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Spectral and Spatial Domain Approach for Fabric Defect Detection and Classification

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Abstract*—Fabric inspection has an important role of preventing delivery of inferior quality product. The fabric defect inspection process is traditionally carried out with human visual inspection that proves to be insufficient and costly. Hence in order to reduce the cost and wastage of time, Computer vision based fabric defect detection is required. Robust and efficient fabric defect detection algorithms are required for inspection. This paper presents spectral domain and spatial domain approach for fabric defect detection. Spectral domain approach includes Fast Fourier Transform (FFT), Discrete Cosine Transform (DCT), wavelet and Gabor filter. Spatial domain approach includes two methods morphological operations and statistical operations.

Keywords*— Fabric defects, statistical analysis, morpholog-ical operations, FFT, DFT, Wavelet, Gabor filtering, defect detection and classification

I. INTRODUCTION

In fabric industry, traditionally defect detection is done by human inspection. This system of defect detection is less reliable and has varying accuracy depending on the inspectors´ skills. Quality measures are not strictly followed, resulting in the decrease in cost of the fabric by 45-65 % [1]. As there is a human intervention probability of error increases. So there is a need for standardization of detection process. Currently PLC based automation is used in the industry which provides an alarm in case of any defect, but they are costly and the loom operator has to manually identify the type and region of the defect. Moreover it is proved to be reactive mechanism to identify the defect and stop the production to reduce further loss in production. Indeed fabric inspection system based on image processing can observe and rectify different defects occurring at various stages of fabric manufacturing. As the system proposes continuous monitoring, analysis during fabric production becomes a difficult task. The defects that are generally observed are: Hole, Missing Weft, Missing Warp, Torn out, Double Warp, Double Weft, Smash and Knot. Fabric inspection system proposed in this paper suggests a better alternative over the existing fabric inspection system. In the proposed system there are 2 stages, in the 1st stage of defect detection presence of the defect is detected using transform domain techniques. The performance is tested using various block processing algorithms of DFT, DCT, Wavelet and Gabor filter. In the 2nd stage of classification type of defect are classified using spatial domain techniques like statistical and morphological processes. Precise results are observed in terms of locating the defect on fabric images. In this paper two different domain approaches are proposed- Spatial and spectral. In spatial domain approach the intensity values are directly operated upon. In this domain the intensity changes in the image can be identified and the defect which exhibit variations in the intensity can be detected. In the spectral domain, transform of the captured image is obtained and then analyzed to find defects, if any.

An outline of this paper is as follows: In Section II, basic design flow of system is discussed. In section III image acquisition and the required setup for the system is discussed. Section IV discusses spectral domain approach for presence of defect detection. In section V spatial approach for defect classification and localization is discussed. Section VI gives performance analysis of different methods used. Section VII concludes the paper.

II. DESIGN FLOW

Fig. 1 shows the block diagram of fabric defect detection and classification process. The image is acquired using 8 Megapixel digital camera. This captured image is passed to the pre-processing block which performs certain pre-processing operations on the image as per the required method. Then this pre-processed image is passed to the defect detection block where the presence or absence of defect is detected. If the image contains a defect then it is passed to the defect classification block where the defect is classified, also the region of the defect is highlighted.

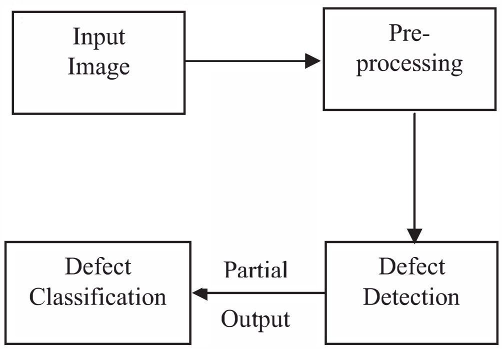

Fig. 1. Block Diagram

III. Image Acquisition and Setup

Fig. 2 shows the prototype of image acquisition set-up used. The lighting scheme used is backlighting. Fabric is rolled on the glass top. Images are captured using Cannon 8 Mega Pixel digital camera with 10X zoom at a fixed height of 60cm from base. The glass top has a thickness of 10mm and is placed at a distance of 30cm from base. Philips CFL (18 W) is used for back lighting to enhance the defect for inspection.

