CHAPTER VI

A STATISTICAL APPROACH FOR IDENTIFYING DEFECTS IN FABRICS AND CERAMIC TILES USING DISCRETE WAVELET TRANSFORM *

6.1 Introduction

Visual inspection constitutes an important part of quality control in industry. Quality control is designed to ensure that defective products are not allowed to reach the customer to a maximum possible extent. For this reason, quality control activities form an essential information feedback loop for the whole business, with potential influence on the design, process planning and logistics functions as well as on manufacturing. Until recent years, this job has been heavily relied upon human inspectors. The work of inspectors is very tedious and time consuming. They have to detect small details that can be located in

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* Content of this chapter with the title Detection of defects in knitted fabrics using discrete wavelet transform has been published in Proceedings of National Conference on VLSI & Communication, Kerala, March 2008, 361 - 366.
a wide area that is moving through their visual field. In addition, the effectiveness of visual inspection decreases quickly with fatigue. Image analysis techniques are being increasingly used to automate the detection of defects in complicated material surfaces. In the recent past, wavelet transforms have been a popular alternative for the extraction of textural features.

6.2 Related Literature Review

Amet et al. [3] presented a defect detection algorithm based on the wavelet decomposition of images. Tsai and Hu [106] used Fourier transforms of solid plane fabric images as the inputs to identify four types of defects, missing pick, missing end, oil fabric stains and broken fabric. Hu and Tsai [36] have also used wavelet packet bases and an artificial neural network for the stated goals. Wavelets had been previously applied to fabric analysis by Jasper et al. [40, 41], Escofet et al. [24] have applied Gabor filters to the automatic segmentation of defects on non-solid fabric images for a wide variety of interlacing patterns. Shakher et al. [91] have developed an image processing system and a wavelet transform based processing technique to find the repeat texture of fabric without any priori information. Lambert and Bock [55] have introduced to exploit multi-scale wavelet methods for texture defect detection.

The ceramic tiles industrial sector has taken significant advantage of the advances in the world of automation in recent years. All production phases have been addressed through various technical innovations, with the exception of the final stage of the manufacturing process, namely the product inspection. This is still performed manually.
and is concerned with the sorting of tiles into distinct categories or the rejection of the tiles found with defects and pattern faults.

The objective of the inspection is to classify the tiles on the basis of two parameters, namely, defects and color grading. Some of the most common and anti-aesthetic defects found on both plain and textured tiles can be categorized as cracks, bumps, depressions, pin-holes, dirt, drops, ondulations, and color. It can be seen that some faults are of extremely small and similar dimensions. This similarity allows defects such as very small cracks, depressions, pin-holes, dirt, and small drops to be categorized together and detected as small spots. Ai Jiaoyan et al. [2] proposed a method to tackle the problem of color grading of ceramic tiles using wavelet texture analysis combined with color information. Boukouvalas et al. [10] proposed an approach for the problem of automatic inspection of ceramic tiles using computer vision. Chun-Chieh Tseng et al. [11] gave a novel image inspection algorithm to detect defects of multilayer ceramic capacitor (MLCC). Costas Boukouvalas et al. [13] described an integrated system for the detection of defects on color ceramic tiles and for the color grading of defect-free tiles. Cristina E. costa and Maria Petrou [14] presented an algorithm for the automatic surface inspection of ceramic tiles for detection of faults in the deterministic patterns printed on them. The algorithm is based on the phase correlation method used to register the reference and test images. Elbehiery et al. [23] described a visual inspection procedure tested on a number of tiles using synthetic and real defects. They introduced a hierarchical wavelet-based framework for modeling patterns in digital images. Murat et al. [63] focuses on a feature extraction algorithm for classification of marble...
tiles. Rimac-Drlje et al. [82] presented a self-learning system for automatic detection of surface failures on ceramic tiles. This system is based on the probabilistic neural network with radial basis.

In this chapter, a statistical approach -- the coefficient of variation -- to detect the defective portions of the fabrics and ceramic tile images with the help of discrete wavelet transform technique is proposed.

6.3 Methodology

6.3.1 Step by step procedure to identify the defects in fabric / ceramic tile image

In this section, a method to identify the defect in fabric image / ceramic tile image is discussed, and the step by step procedure is given.

step 1: The defective fabric image/ ceramic tile image is taken for analysis. The image size is considered in powers of two \(2^j\) (\(j=1,2,\ldots\))

step 2: This image is divided into equal number of rows and columns (blocks)

step 3: Every block contains \(2^j\) (\(j=1,2,\ldots\)) coefficients and is decomposed by Discrete Wavelet Transform (DWT) technique. This decomposition is called first level of decomposition.

step 4: Taking only \(2^{j-1}\) (\(j=1,2,\ldots\)) approximation coefficients and apply DWT technique once again.

step 5: The procedure from step 3 to step 4 is repeated until a single approximation wavelet coefficient is obtained.
step 6: All the single approximation wavelet coefficients corresponding to each block for the image are tabulated.

step 7: The coefficient of variation for every row \( (R_j) \) and column \( (C_j) \) corresponding to single approximation wavelet coefficient is obtained.

step 8: The average of all coefficient of variation values in all \( R_j \)'s and \( C_j \)'s are calculated respectively.

step 9: The coefficient of variation values in which above the average values are marked.

step 10: The intersection of marked high values corresponding to rows and columns indicate the defective blocks in the image.

