Fault Detection in Textile Web Materials using Machine Vision Technique

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Abstract

Quality control is an important aspect in modern industrial manufacturing. In textile production, automatic fabric inspection is important for maintaining the fabric quality. At present the fabric defect inspection process is carried out with human visual inspection, or by imported machines. But it is a time consuming and costly. The detection of fabric defects is one of the most intriguing problems in computer vision. The inspection of fabric defects is particularly challenging due to large number of fabric defect classes which are characterized by their vagueness and ambiguity. The videos of the knitted fabric that is rolled are being captured. The captured video is converted into individual frame and the key frames are extracted for processing. Then the extracted frames are processed to find defects in it and the defects are classified using various machine vision techniques. This paper presents the detailed report about the classification of various types of fabric faults.

Keywords: Fabric fault detection, Feature extraction, Machine vision, Quality control, Textile Web material.

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 proposes a machine vision based fault detection technique. This work inspects woven web material to detect the manufacturing faults. The video of the moving fabric material is captured and the videos are processed into individual frames. The individual frames are examined to detect and classify the different faults. After analyzing the frames, the percentage of faults are determined and the inferences are listed.

This paper is organized into seven sections. Section 2 discusses about the fabric defects. Section 3 provides the various fault detection methods. Section 4 details the machine vision concepts and Section 5 gives the System design for the proposed system. Section 6 details the results obtained by the proposed fault detection algorithm and the conclusions are drawn in section 7.

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.

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

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automated textile web inspection system [3] is shown in Figure.1. 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[2]. 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

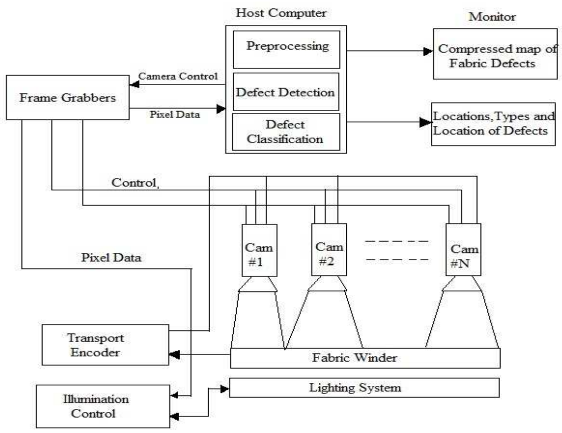

Figure 1 Automated Textile Web Inspection

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 Figure 2.

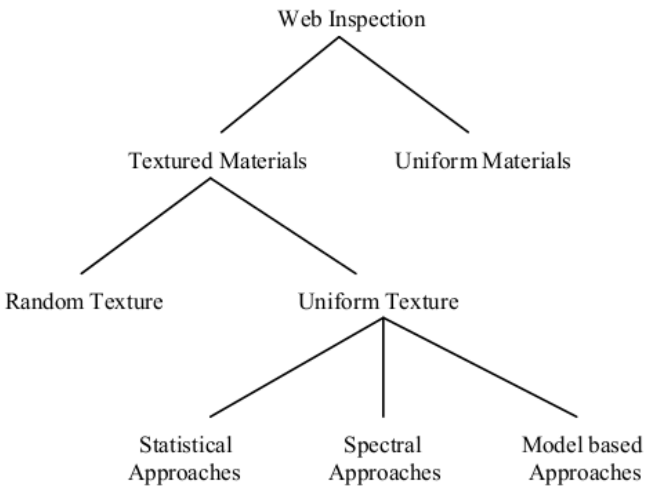

Figure.2 Classification of Inspection Methods

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. Machine Vision Inspection

Many attempts are carried to apply machine vision to automate the inspection of moving webs, for a wide range of materials including tinplate, cold rolled steel strip, sand paper, etc in addition to textiles. Machine vision finds its application in many fields due to its accuracy in analyzing the system with the minimum utilization of the sources. Moreover in other inspection techniques only off line processing is done. Where as in the machine vision technique online processing is done and the interfacing of the inspection system with the real-time process can also be achieved. The overview of the machine vision technique used for the textile fault analysis is discussed in detail in the following sub sections

4.1 Components of Machine Vision

The thing that makes the machine vision technique a most successful one is the various ranges of components it possess. In other systems these components will not be present and the performance of these systems will also be poor when compared to machine vision components.

