further processing. The video is taken using high resolution Charge Coupled Device (CCD) cameras. After the video is taken, the video is converted into individual frames using frame grabbers. In the recently developed smart cameras, the camera itself will have the inbuilt frame grabbers. This makes the process of getting data about process very easier and the key frames are extracted to do the inspection on the quality of the material. The extracted key frames are preprocessed in next step. It is very difficult to isolate the minor faults from its texture pattern as the minor faults appear as small one on the web fabric image. Hence it should be preprocessed. Here the preprocessing is carried out by converting the colour image into Gray scale image and then adjusting the brightness of the image. Fig 5 shows the original and preprocessed image.

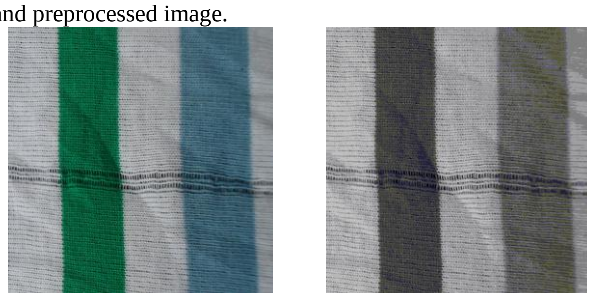

Fig 5 : Preprocessed Image

4.2 Feature Extraction

The textural features are extracted by forming the Gray Level Co-occurrence Matrix. A co-occurrence matrix *is* used to describe the patterns of neighboring pixels in an image. More specifically, one co-occurrence matrix describes pixels that are adjacent to one another horizontally. This is called zero orientation. This orientation is considered here for extracting the textural features. 9 features are extracted to identify and classify the faults. The extracted features are Autocorrelation, Contrast, Cluster Shade, Dissimilarity, Energy, Entropy, Homogeneity, Sum average and Cluster Prominence.

4.3 Fuzzy Logic System

Fuzzy logic is a problem-solving control system methodology which lends itself to implementation in systems ranging from simple, small, embedded micro-controllers to large, networked, multichannel PC. It can be implemented in hardware, software, or a combination of both. FL provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy, or missing input information. FL's approach to control problems mimics how a person would make decisions, only much faster. FL incorporates a simple, rule-based IF-THEN rules approach to solve the control problem rather than attempting to solve it mathematically. Fuzzy logic is a very useful method of reasoning when mathematical models are not available and large amount of input is present. It provides a simple way to arrive at a definite conclusion based upon ambiguous, imprecise, noisy or missing input information. It is quiet helpful in accelerating the speed of decision making. When true or false is inadequate to describe human reasoning, fuzzy logic is used. The block diagram of the Fuzzy logic process is shown in the Fig 6.

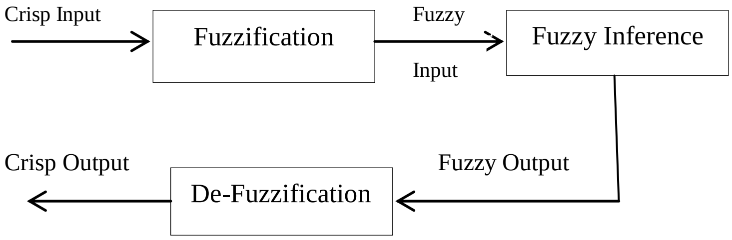

Fig 6 : Fuzzy Logic Process

4.3.1 Crisp Input

The first step is to take the crisp inputs and determine the degree to which these inputs belong to each of the appropriate fuzzy sets. Here the crisp inputs are the textural features extracted from the images. These crisp inputs are converted into fuzzy value by the fuzzification process. The crisp values are tabled in the table 1 below.

Table 1 Input Variables

S.No	Features	Range
1	Autocorrelation	18-40
2	Contrast	0-0.6
3	Cluster Shade	-20-0
4	Dissimilarity	0- 0.4
5	Energy	0-0.14
6	Entropy	2-3
7	Homogeneity	0.6-1
8	Sum average	9-13
9	Cluster Prominence	200-320

4.3.2 Fuzzification

The crisp values are converted into Fuzzy input values by defining their membership values. Here, for developing the fuzzy system for the proposed system, the trapezoidal shaped membership is selected. After forming the fuzzy inputs, using that the rules are framed to form the FIS. Based on the rules framed the faulty images are identified and classified effectively. The Fuzzy system for the proposed system is established with the help of LabVIEW Fuzzy system Designer Toolbox. The snapshot of the window for defining the membership functions is shown in the Fig 7.

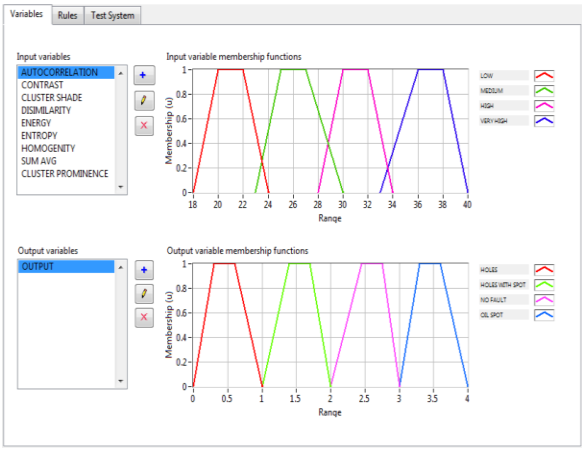

Fig 7 : Membership Window

The Table 2 shows the membership values defined for the Input variables.

