

Automatic Fabric Fault Detection Using Morphological Operations on Bit Plane

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Abstract — Quality is the watchword of any type of business. A product without quality leads to loss and lack of customer satisfaction. This is true in case of textile industries also. Textile manufacturing is a process of converting various types of fibers into yarn, which in turn woven into fabric. Weaving process is used to produce the fabric or cloth by interlacing two distinct set of yarn threads namely warp yarn and weft yarn. In textile industries, quality inspection is one of the major problems for fabric manufacturers. Currently in textile industries manual inspection is carried out. The fabric obtained from the production machine are batched into larger rolls and subjected to the inspection frame. The nature of the work is very dull and repetitive. Due to manual inspection of the manufactured fabric, there is a possibility of human errors with high inspection time. The development of an automated web inspection system requires robust and efficient fabric defect detection techniques. For the detection of fabric defects, the pre-processed image is decomposed into its bit planes. The lower order bit planes are found to carry significant information of the location and shape of defects. Then we find the exact location by means of weighted morphology. Robustness with respect to the changes in parameters of the algorithm has been examined. The test results obtained exhibit accurate defect detection with low false alarms, thus showing the effectiveness and robustness of the proposed detection scheme.

Keywords— Defect detection, bitplane decomposition, morphology, dilation, erosion, opening, closing.

I. INTRODUCTION

Indian textile production has a major impact on the world economy through millenniums. At present fabric inspection depends on human sight, the result of inspection influenced by the physical and mental condition of inspector. Now, all the textile industries aim to produce good quality fabrics with high production rate. In the textile sector, there are huge losses due to faulty fabrics. The fabric is obtained by interweaving of warp and weft yarn. The faults found in the fabrics are around 80 - 85% of the defects in the garment industry. These faults are obtained in the fabrics due to irregular weaving of warp and weft yarn in the weaving process. Some of these fabric defects are visible, while others are not. Other than classifying a certain appearance of the fabric, registration of the exact location of the defects and determining their type are also important. Inspection of 100% of fabric is necessary, first to determine its quality and second to detect any disturbance in the weaving process to prevent defects from reoccurring. The advantage for the manufacturer here is to get a warning when a certain amount of defect or imperfection occurs during the production of the fabric so that precautionary measures can be taken before the product hits the market [1]. It has been

observed that, price of textile fabric is reduced by 45% to 65% due to defects [2]. Fabric faults or defects are responsible for nearly 85% of the defects found in the garment industry and manufacturers recover only 45-65% of their profit from seconds or off- quality goods [3]. Based on advancements in computer technology, image processing and pattern recognition, automatic visual inspection systems can provide reliable and stable performance.

The work of a human observer in the textile industry is very tedious and time consuming. They have to detect small details that can be located in a wide area that is moving through their visual field at a high speed. It has been reported that the identification rate is only about 70%. The effectiveness of a human observer decreases quickly with fatigue and boredom. Digital image processing techniques have been increasingly applied to textured sample analysis over the past few years.

The task of textile web inspection is particularly complex, since there exists a large variety of fabrics of different structures, compositions, colors, and other properties. Moreover, a massive irregularity in periodic structures of woven fabric introduces a very high degree of noise, which makes the identification and classification of defects difficult. Human visual inspection systems are still preferred in the textile industry since an alternate solution, reliable and versatile enough is not available yet. Owing to the very slow speed of human inspection compared to the production rate in modern manufacturing industries, automatic inspection systems are becoming more important than ever. Therefore, the research in this field is still wide open.

The various fault detection approaches for textile web material is given in [15]. An automated defect detection and classification system enhances the product quality and results in increased productivity [16] and [17]. Improved gabor filters for textile detection results in less computational complexity as well as possibility of online implementation. Auto- correlation is used as a robust algorithm for patterned and un- patterned fabric defect detections [18]. In the fabric fault detection methodology, particle analyzer gives better results compared to other traditional methods. Particle analyzer constrains the analysis to a defined region using an Region of Interest (RoI) and defines a particle to consist of a minimum number of pixels. All the classifiers require training from the known classes of fabric defects. A large number of classes with large intra-class diversity remain as major problem in using Feed-Forward Neural Network (FFN) and Support Vector Machines (SVM) based inspection techniques [19] and [20]. By using PIC microcontroller,

detection of fault is done by using Neural Network. The overall accuracy of the microcontroller based system is 76.33% [21].