Two fabric images with different defects of same size has been taken for analysis. The size of the image is 330 x 330 matrix. This is divided into eleven equal rows and columns of 30 x 30 matrix size. Each block size is now considered as \( 2^5 \) \( (j=5) \). By using DWT technique, the image is decomposed. For next level decomposition, only \( 2^4 \) \( (j=4) \) approximation coefficients are considered. Using DWT technique, the image is further decomposed. From this stage, only \( 2^3 \) \( (j=3) \) approximation coefficients are considered for next level decomposition. Continuing this way, finally a single approximate wavelet coefficient is obtained. Similarly, for each division, a single wavelet (approximate) coefficient is obtained. All the wavelet coefficients are tabulated into rows and columns of the image. The statistical measure, coefficient of variation (c.v.) is obtained for each row and column of the image and these values are analyzed.
statistically. Based on the comparison of the values in the rows and columns, the
defective portion of the image is identified corresponding to higher variation.

Two defective pieces of ceramic tiles are taken for analysis. The size of the
image is 300 x 300 matrix. This is divided into 10 equal rows and columns of 30 x 30
matrix size. By using DWT technique, the image is decomposed. The methodology for
identifying defects in ceramic tile image is similar to the methodology for identifying
defects in fabric image.

6.4 Results and Discussion

The fabric images and ceramic tiles have been captured through the online camera
held on the line production at the industry. The image captured is converted to other
kinds of images (Binary and Gray Scale) suitable for the various defect detection
algorithms used for the different types of defects. Gray scale images of fabric and
ceramic tiles are taken for analysis.

6.4.1 Discussion with Fabric Images

Table 6.1 shows the coefficient of variation values of the defective fabric image 1
(figure 6.1).
Figure 6.1 Defected Fabric image 1

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| Column Wise c.v.% | 1.24 | 1.12 | 1.25 | 4.84 | 20.97 | 11.11 | 1.14 | 0.85 | 1.29 | 1.24 | 1.04 |

Table 6.1 Wavelet Coefficients and Coefficient of Variation corresponding to Image 1
In table 6.1, the coefficient of variation values for each rows and columns are obtained. In order to locate the defective portion of the image, the average of coefficient of variations of all the 11 rows, $r_{avg}$ c.v. is obtained.

$$r_{avg} \text{ c.v.} = \frac{1}{11} \sum_{i=1}^{11} R_{cv_i} = 3.213685 \quad (6.1)$$

The coefficient of variation values which are greater than $r_{avg}$ c.v. are marked bold. From the table 6.1, it is clear that, coefficient of variation value of fifth row ($R_{cv5}$) is greater than $r_{avg}$ c.v. value.

Similarly, the average of coefficient of variations of all the 11 columns, $c_{avg}$ c.v. is obtained.

$$c_{avg} \text{ c.v.} = \frac{1}{11} \sum_{i=1}^{11} C_{cv_i} = 4.194976 \quad (6.2)$$

The coefficient of variation values which are greater than $c_{avg}$ c.v. are marked bold. From the table 6.1, it is clear that the fourth ($C_{cv4}$), fifth ($C_{cv5}$) and sixth ($C_{cv6}$) columns are having greater coefficient of variation than the $c_{avg}$ c.v. value. It is identified that, the blocks corresponding to the intersection of row 5 with columns 4, 5 and 6 as the defective portion of the fabric image 1.
Figure 6.2 Defected Fabric Image 2

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| Column Wise c.v.% | 8.60 | 11.36 | 2.36 | 1.96 | 9.47 | 26.36 | 1.89 | 1.47 | 1.29 | 1.87  | 1.76  |

Table 6.2 Wavelet Coefficients and Coefficient of Variation corresponding to Image 2
From table 6.2, the average of coefficient of variations of all the 11 rows, $r_{avg \ c.v.}$ is obtained.

$$r_{avg \ c.v.} = \frac{1}{11} \sum_{i=1}^{11} R_{cv_i} = 5.599479$$  \hspace{1cm} (6.3)

The coefficient of variation values which are greater than $r_{avg \ c.v.}$ are marked bold. From the table 6.2, it is clear that, the second ($R_{cv2}$), third ($R_{cv3}$) and tenth ($R_{cv10}$) rows are having greater coefficient of variation values than $r_{avg \ c.v.}$ value.