The various components are discussed below.

4.1.1 Smart Cameras

Charge Coupled Device (CCD) cameras are becoming smaller, lighter and less expensive. Images captured are sharper and more accurate, and the new dual output cameras produce images twice as fast as previous models. A new generation of CCD color cameras adds another dimension to machine vision by enabling systems in better detection and discrimination between objects, removing backgrounds and perform spectral analysis. Smart cameras are the new generation of CCD cameras which forms the recent trends in the machine vision techniques. They have the internal processor and memory within them which makes the cameras to work independently. These cameras are ethernet supported and they can be linked to the remote monitoring system. Based on the applications the range and performance of the smart camera varies accordingly.

4.1.2Inbuilt Frame Grabbers

Frame grabbers developed recently offer greater stability and accuracy than the earlier models, and some can even handle image processing and enhancement on the fly, using digital signal-processing techniques. In other inspection system frame grabbers are to be installed individually. But in machine vision, the camera itself will have the inbuilt frame grabbers which are able to produce even 1058 frames/sec from the captured video. This makes the process of getting data about a process very easier and the key frames are extracted to do the inspection on the quality of the material.

4.1.3Software support

Software support is the most important one which the other inspection system lacks. In the existing system, the extracted frames are processed by using any of the specific image processing tool and soft computing techniques to identify and classify the faults. But in the proposed method the hardware system itself provided with the software support which simplifies the above mention process. Graphical user interfaces and libraries of high-level software modules operating in standard environments such as Windows have eased the development process and made machine vision as a user-friendly tool. Leading-edge software suppliers are providing object-oriented application development tools that will speed the application development even more.

4.1.4Real-Time Interfacing

The unique feature which the machine vision tool box possesses is the real-time interfacing. There are some features provided, which helps to interface the embedded processor to the real-time environment using some standard interfaces. High-speed serial data ports like the Universal Serial Bus and Fire Wire (IEEE 1394) will speed up the data transfer and information throughput, increasing the overall capability of machine vision systems. USB has already been adopted as an industry standard by PC and peripheral vendors, and will make it simpler to connect digital cameras to powerful embedded PCs. However, reaching real-time video rates will require the higher-speed Fire Wire which is available in the machine vision embedded processors.

4.1.5Portable Embedded PC's

With the advent of the PCI bus, the PC has had a major impact on the use of machine vision in manufacturing applications. Personal computers couldn't gather data at a rate fast enough to keep up with machine vision's heavy I/O requirements, including data transfer rates of 20 MB/second or greater. These requirements have led to the development of portable embedded PC's. These PC's has a high speed processors and large internal memory which makes high speed processing easier The VME (Versa Module Europa) bus, a specialized architecture for data acquisition and process control, with bus speed of 40 MB/second, became a development standard instead. The distributed intelligence made possible by PC technology has contributed immeasurably to the pace and effectiveness of factory automation. These PC's also possess the real-time interface bus support.

5. System Design

The system to analyze the faults in the textile web material should be designed effectively to detect all the faults in the web material. For this the system should be designed in such a way that it should function irrespective of the external environment. The system design can be categorized into two ways as

- Hardware design
- Software design

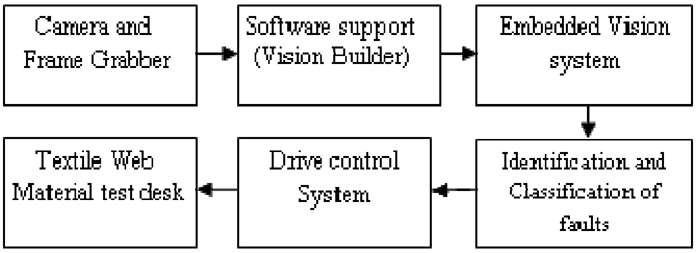

Figure 3 Block Diagram of Proposed System

5.1 Hardware Design

The hardware design plays the major role in the system design. The various components that are included in the hardware design are