IV. Spectral Domain Approach

A. Feasibility

As Fabric has uniform texture, regularity is observed in it. When there is a defect this regularity is lost, which reflects in the frequency domain. When there is a defect, high frequency components are observed in the Image. Hence it becomes easy to find defects in frequency domain. While capturing fabric images lighting conditions have to be very specific to detect the defect. In spectral domain it is not possible to classify the defects. As this is the spectral approach, spatial co-ordinates are lost, the location of defects cannot be found out.

B. Algorithm

In spectral domain, 4 methods are used to find the defects. Fast Fourier Transform (FFT) [2] [3], Discrete Cosine Transform (DCT), Wavelet and Gabor Filtering [4] are the methods used. As the defects in the image correspond to the high frequency components and non-defective elements are low frequency components, high pass filtering is done in the frequency domain to determine the elements with defects. This approach is followed for Fast Fourier Transform and Discrete Cosine Transform. When there is defect in the fabric, the spectral energy of the image changes which can be a parameter used in wavelet method. Frequency and spatial coordinates are available in wavelet.

1) Fast Fourier Transform :

Find Fast Fourier Transform of the input image. Pass the transformed image through high pass filter. Take Inverse Fast Fourier Transform of the filtered image. Partition the image into non overlapping blocks. Compare the statistical properties of the blocks to find whether the image has defect or not. If there is a defect in the block the statistical property of the block varies to a large extent. Fig. 3 shows spectrum of defect free fabric and Fig. 4. Shows spectrum of defective fabric.

2) Discrete Cosine Transform :

Find Discrete Cosine Transform of the input image. Pass the transformed image through high pass filter. Take Inverse Fast Fourier Transform the filtered image. Partition the image into non overlapping windows/blocks. Compare the statistical properties of the blocks to find whether the image has defect or not. If there is a defect in the block the statistical property of the block varies to a large extent.

3) Wavelet Transform :

Pre-process the input image. Decompose the image obtained by wavelet transform. Extract horizontal and vertical transformed images. Partition the transformed image into non-overlapping windows. Calculate standard deviation inside each window. Add the number of windows whose energy exceeds the threshold. By a decision rule, find whether the image has defect or not.

4) Gabor Filter :

Pre-process the input image. Calculate the Gabor Kernel. Filter the image using Gabor Kernel. Partition the filtered image into non-overlapping windows. Calculate standard deviation inside each window. Add the number of windows whose energy exceeds the threshold. By a decision rule, find whether the image has defect or not.

C. Implementaion Issues

Partitioning the image into non-overlapping windows is an important task. Size of window has to be appropriate to find the defects. It should not be too small or too big. For wavelet transform method and Gabor filtering method there is a need to set a threshold for the number of windows whose energy exceeds the threshold energy. Setting threshold for energy and number of windows is important and hence needs to be set carefully to find the images with defect. The location and type of defect cannot be found using this method.

