Fabric Textile Defect Detection, By Selecting A Suitable Subset Of Wavelet Coefficients, Through Genetic Algorithm

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Abstract

This paper presents a novel approach for defect detection of fabric textile. For this purpose, First, all wavelet coefficients were extracted from an perfect fabric. But an optimal subset of These coefficients can delete main fabric of image and indicate defects of fabric textile. So we used Genetic Algorithm for finding a suitable subset. The evaluation function in GA was Shannon entropy. Finally, it was shown that we can gain better results for defect detection, by using two separable sets of wavelet coefficients for horizontal and vertical defects. This approach, not only increases accuracy of fabric defect detection, but also, decreases computation time.

Keywords: Fabric Textile Defect Detection, Genetic Algorithm, Wavelet Coefficients.

1. INTRODUCTION

In loom industry, it's very important to control quality of textile generation. Though, loom machines improvement, decreases defects in fabric textile, but this process can't perform quite perfect [1]. In the past, human resource performed defect detection process in factories but this tedious operation, depended on their attention and experiment. So we couldn't expect high accuracy from them. In other words, according to experimental results that were shown in Ref [1], human eyesight system can recognize just 50-70% of all defects in fabric textile. In the other hand, Ref [2] claimed that human's accuracy in fabric defect detection isn't higher than 80%. So, it seems that automatic evaluation of fabric defects is very necessary.

Because of improvement in image processing and pattern recognition, automatic fabric defect detection can presents an accurate, quick and reliable evaluation of textile productions. since fabric evaluation is very important in industrial applications, Different researches were done on fabric textile, surface of wood, tile, aluminum and etc [2,3,4,5,6]. [3] presented a method for fabric defect detection based on distance difference. In this method, user can adjust some parameters, according to the type of textile. [7] evaluated effects of using regularity and local directions as two features for fabric textile defect detection. [8] used Gabor filters for feature extraction and Gaussian Mixture model for detection and classification of fabric defects. [9] used structure characters of fabrics for defect detection and [10] was done this process by using adaptive local binary patterns.

Many defect detection systems that were presented up now, work on offline mode. In this mode, if occur some defects in a part of the fabric textile because of machine's problem, all parts of the fabric will be defective. But in online mode, since defect detection operation perform on textile generation time, we can stop generation process as soon as occurs a defection. The goal of this paper is to presents a method for online processing with acceptable accuracy and speed in defect detection.

Here, we used wavelet filter for fabric defect detection. This filter puts special information in each quarter of filtered image. In two dimensional wavelet transform, initial image divides to four parts. The first part is an approximation of initial image and the other parts include components with high frequencies or details of image, so vertical, horizontal and diagonal defects can be found in part 2, 3 and 4 respectively. There is a problem for using wavelet transform in fabric defect detection. The wavelet coefficients that are suitable for a special fabric, may aren't suitable for the other one. So in this paper, we used separable wavelet coefficients sets for each fabric.

After extracting all wavelet coefficients from a perfect fabric, we found a suitable subset of these coefficients using genetic algorithm. Then applied this suitable subset to other images and gain the available defects in each of them. In fact, our final goal is to design a system that can recognize defective and perfect fabrics. This paper is organized as follows: in Section 2 and 3, we briefly introduce Wavelet transform and Genetic algorithm. Section 4 describes the proposed method for fabric defect detection and Our experimental results is shown in Section 5.

2. WAVELET TRANSFORM

Wavelet transform analyses the signal by a group of orthogonal functions in the form of $\Psi_{m,n}(x)$, that computed from translation and dilation of the mother wavelet Ψ. These orthogonal functions are shown in Equation 1.

$$\Psi_{m,n}(x) = 2^{-\frac{m}{2}}\psi(2^{-m}x - n) \tag{1}$$

m and *n* are real numbers in this equation. Analysis and synthesis formulas are shown in Equation 2 and 3 respectively.

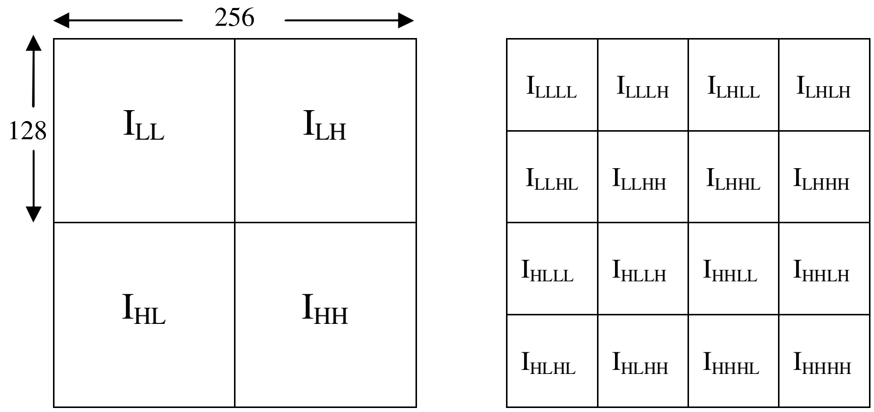
$$C_{m,n} = \int_{-\infty}^{+\infty} f(x)\,\psi_{m,n}(x)\,dx \tag{2}$$

$$f(x) = \sum_{m,n} C_{m,n}\,\psi_{m,n(x)} \tag{3}$$

Coefficients of this transform are obtained recursively. A synthesis of level *j* are shown in Equation 4.