- Camera
- Lighting system
- Frame Grabber
- Real time Embedded Vision system

5.1.1Camera

The cameras preferred are area scan cameras. VGA cameras are likely replaced by mega pixels cameras with a frame speed of about 120fps. CCD and CMOS sensors are used here and the interface preferred are Gigabit Ethernet (GigE) and IEEE 1394b (FireWire b interfaces). The cable length of about 4 meters can be extended from the camera and the control can be held in the remote section. The resolution of a camera is limited by the number of pixels in the camera photo sensor and the object Field of View (FOV). The FOV dependents on the characteristics of the background and the nature of defects present.

5.1.2Lighting system

The qualities of acquired images play a vital role in simplifying an inspection problem. The image quality is drastically affected by the type and level of illumination. There are four common types of lighting schemes used for visual inspection i.e. front, back, fiber-optic, and structured. The backlighting eliminates the shadow and glare effects, and is used for fabric inspection. It is also possible to employ fiber optic illumination for the fabric inspection, as it provides uniform illumination of products without any shadow or glare problem. However, fiber-optic illumination is the most expensive to realize and is not economical for 6-8 feet wide textile webs. In the designed system we use monochrome white light for the backlighting and overhead front lighting can be done using UV lightings and high current LED lighting.

5.1.3 Frame grabber

The pixel data coming from each of the camera is converted into a digitized image by the frame grabber. All web inspection systems have to cope with the multiple camera inputs. Some systems receive multi camera input by using some kind of video multiplexer unit between the camera and the frame grabber. A rather expensive way to cope with multiple cameras is to use one frame grabber unit per camera. Camera with inbuilt frame grabber is used in the proposed machine vision based inspection system.

5.1.4 Real time embedded vision system

This real time embedded machine vision system has a high performance multicore processor for fast inspections and high speed functioning [8]. This system has multi camera connectivity with no movable parts. The system also has high I/O count for synchronization and industrial communications. This supports Gigabit Ethernet (GigE) and IEEE 1394b (FireWire b interfaces).

5.2 Software Design

5.2.1 Vision Acquisition System

The Vision Acquisition system present in the developed system consists of the Software components that support the wide range of hardware components such are camera and the frame grabbers. The software components used in the acquisition system are:

- Vision Builder
- Vision Development Module

Vision Builder

The new version of Vision Builder AI(Automatic Inspection) has more machine vision options in it. Inbuilt Vision Assistant Tool helps to develop the algorithm for the fault identification. Then it has many inbuilt options like pattern matching, contour matching and many more image processing tools such as edge detection, filtering operations and many more which helps in easy detection and classification of faults.

Vision development module

The development module has LabVIEW software and the Vision Assistant support. After developing the machine vision algorithm in the Vision Builder tool the Vision Assistant converts the algorithm into LabVIEW codes. This LabVIEW code can be deployed into the Embedded vision system through the support of the LabVIEW software.

6. Results And Discussion

6.1 Image Acquisition

USB cameras are used to obtain the images for simulating the results of various faults. The images acquired are stored and they are retrieved for processing by framing the fault detection algorithm. To perform fault identification and classification, about 70 fabric image samples are analyzed and results are verified. Different algorithms for pattern matching, edge detection and contour matching are framed for various faults and the classification is done using soft computing techniques like Fuzzy logic, ANFIS etc.

6.2 Fault Detection

6.2.1 Hole

The original faulty image captured is converted into gray scale image and then pre-processing is performed [9]. The pre-processed image is shown in Figure 4.

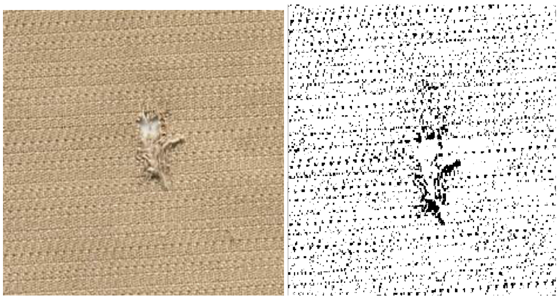

Figure 4 Detection of Hole

Then exact fault location is found using pattern matching by matching with the predefined template described in Figure 5.