Table 2 Membership Values

Input Variables	Membership Name			
	Low	Medium	High	Very High
Autocorrelation	18-24	23-30	28-34	33-40
Contrast	0-0.2	0.18-0.3	0.28-0.4	0.38-0.6
Cluster Shade	-20- -14	-15- -10	-11 - -4	-5 - 0
Dissimilarity	0-0.15	0.13-0.3	0.28-0.4	-
Energy	0-0.08	0.07-0.11	0.1-0.12	0.115-0.14
Entropy	2-2.4	2.3-2.8	2.7-3	-
Homogeneity	0.0-0.75	0.7-0.85	0.8-1	-
Sum average	9-11	10-11.5	11-13	-
Cluster Prominence	200-240	230-280	270-320	-

The Table 3 shows the membership values defined for the Output variables.

Table 3 Output Variables

S.No	Output Variables	Fuzzy output Range
1	Holes	0-1
2	Holes with Oil spot	0.8-2
3	No Fault	1.8-3
4	Oil Spot	2.8-4

4.3.3 Fuzzy Rules

After the membership values are defined, next step is to frame the fuzzy rules for the FIS. Once the rules have been established, the FIS can be viewed as a system that maps an input vector to an output vector. The fuzzifier maps input numbers into corresponding fuzzy memberships. It is possible that one or more rules may fire at the same time. In the proposed system, there are 9 antecedents and 4 consequents. While framing a rule, if more antecedents are used, then they are connected using the connective operator like AND or OR operator. Totally 31 rules are framed to establish the FIS for the proposed system. The Snapshot of the window showing the framed rules is shown in the Fig 8

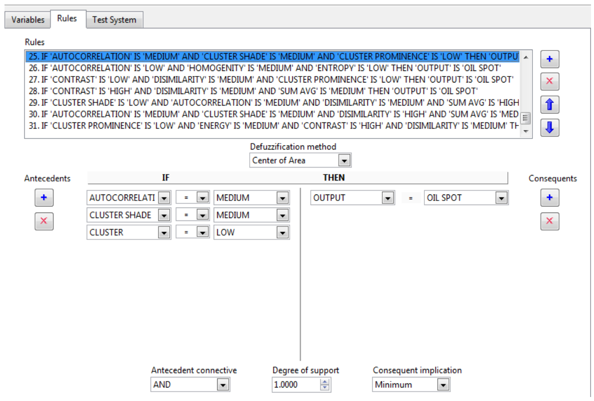

Fig 8 : Fuzzy Rules

4.4 Developed system

After forming the fuzzy system for the proposed system, the fuzzy system is interfaced with the fuzzy controller. The fuzzy controller has two inputs, namely one from Fuzzy system loader, which loads the designed fuzzy system and Fuzzy rules and another one is the Extracted features, which acts as the input values from the fuzzy controller. The block diagram of the designed system to identify and classify the faults is given in the Fig 9.

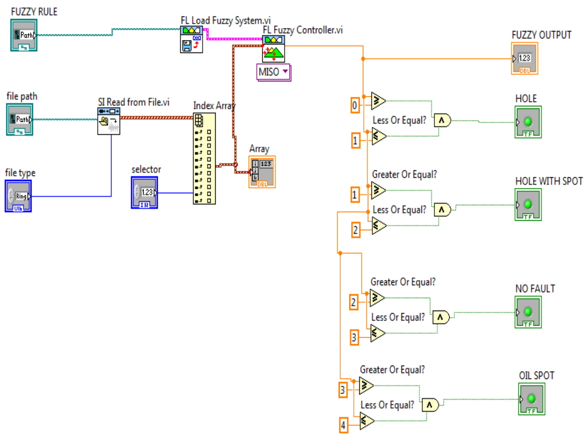

Fig 9 : Block Diagram of Developed System

In this system, the Fuzzy controller produces a crisp value as the output. Based on the fuzzy rules framed, the generated crisp value will be in the range of 0 - 4. Using this crisp value, the faults in the fabric can be identified and classified by configuring the LabVIEW blocks.

5. RESULTS AND DISCUSSIONS

5.1 Fault Identification

For validating the result for the proposed method, 40 fabric samples are considered, in which 30 are faulty fabric samples. Comparing to the existing microcontroller based automatic fabric inspection method, the proposed Fuzzy based method produces 23.66 % better result. Table 4 shows the comparison of fault identification results for the existing and proposed method.

Table 4 Fault Identification Results

Inspection method	No of Fabric image samples	No of faulty image	Fault identified images
Existing Micro controller based automatic inspection	40	30	21
Proposed Fuzzy based inspection	40	30	29

5.2 Fault Classification

In fault classification, when less no of features are considered, the proposed method produces the same result as the existing method. Table 5 shows the classification result of the proposed method with different no of features considered.

Table 5 Classification Results

Inspection method		No of Fabric image samples	No of faulty image	Fault identified images	Classified images
Existing Micro controller based automatic inspection		40	30	21	18
Proposed Fuzzy based inspection	4 Features considered	40	30	29	25
	9 Features considered	40	30	29	28

6. CONCLUSION

Thus the proposed fabric fault inspection using Fuzzy logic implemented with LabVIEW provides about 23.66% better result in identifying the types of faults and about 10.83% better result in classifying them when compared to the existing micro controller based automated fabric inspection method. The above proposed system produces an overall accuracy of 85.714% by considering the 4 textural features whereas the same proposed system produces an accuracy of 96.55% considering 9 textural features. So the classification accuracy is characterized by textural features.

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