The techniques of morphological image processing are widely used for image analysis and have been a valuable tool in many computer vision applications, especially in the areas of automated inspection [4]. The morphological operations for defect detection in fabric are inherently sensitive to the size and shape of the defect. Therefore, while applying morphological image processing technique on the fabric image for the detection of defects, the software-based morphological operations may give poor result when the defects are relatively small in comparison to the fabric structure. Several techniques have been proposed to overcome this.

II. BACKGROUND

The defects in fabric are generally classified into three subdivisions according to their occurrence in the fabric. They are (i) weft-way defects (ii) warp-way defects and (iii) defects with no directional dependence. There are about twenty-two types of defects usually associated with woven fabric due to various processing irregularities. Out of these twenty-two, only few are severe defects and need elimination by rejection at the production stages. These are pick defects, slub or fly, knot, snarl and snug, reed mark or crack and thin place [5]. Apart from the above-mentioned major defects, mechanical defects such as hole piling, oil marks and other anomalies manifest themselves as defects in woven fabric. Numerous approaches were proposed to address the problem of detecting defects in woven fabrics, which can be broadly categorized into three classes: statistical, spectral and model based. Wang et al. [6] demonstrated that 90% of the defects in a plain fabric could be detected simply by thresholding. Table 1 summarizes a comparison between human visual inspection and automated inspection [7]. Zhang et al. [8] Have introduced two approaches to detect defects: gray-level statistical and morphological methods. Lanes [9] has defined a number of convolution masks to detect the defect. These methods, which depend on intensity change on the fabric image, can only capture significant defects such as knot, web, and slub.

TABLE I
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Inspection Type	Visual inspection versus automated inspection	
	Visual	Automated
Fabric Types	100%	70%
Defect Detection	70%	80%
Reproducibility	50%	90%
Objective Defect Judgment	50%	100%
Statistics Ability	0%	95%+
Inspection Speed	30m/min	120m/min
Response Time	50%	80%
Information Content	50%	90%+
Information Exchange	20%	90%+

In view of the high degree of periodicity for textile fabrics, Fourier transform based approaches were developed for defect detection by some researchers. Wood [10] has used Fourier and associate transform to characterize carpet patterns, while in [11], the method used is Histogram equalization followed by FFT and central spatial frequency spectrum analysis. It has been reported in the recent past that the detection capability is greatly improved by rank-order filtering which is otherwise termed as generalized morphological operations.

When a piece of textile fabric with defects leaves the production line, the locations, the shapes and the sizes of the defects normally cannot be predetermined. A conventional supervised defect detection approach developed on the basis of some particular defect types therefore may not be very suitable in practice and an unsupervised approach is usually preferred. However, the design of an unsupervised approach is rather complicated and the approach usually requires excessive computational efforts because of the large number of filters used. Thus, most of the algorithms for defect detection in woven fabric are computationally intensive and are less accurate, particularly in the presence of a number of patterns and print. The proposed algorithm is simple and more efficient for computer implementation. There is no mathematical complexity as in the other methods and hence there is a big saving in computational time also.

III. PRE-PROCESSING

The main purpose of the pre-processing step is to correct the non-uniform illumination and image de-noising. The goal of illumination correction is to remove uneven illumination of the image caused by sensor defaults (vignetting), non uniform illumination of the scene, or orientation of the surface. Textile image pre-processing consists of correction of non-uniform luminosity and contrast enhancement. In this work we use a method of luminosity correction that is based on segmentation of background pixels and subsequent computation of luminosity function based only on the background image. The advantage of this approach is that it does not produce any ringing effect. All paragraphs must be indented. All paragraphs must be justified, i.e. both left-justified and right-justified.

IV. BITPLANE DECOMPOSITION

Slicing a digital image into its component bit planes is useful for analysing the relative importance played by each bit of the image. Instead of highlighting gray level images, highlighting the contribution made to total image appearance by specific bits is examined here [12]. In an n bit gray level image, each pixel in an image is represented by n bits. The image is composed of n, 1-bit planes ranging from bit plane 0 (LSB) to bit plane n-1 (MSB). In terms of n-bits, plane 0 contains all lowest order bits in the bytes comprising the pixels in the image and plane n-1 contains all higher order bits. Thus bitplane decomposition of an n

bit image yields n binary images. The grey level of each pixel in a digital image is stored as one or more bytes in the computer. When the grey level is represented as a single byte, it is called an 8 bit image, representing grey level values in the range from 0 to 255. The bit-plane decomposition of an 8 bit image is shown in Fig. 1.