Similarly, the average of coefficient of variations of all the 11 columns, $c_{avg \ c.v.}$ is obtained.

$$c_{avg \ c.v.} = \frac{1}{11} \sum_{j=1}^{11} C_{cv_j} = 6.221815$$  \hspace{1cm} (6.4)

The coefficient of variation values which are greater than $c_{avg \ c.v.}$ are marked bold. From the table 6.2, it is clear that, the first ($C_{cv1}$), second ($C_{cv2}$), fifth ($C_{cv5}$) and sixth ($C_{cv6}$) columns are having greater coefficient of variation values than the $c_{avg \ c.v.}$ value. It is identified that, the blocks corresponding to the intersection of rows 2, 3 and 10 with columns 1, 2, 5 and 6 as the defective portion of the fabric image 2 (figure 6.2).

Using the coefficient of variation, defective portions of the fabric images are identified with the help of discrete wavelet transform technique. The statistical approach clearly shows that the values varied significantly in the defective portions of the fabric.
6.4.2 Discussion with Ceramic Tile Images

Table 6.3 shows the coefficient of variation values of the defective ceramic tile image of figure 6.3.

Table 6.3 shows the coefficient of variation values of the defective ceramic tile image of figure 6.3.

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Column Wise c.v.%

| Blocks | 11.16 | 6.00 | 0.70 | 0.62 | 0.79 | 0.88 | 0.99 | 1.06 | 1.03 | 0.77 |

Table 6.3 Wavelet Coefficients and Coefficient of Variation corresponding to Image 1.
From table 6.3, the average of coefficient of variations of all the 10 rows, \( r_{\text{avg} \text{ c.v.}} \) is obtained.

\[
r_{\text{avg} \text{ c.v.}} = \frac{1}{10} \sum_{i=1}^{10} R_{cvi} = 2.469113
\] (6.5)

The coefficient of variation values which are greater than \( r_{\text{avg} \text{ c.v.}} \) are marked bold. From the table 6.3, it is clear that, the seventh (\( R_{cvi7} \)) and eighth (\( R_{cvi8} \)) rows are having greater coefficient of variation values than the \( r_{\text{avg} \text{ c.v.}} \) value.

Similarly, the average of coefficient of variations of all the 10 columns, \( c_{\text{avg} \text{ c.v.}} \) is obtained.

\[
c_{\text{avg} \text{ c.v.}} = \frac{1}{10} \sum_{i=1}^{10} C_{cv} = 2.405525
\] (6.6)

The coefficient of variation values which are greater than \( c_{\text{avg} \text{ c.v.}} \) are marked bold. From the table 6.3, it is clear that, the first (\( C_{cv1} \)) and second (\( C_{cv2} \)) columns are having greater coefficient of variation values than the \( c_{\text{avg} \text{ c.v.}} \) value. It is identified that the blocks corresponding to the intersection of rows 7 and 8 with columns 1 and 2 as the defective portion of the ceramic tile image 1.
Table 6.4 Wavelet Coefficients and Coefficient of Variation corresponding to Image 2

From table 6.4, the average of coefficient of variations of all the 10 rows, $r_{avg}$ c.v. is obtained.
The coefficient of variation values which are greater than $r_{\text{avg c.v.}}$ are marked bold. From the table 6.4, it is clear that, the second ($R_{cv2}$), third ($R_{cv3}$) and fourth ($R_{cv4}$) rows are having greater coefficient of variation values than the $r_{\text{avg c.v.}}$ value.

Similarly, the average of coefficient of variations of all the 10 columns, $c_{\text{avg c.v.}}$ is obtained.

\[
 c_{\text{avg c.v.}} = \frac{1}{10} \sum_{i=1}^{10} C_{cv_i} = 0.153108 \tag{6.8}
\]

The coefficient of variation values which are greater than $c_{\text{avg c.v.}}$ are marked bold. From the table 6.4, it is clear that, the fourth ($C_{cv4}$) and fifth ($C_{cv5}$) columns are having greater coefficient of variation values than the $c_{\text{avg c.v.}}$ value. It is identified that, the blocks corresponding to the intersection of row 2, 3 and 4 with columns 4 and 5 as the defective portion of the ceramic tile image 2 (figure 6.4).

6.5 Conclusion

In this chapter, a statistical approach for identifying defects in fabric images and ceramic tiles using discrete wavelet transform is analyzed. Using the coefficient of variation, defective portions of the fabrics and ceramic tile images are identified with the help of discrete wavelet transform technique. The statistical approach effectively identifies the defective portions of the fabrics and ceramic tiles. It is simple (complex free) and easy to use.