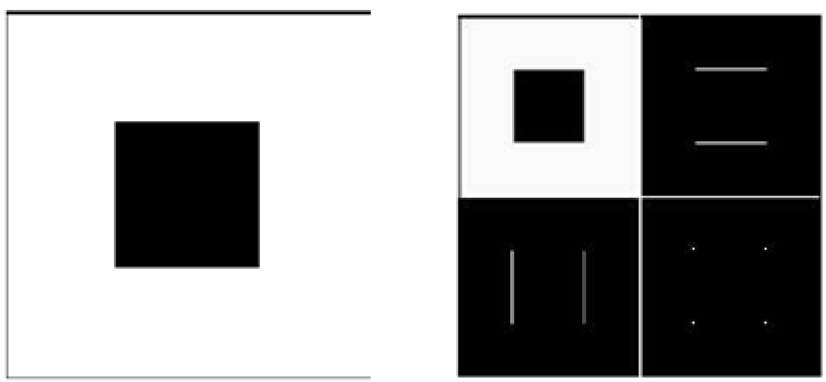
$$f(x) = \sum_k C_{0,k}\,\phi_{0,k}(x) = \sum_k C_{j+1,k}\,\phi_{j+1,k}(k) + \sum_{j=0}^{J} d_{j+1,k}\,\psi_{j+1,k}(x) \tag{4}$$

In two dimensional wavelet transform, initial image in each level, divides to four parts. The first part is an approximation of initial image and the other parts include components with high frequencies of image and show edge points in vertical, horizontal and diagonal directions. Figure1-(a) and (b) show this partitioning for the first and the second order of DWT on a 256 X 256 pixels image. After applying the first order of DWT on image, it is divided to four images I_{HH}, I_{LL}, I_{LH} and I_{HL} where H and L are high and low bounds respectively [11,12]. This operation can be performed For each of these four images repeatedly that the result is shown in part (b). Figure 2 shows a real example and the result of applying the first order of DWT on it in part (a) and (b) respectively.



(a) (b)

FIGURE 1: decomposition of an 256 x 256 pixels Image for the (a) first order, (b) second order of DWT



(a) (b)

FIGURE 2: (a): an image, (b): the result of applying the first order of DWT on (a)

Wavelet transform evaluates the difference of information in two different resolutions and creates a multi-resolution view of image's signal [11], so these transformation are useful for fabric defect detection.

3. GENETIC ALGORITHM

Genetic Algorithm is a stochastic optimization method. One of the main characteristic of this algorithm is that it leaves a set of best solutions in population. This algorithm has some operators for selecting the best solutions, crossing over and mutation in each generation [13]. GA starts with an initial and random population of solutions. Then a function that called fitness function, are calculated for each solution. Among initial population, solutions that their fitness values are higher than the others, are selected for next generation. In the other hand, Crossover and mutation operators add new solutions to next generation. this operation performs repeatedly to at the final, the algorithm converges to a good solution. In this paper, we used genetic algorithm for finding a suitable subset of wavelet coefficients of a special fabric textile.

The simplest form of GA involves three types of operators: [14]

- Selection: This operator selects chromosomes in the population for reproduction. The fitter the chromosome, the more times it is likely to be selected to reproduce.

- Crossover: This operator exchanges subsequences of two chromosomes to create two offspring. For example, the strings 10000100 and 11111111 could be crossed over after the third locus in each to produce the two offspring 10011111 and 11100100. This operator roughly mimics biological recombination between two single-chromosome (haploid) organisms.
- Mutation: This operator randomly flips some bits in a chromosome. For example, the string 00000100 might be mutated in its second position to yield 01000100. Mutation can occur at each bit position in a string with some probability, usually very small (e.g., 0.001).

the simple GA works as follows: [14]

1. Start with a randomly generated population of N L-bit chromosomes (candidate solutions to a problem).
2. Calculate the fitness F(x) of each chromosome x in the population.
3. Repeat the following steps (a)-(c) until N offspring have been created:
   a. Select a pair of parent chromosomes from the current population, with the probability of selection being an increasing function of fitness. Selection is done with replacement," meaning that the same chromosome can be selected more than once to become a parent.
   b. With probability P_c (the crossover probability), cross over the pair at a randomly chosen point (chosen with uniform probability) to form two offspring. If no crossover takes place, form two offspring that are exact copies of their respective parents.
   c. Mutate the two offspring at each locus with probability P_m (the mutation probability), and place the resulting chromosomes in the new population.
4. Replace the current population with the new population.
5. If the stopping condition has not satisfied, go to step 2.