In the pre-processed images of the textile fabric, bit-plane 0 and bit-plane 1 are found to carry vital information corresponding to the position and shape of the defects. Bitplane 0 of the chosen image is shown in Fig. 5. As bit-plane images are binary images, they are highly suited for morphological image processing.

In general, it can be seen that the higher order bit planes contain a majority of visually significant data while the lower order ones contribute to more subtle details in an image. But, on examining the eight bit planes of the pre-processed images, the lower order ones are found to be valuable for the detection of defects.

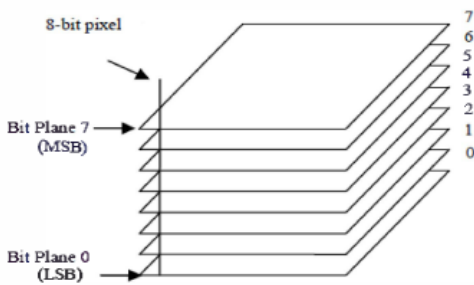


Fig.1 Bit plane Decomposition

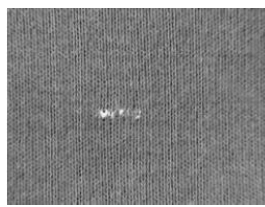


Fig.2 Original Image

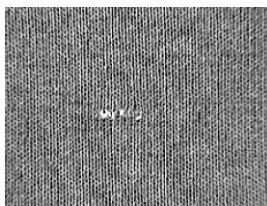


Fig.3 Contrast Enhanced Image

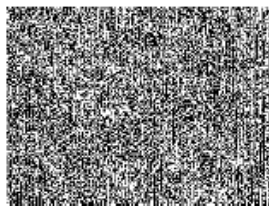


Fig.4 Histogram Equalized Image

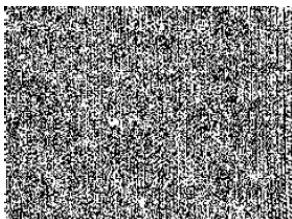


Fig.5(a) Bitplane 0

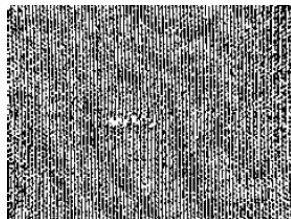


Fig.5(b) Bitplane 1

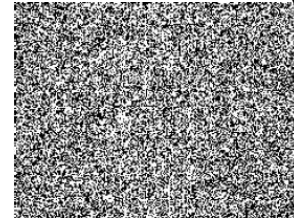


Fig.5(c) Bitplane 2

V. MORPHOLOGICAL OPERATIONS OVER BITPLANE

The language of Mathematical Morphology (MM) is set theory. Sets in MM represent objects in an image. MM is the science of appearance, shape and organization. MM deals with non-linear processes which can be applied to an image to remove details smaller than a certain reference shape called the structuring element [13]. MM is also the foundation of morphological image processing, which consists of a set of operators that transform images according to the above characterizations. The most widely used morphological operations used in image processing are dilation, erosion, opening and closing. Binary images are best suited for performing morphological operations. The images obtained after bit plane decomposition are binary images, which are thus suitable for performing morphological operations. MM was originally developed for binary images, and was later extended to grayscale functions and images. In MM, top-hat transform is an operation that extracts small elements and details from given images. There exist two types of top-hat transforms. The white top-hat transform, which is the difference between the input image and its opening by some structuring element, and the black top-hat transform which is defined as the difference between the closing and the input image. Top-hat transforms are used for various image processing tasks, such as feature extraction, background equalization, image enhancement and others [14]. Dilation is an operation in which the binary image is expanded from its original shape. The amount of expansion is controlled by the structuring element (SE). Dilation is similar to convolution, in which the structuring element is reflected and shifted from left to right and then from top to bottom. In this process, any overlapping pixels under the centre position of the structuring element are assigned with 1 or black values