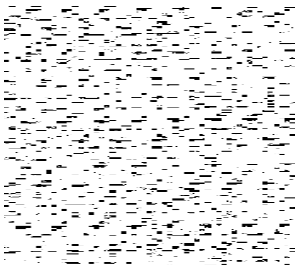

Figure 5 Predefined Patterns

6.2.2 Missing yarn

By applying the threshold operation, missing yarn can be detected. Threshold value is selected based on the nature of the fabric material. The original image and the threshold image are shown in the Figure 6. Lighting is the important factor in detecting the missing yarn in the web material.

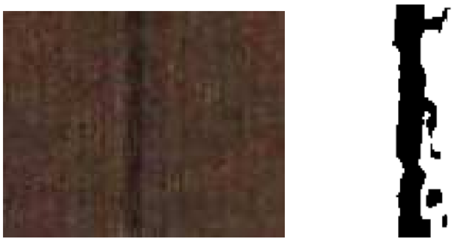

Figure 6 Detection of Missing yarn

6.2.3 Spot

Spot identification means identifying any unwanted change in the fabric caused by the external environments. Machinery lubricants and other addictives used during the knitting process create spots over the fabric surfaces.

The simulated resultant image for the Spot identification is shown in Figure 7.

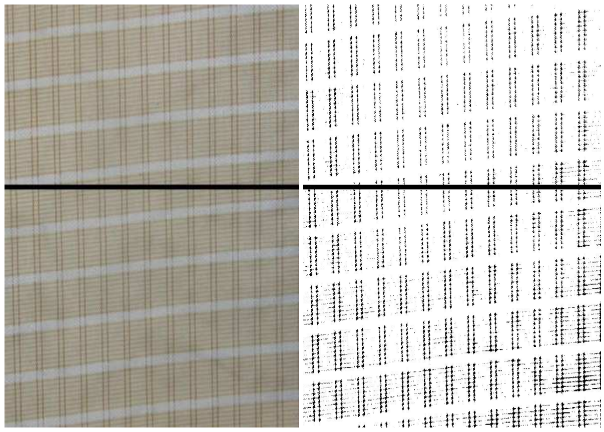

Figure 7 Spot Identified Image

6.2.4 Scratch

Scratches are formed on the fabric because of the machinery parts during manufacture. The scratches are very easy to detect as these scratches are geometrically distinct from the fabric. Figure 8 shows the simulated results for the scratch identification in the woven web materials

Figure 8 Detection of Scratch

6.3Comparison of Results

Table.1 Comparison Table

Inspection method	**No of Fabric image samples**	**No of faulty image**	**Fault identified images**	**Classified images**
Existing automatic inspection	70	55	40	30
Machine vision based inspection	70	55	50	47

6.3.1 Percentage of Fault Identification

When the fabric image samples are analyzed using the existing method and the proposed method, the proposed method gives very good result. Among the 70 samples used, 55 are faulty fabric images and the rest are fabric images without faults. Performance of various inspection methods is shown in the Figure 9. When the inspection is carried out using these images, the existing methods identifies only 72.7% of faulty images and misreads remaining images as faultless. Comparing to the existing inspection methods, the proposed Machine Vision based fabric inspection method produces better result of about 90.9% in identifying the faults present in the fabric. Almost all the faulty fabric images are identified and classification of different faults can be carried out as detailed in next subsection.