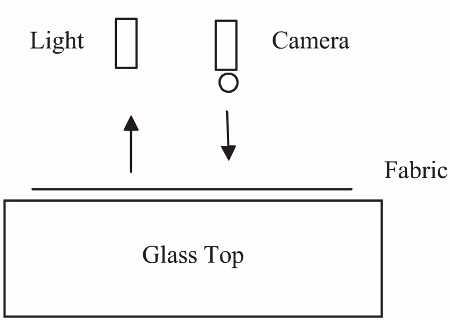

Fig. 2. Prototype of Image Acquisition Setup

D. Results

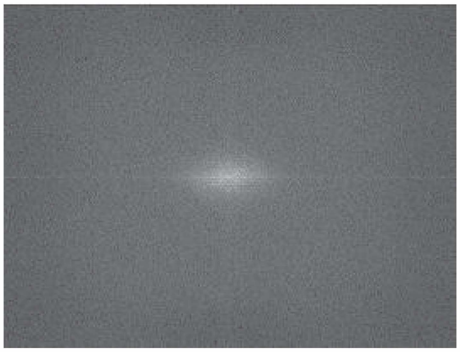

Fig. 3. Spectrum of defect free fabric image

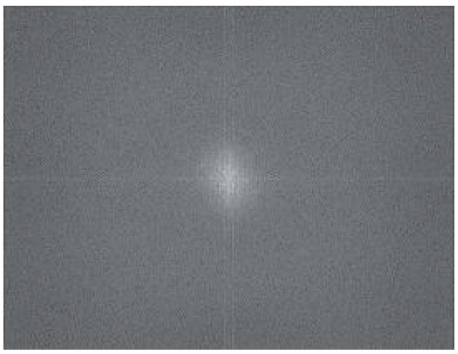

Fig. 4. Spectrum of defective fabric image

V. SPATIAL DOMAIN APPROACH

A. Morphological Operations

In morphological approach, image erosion is performed on the binary image and the image is classified further depending upon the presence of defects.

1) Feasibility

Defect occurs in fabric only when the alignment of the vertical and horizontal threads is disturbed. The distance between the two threads is non uniform in the presence of defect. Thus average distance between the horizontal and vertical distance is measured. This is taken as the optimum size of structuring element for image erosion. Thus presence of any defect is easily captured. The lighting conditions play an important role while capturing the image in this approach. The classification of the defects can be done through this approach. As this is spatial domain method, location of the defect can also be identified.

2) Algorithm

Optimum size of the structuring element is calculated and passed over the image to perform image erosion. The eroded binary image marks the defective region with the white pixels, rest all with the black pixels [5]. Further classification of the defect is done using Horizontal Profile Density (HPD) and Vertical Profile Density (VPD). HPD and VPD of the eroded image are negligible in case of defect free image. First Perform Histogram equalization of the input image. Convert gray image to binary form using threshold obtained by Otsu's method [6]. Fig. 5 shows a gray-scale image. Calculate Horizontal Profile Density (HPD) and Vertical Profile Density (VPD) of the binary image. Calculate the average distance between the two vertical and horizontal threads using HPD and VPD respectively. Create a matrix having all ones and size as the average distance between the threads as the structuring element. Perform erosion of the binary image with the structuring element. Fig. 6 image obtained after erosion. Compare HPD and VPD of the eroded image to classify the defect as vertical and horizontal. In case of no defect HPD and VPD are negligible. Fig. 7 shows the output image highlighting location as well as the presence of defect.

3) Implementation Issues

Backlighting scheme is necessary to calculate the distance between the two threads for morphological approach. Thus the images captured with the backlighting scheme can only be used. Defects which pass light through them can only be detected. Thus in case of defects such as double warp, double weft, and knot, negative of the image must be processed. This method does not work for fabric having hole as a defect.

4) Results

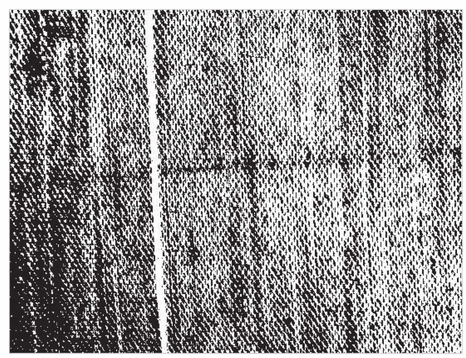

Fig. 5. Gray-scale image of defective fabric

Fig. 6. Image after erosion

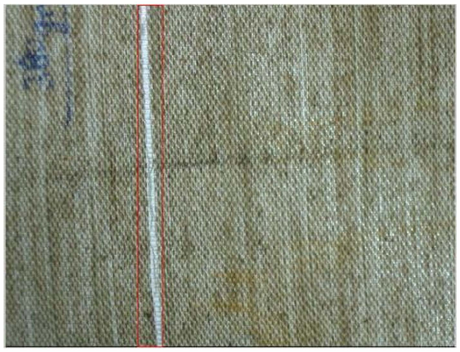

Fig. 7. Output image using Morphological approach

B. Statistical Operations

The structure of fabric is regular and uniform. A defect is accompanied by irregularity in the fabric. This irregularity can be easily identified by statistical method since there is a change in the intensity values in the region of the defect. In statistical approach the statistical parameter like mean, standard deviation and variance of the image is calculated. In case of defect in any region of the image there is some irregularity in the region and this irregularity can be easily identified by the statistical parameter of the image and the region of the defect can be identified. Further the image is filtered to identify the defective region and the type of the defect can be identified using VPD and HPD of the image. Thus the type of defect and the region of defect can be identified.