If X is the reference image and B is the structuring element, the dilation of X by B is represented as

$$X \oplus B = \{Z \mid [(\hat{B})_z \cap X] \subseteq X\}$$

Where \hat{B} is the image B rotated about the origin. When an image X is dilated by a structuring element B, the outcome element Z would be that there will be at least one element in B that intersects with an element in X Erosion process is a thinning operation that shrinks an image. The extent by which, shrinking takes place is determined by the structuring element. Here, if there is a complete overlapping with the structuring element, the pixel is set white or 0. The erosion of X by B is given as

$$X \ominus B = \{Z \mid [(B)_z] \subseteq X\}$$

In erosion, the outcome element Z is considered only when the structuring element is a subset or equal to the binary image X . Note that dilation and erosion on binary images can be viewed as a function of convolution over a Boolean algebra of operations (NOT, AND, OR, XOR), which are defined between pixels of corresponding locations in two images of equal dimensions.

Opening operation is done by first performing erosion, followed by dilation. Opening smoothens the inside of object contours, breaks narrow strips and eliminates thin portions of the image. It is mathematically represented as

$$X \circ B = (X \ominus B) \oplus B$$

Closing operation does the opposite of opening. It is dilation followed by erosion. Closing fills small gaps and holes in a single pixel object. The closing process is represented by

$$X \cdot B = (X \oplus B) \ominus B$$

Closing operation protects coarse structures, closes small gaps and rounds off concave corners. It is well-known that the opening operation will smooth contours, breaks narrow isthmuses, and eliminates small islands and sharp peaks, while the closing operation will smooth contours, fuses narrow breaks and long thin gulfs, and eliminates small holes.

Morphological operations are widely used in the detection of boundaries in a binary image. For an image X , the following can be applied to obtain a boundary image

$$Y = X - (X \ominus B)$$

$$Y = (X \oplus B) - X$$

Or

$$Y = (X \oplus B) - (X \ominus B)$$

Where, the operator ' \oplus ' denotes dilation, ' \ominus ' denotes erosion and '-' indicates set theoretical subtraction.

The results are that if structuring elements are defined properly, texture background can be removed easily by the opening and closing operations. Also, the defect images left behind will be sharpened by the operations. Hence, alternating sequential filters can be constructed by combining a number of openings and closings.

Most binary morphological operations have natural extensions to gray scale processing. Some, like morphological reconstruction, have applications that are unique to gray scale images, such as peak filtering.

VI. PROPOSED METHODOLOGY

The image after pre-processing becomes an illumination corrected and de-noised one. Now contrast of the pre-processed image is further enhanced by a combination of top-hat and bottom-hat transforms. In order to achieve this, the original image obtained after pre-processing is added to the top-hat filtered image, and then the bottom hat filtered image is subtracted from it. Then a histogram equalization operation is performed on this image. Figure 3 shows the contrast enhanced image after applying a combination of top-hat and bottom hat transforms while Fig. 4 shows its corresponding histogram equalized image. Later on, bit plane slicing is performed on this to decompose it into its component bit planes. The lower order bit planes are

preserved for further processing and the higher order ones are discarded. Figure 5 shows bit planes 0, 1 and 2 of the original image. As bit plane 1 represents the image more clearly than bit plane 0 and 2. So, we take bit plane 1 image for further processing. Now a series of morphological operations are applied on this image. Bit plane 1 is now complemented and opened by a disc shaped structuring element to obtain a white region corresponding to the defect in the woven material such as shown in Figure 6.

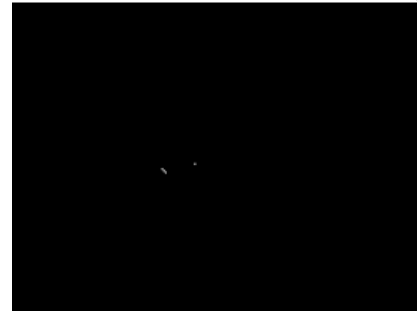


Fig.6 Opened Bitplane 1

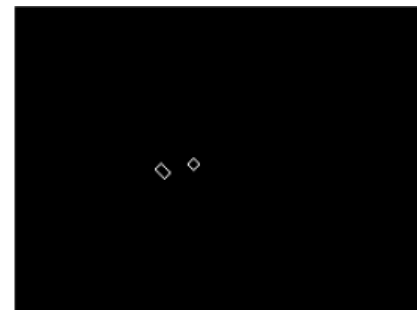


Fig.7 Dilated Outline

The Matlab function `bwperim` is used to obtain the outline of the defect. This outline is subsequently dilated by a carefully selected structuring element to obtain an image as shown in Figure 7. Finally, the fabric defect can be localized by superimposing the outline on the original grayscale image as shown in Figure 8.