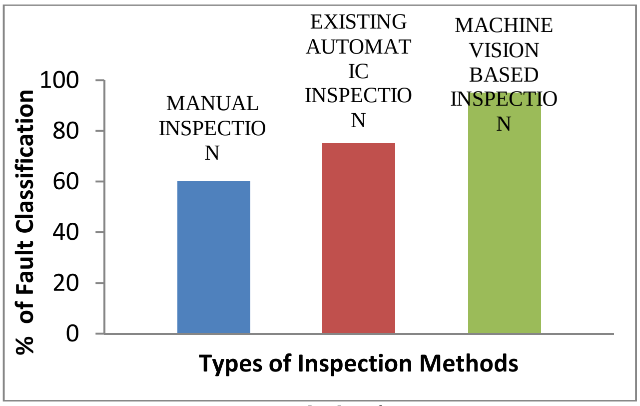

Figure 9 Fault Identification

6.3.2Percentage of Classification

Figure 10 shows the statistics of the inspection methods in classifying the identified faults. In manual inspection classification of identified faults is done by inspectors itself and in existing automatic inspection the classification is carried using microcontroller programming and neural network application. The proposed machine vision based fault identification system classifies almost all the faults and gives better performance when compared with the existing methods by using soft computing techniques like Fuzzy logic and ANFIS.

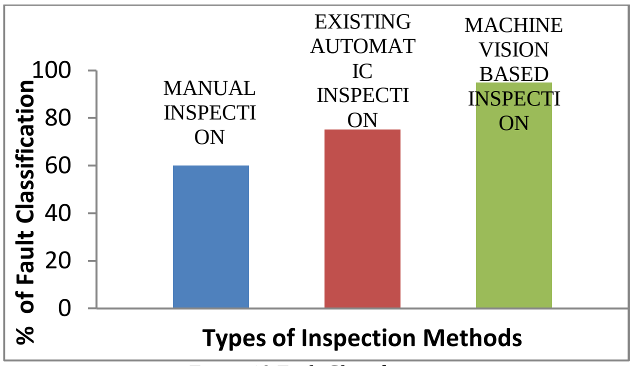

Figure 10 Fault Classification

7. Conclusion

Thus the proposed fabric fault inspection using LabVIEW Machine Vision provides about 18.2% better result in identifying the types of faults and about 20% better result in classifying them when compared to the existing automated fabric inspection method. Here the fabric faulty image is inspected using the machine vision tools like pattern matching, particle detection, shape matching, geometric matching and many present in the LabVIEW Vision Assistant 2010 and the defects are detected to an accuracy of 0.1mm. In future hardware implementation can be done and the real time processing can be carried out to inspect the defect in the textile web material.

References

[1] Atiqul Islam, ShamimAkhter, and Tumnun E. Mursalin,” Automated Textile Defect Recognition System Using Computer Vision and Artificial Neural Networks”, World Academy of Science, Engineering and Technology 13, 2006

[2] Bradshaw.M, “The application of machine vision to the automated inspection of knitted fabrics,”Mechatronics, vol. 5, no. 2/3, pp. 233-243, 1999

[3] B. N. Nickolay and H. Schmalfuβ, “Automatic fabric inspection – utopia or reality?,” MellindTextilberichte, vol. 73,pp. 33 37, 1993

[4] C.-S. Cho, B.-M. Chung and M.-J. Park, “Development of real-time vision-based fabric inspection system”, IEEE Trans. Ind. Electron., vol.52, no. 4, pp. 1073-1079, 2005

[5] J. L. Dorrity and G. Vachtsevanos, “On-line defect detection for weaving systems,” Proc. IEEE AnnualTechnical Conf. Textile, Fiber, and Film Industry, pp. 1-6, May 1996

[6] Kumar A., “Computer-Vision-Based Fabric Defect Detection: ASurvey”, IEEE Trans. of Industrial Electronics, vol. 55,No. 1, pp. 348-363, 2008

[7] Mahajan P.M., Kolhe S.R. And Patil P.M., “A review of automatic fabric defect detection techniques” Advances in Computational Research,Volume 1,Issue 2,pp-18-29, 2009

[8] Newman T. S. and A. K. Jain, “A survey of automated visual inspection,”Comput. Vis. Image Under.,vol. 61, no. 2, pp. 231-262, 1995

[9] Siew. L. H., R. M. Hodgson, and E. J. Wood, “Texture measures for carpet wear assessment,” IEEE Trans. Patt. Anal. Machine Intell., vol. 10, pp.92-105, Jan. 1988

[10] Srinivasan. K., P. H. Dastor, P. Radhakrishnaihan, and S. Jayaraman,“FDAS: A knowledge-based frame detection work for analysis of defects in woven textile structures,” J. Text. Inst., vol. 83, no. 3, pp. 431-447,