1) Feasibility

For this approach to work it is necessary to capture the image under very proper lighting condition because the statistical parameter change due to slight change in the intensity values which may lead to false alarms or false identification of the defects.

2) Algorithm

Convert the input image into gray-scale image. Fig. 8 shows the gray-scale image. Calculate the mean of the image. Divide the image into four parts and calculate the mean of each part. From the mean values compare and identify the region of the defect. Calculate the standard deviation of the part which contains the defect and the image is converted into only two levels. Check if the defect type in the region is a hole by taking a square mask and filtering the image. If no hole is identified then using mean, the image is converted into two levels. Perform filtering of the image by a horizontal and vertical mask to check if the defect is weft or warp respectively. Fig. 9 shows the filtered image. By calculating the HPD and VPD of the image the region of the defect is identified. Fig. 10 shows the output image highlighting location as well as the presence of defect.

3) Implementation Issues

The image should be without any blur or any other type of noise otherwise the defect will not be identified and classified correctly. Also backlighting scheme must be used. Appropriate distance should be maintained between the fabric and the camera.

4) Results

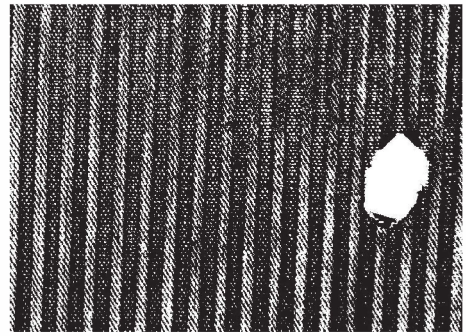

Fig. 8. Gray-scale image of defective fabric

Fig. 9. Filtered image

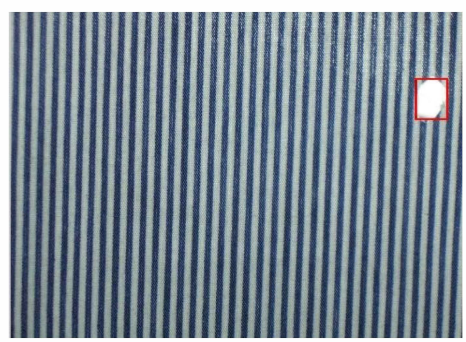

Fig. 10. Output Image using Statistical Approach

VI. PERFORMANCE ANALYSIS

The database contains 4 types of fabric defects namely missing warp, missing weft, hole and torn out. Performance of all the methods mentioned in earlier sections have been tested for these defects. TABLE I gives the percentage accuracy of various methods.

TABLE I: Comparison Table

Method	**Type of Defect**				
	Missing Warp (%)	***Missing Weft (%)***	***Hole (%)***	***Torn out (%)***	***Average (%)***
Statistical Approach	66.66	66.66	62.5	62.5	64.55
Morphological Approach	39.39	51.28	-	66.66	52.44
FFT	96.96	92.30	62.50	100.0	87.94
DCT	90.90	87.17	62.50	100.0	85.14
Gabor Filter	79.41	71.79	75.00	100.0	81.55
Wavelet	54.54	64.10	87.50	100.0	76.53

VII. CONCLUSION

Spectral domain approach and spatial domain approach has been discussed to detect the defect in fabric. From Table I it has been observed that for detecting the presence of defect, FFT and DCT are the most suitable methods. Spectral domain methods only detect presence or absence of defects whereas spatial domain methods also give the type and location of the defect. It has been observed that statistical approach is better than morphological approach for classification of missing warp, missing weft and hole. Whereas for detection and classification of Torn out defect, morphological approach performs better. Experiments have shown that to get maximum accuracy of detection and location of the defect, combination of spatial domain method and spectral domain method gives better result than using just one type of method.

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