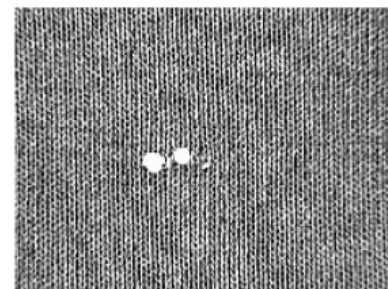


Fig.8 Defect Marked Image

The algorithm has been implemented by using Matlab version 7.9 (Release 2009 b) and is found to be reasonably fast and accurate than the existing computationally intensive methods. The results are promising even when it is applied to localize defects on images with varying lighting or exposure levels. The algorithm has been tested and compared with the commonly used methods and the

results show that the method proposed here can not only detect defects but also provide more acceptable location of the defect.

VII. RESULT ANALYSIS

Industrial manufacturing of materials such as fabric, paper, wood, leather, etc. requires a large number of inspection tasks concerning the visual appearance of the material surface (texture, color, fault detection, etc.). The task of textile web inspection is particularly complex, since there is a large variety of fabrics of different structures, compositions, colours, and other properties. Quality control in the textile industry involves, among other tasks, the detection of defects that cause a distortion of the basic structure of the material, which generally shows a high degree of periodicity. Numerous techniques of image analysis have been proposed for this purpose. If the fabric sample exhibits an overall distortion, Fourier-domain-based techniques allow one to obtain successful results to detect shrinking, abrasion and skewness. If the sample has local defects such as holes, stains, broken threads, etc., then it is a common practice to apply methods based on wavelet transforms, used as multi resolution spectral filters that localize and analyse features in both the spatial and the frequency domain. Some other tasks concerning pattern recognition, weave-repeat identification and classification can also be performed using techniques based on Fourier analysis.

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

We, human beings, have a unique capability to easily find imperfections in spatial structures. Our visual mechanism works well even when we do not know what the ideal pattern is and what the possible types of defects are. Just by looking at a relatively regular structure containing an imperfection, we can usually identify what is wrong there. But human inspector based defect detection is subject to errors for many reasons.

There are large influences of human errors and subjectivity on the results of inspection. Presence of other factors such as noise, non-uniform illumination and variety of defect types in textiles make the defect detection a challenging problem. Due to these reasons, an expert system for the automatic detection of such anomalies has inspired much research in this direction. The performance of the proposed defect detection scheme has been extensively evaluated by using an off-line test database, which consists of a variety of fabric defects including (1) different types, sizes, and shapes of defects, and (2) different texture backgrounds. The test results obtained have shown that this scheme is a simple and effective defect detection method. This algorithm is more efficient for automation. There is no mathematical complexity as in other methods and hence there is a significant reduction in computational load also. Moreover, this method does not just detect the defect but the shape and size of the defect also. It extracts most defect pixels accurately.

The algorithm is found to be superior to the existing ones in terms of computational speed and accuracy. Several images with different types of defects were also tested using the algorithm. The false alarm rate is found to be 2.2% for the test data set. Our algorithm has an average accuracy of 93.2%. The main attraction of the proposed method is its simplicity, accuracy and computational time. This algorithm demonstrates its strong ability to differentiate defects from other regions in the image even in the presence of certain prints in the fabric. The method works pretty well even when the input image is a low-contrast one. The experimental results demonstrate that the proposed algorithm is fast and robust.

Table 2

Correlation	No. of Samples
True detection	92.67%
False alarm	05.90%
Missed Detection	02.33%

The performance of the scheme is evaluated by visually assessing the quality of the binary output images. True detections (TD) 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 (FA) 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 TD and FA. Missed detection (MD) means that no white area appears in the binary output image even if the fabric image contains a defect. Table 2 summarizes the test result.

Further research can be conducted to apply the proposed scheme to detect defects in other products, such as non-woven fabrics, wood or metal castings. In addition, the possibility of developing faster methods of morphological filtering for implementation in the proposed scheme may also be investigated.

VIII. CONCLUSION

However, the design of an unsupervised approach is rather complicated and the approach usually requires excessive computational efforts because of the large number of filters used. In this paper, a novel supervised defect detection scheme for automated inspection of textile fabrics has been proposed. A method for defect detection and localization in woven fabric is proposed in this paper based on bitplane decomposition and weighted morphology. The algorithm is superior to the existing ones in terms of computational time and accuracy.

REFERENCES

- [1] S. Priya .T. Ashok kumar and Varghese Paul, "A novel approach to fabric defect detection using digital image processing," Proc. of IEEE Int. Con! on ICSCCN,pp228-232, July 20 1 1.
- [2] K. Srinivasan, P. H. Dastoor, P. Radhakrishnaiah, and S. Jayaraman, "FDAS: A knowledge-based framework for analysis of defects in woven textile structures", J. Textile inst., pt. I, vol. 83, no. 3, pp. 43 1-448, 1992
- [3] P.M. Mahajan, S.R. Kohle and P. M patil "A review of automatic fabric defect detection techniques", J. of Advances in Computational Research ,voLI, No.2, pp I 8-29, 2009.
- [4] R.Haralick, S. Sternberg, and X. Zhuang, "Image analysis using mathematical morphology", IEEE Trans Pattern Analysis and Machine intelligence. Vol 9, no 4,532,1987.
- [5] A.K. Datta and J.K. chandra, "Detection of defects in fabric by morphological image processing", In Tech Publishers, pp2 17-232, Nov 20 10.
- [6] J. Wang, R.A. Campbell, and R.J. Harwood, "Automated inspection of carpets", in Proc. SPIE, vol. 2345, pp. 180- 19 1, 1995.
- [7] T. E Mursalin, F. Z Eishita and A.R Islam, "Fabric defect inspection using Neural network and M.icrocontroller," Journal of Theoretical and Applied Information Technology,pp 560-570, 2008.
- [8] X.F. Zhang and R. R. Bresee, "Fabric defect detection and classification using image analysis," Textile Res. J., vol. 65, no. I, pp. 1-9, 1995.
- [9] J. S. Lane and S. C. Moure, "Textile fabric inspection system," U.S. Patent 5 774 I 77, 1998.
- [10] E. J.Wood, "Applying Fourier and associated transforms to pattern charecterization in textiles," Textile Res. J., vol. 60, pp. 2 12-220, 1990.
- [11] C. Chan and G. K. H. Pang "Fabric defect detection by Fourier analysis", IEEE Trans. on ind. Appl, vol 36, no.5,pp1267- 1276 Oct 2000
- [12] S. Jayaraman., S. Esakkirajan and T. Veerakumar Digital Image ProceSSing, Tata Mc Graw Hill, New Delhi, ch 10,2009.
- [13] http://en.wikipedia.org/wiki/Mathematical_morphology.
- [14] J . Serra, Image analysis and mathematical morphology, vol. 2, Academic Press, New York, 1988.
- [15] Henry Y, T. Ngan, Grantham K.H.Pang, and Nelson H.C.Yung (2011), "Automated Fabric Defect Detection-A Review", Image and Vision Computing, Vol. 29, pp. 442-458.
- [16] Che-Seung Cho, Byeong-Mook Chung and Moo-Jin Park (2005), "Development of Real-Time Vision-Based Fabric Inspection System", IEEE Transactions on Industrial Electronics, vol. 52, no. 4, pp. 1073-1079.
- [17] Sabeenian R.S., Paramasivam M.E. and Dinesh P.M., (2012), "Computer Vision based Defect Detection and Identification in Handloom Silk Fabrics", International Journal of Computer Applications, vol. 42, no. 17, pp. 41-47.
- [18] Elham Hoseini, Farnoush Farhadi and Farshad Tajeripour, (2010), "Fabric Defect Detection Using Auto-Correlation Function", The 3rd International Conference on Machine Vision (IEEE Trans.), pp. 557-561.
- [19] A. Kumar (2003), "Neural network based detection of local textile defects", Pattern Recognition, Vol. 36, pp. 1645-1659.
- [20] A. Kumar and H. C. Shen (2002), "Texture inspection for defects using neural networks and support vector machines", Proc. Intl. Conference on Image Processing, ICIP-2002, pp. 353-356, Rochester, New York.

- [21] Tamnun E Mursalin, Fajrana Zebin Eishita, Ahmed Ridwanul Islam and Dr. Md Jahangir Alam (2008), "Real Time Automated Fabric Defect Detection System using Microcontroller", Journal of Convergence Information Technology, Vol. 3, No. 1.