4. FABRIC DEFECT DETECTION

Our proposed method has two phases. the First phase includes extracting all wavelet coefficients from a perfect fabric image and the second one includes finding a suitable subset of all coefficients using genetic algorithm. This subset can delete main fabric of image and indicate defects of fabric textile. So after these two phases, we can apply the suitable subset to the other images and gain the available defects in each of them.

Jasper in [15] showed that if the optimization problem in Eq. 5 can be solved, we can find a suitable subset of wavelet coefficients.

$$\min \ J = C * P * P^T * C^T$$

Where

$$C_{j(c)} = \sum_{k=0}^{n-1} c_k c_{k-2j} = 0 \tag{5}$$

In this equation, *J* function is the normal form of high frequency components of image, *n* is the number of coefficients, *c* is a subset of wavelet coefficients as a solution and *p* is an array of image's pixel values. Our goal is to find a *c* subset that minimize *J* function. For this purpose, we can use genetic algorithm. In this algorithm, each solution *c* is a chromosome and different fitness functions can be used. In this paper we evaluated some fitness functions but sum of squares and entropy functions had the best results.

Using a wavelet coefficients subset as a filter that filters images in both horizontal and vertical directions, has not good results for real fabrics that aren't symmetric. So by using two separable filters for horizontal and vertical directions, we can obtain the better results. If W_1 and W_2 be horizontal and vertical filters respectively and *U* be a perfect image, then the filtered image F, can be shown as Equation 6.

$$F = W_1 * U * W_2^T \tag{6}$$

Now we must calculate a fitness function for filtered image *F.* as mentioned previously, in this paper, we used sum of squares and entropy functions. These functions can be shown in Eq. 7 and 8 respectively.

$$Sum = \sum_{i=1}^{n} \sum_{j=1}^{m} F(i,j)^2 \tag{7}$$

$$\mathrm{H} = -\sum_{i=1}^{n} \mathrm{d(i)} * \log_2 (\mathrm{d(i)}) \tag{8}$$

In Eq. 7, *n* and *m* are the number of lines and columns in image and *F(i , j)* is the pixel value of image, in line *i* and column *j*. in Eq. 8, *n* is the number of gray levels that here is 256 and *d(i)* is probability of gray level *i* in filtered image *F*. this probability is a real number between 0 and 1. For example if 1024 pixels among all pixels have the same gray level value like 100, then can be written: d(100) = 1/64.

With these fitness functions in Eq. 7 and 8, the optimization problem that were shown in Eq. 5, can be written in form of Eq. 9 and 10 respectively. As mentioned previously, our purpose is to minimize *J* function.

$$J = \sum_{i=1}^{n} \sum_{j=1}^{m} (W_1 * U * W_2^T)^2 \tag{9}$$

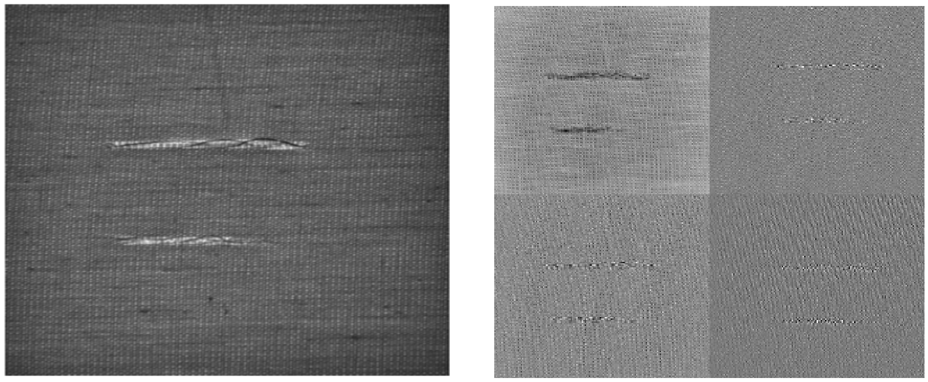
$$J = Entropy(W_1 * U * W_2^T) \tag{10}$$

The entropy function optimizes wavelet coefficients based on monotony of background. So if the entropy function value be small, the image will be more monotonic. But the sum of squares function optimizes image by minimizing its pixel values. furthermore entropy function has simpler computation in comparison with sum of squares. So we continued our experiments with entropy function as fitness function of GA.

5. EXPERIMENTAL RESULTS

In this paper, for evaluating the proposed technique, we used two image databases that are called Tilda [16] and Brodatz [17]. Tilda includes 8 groups of different fabric textile types and Each group has 50 images with 512 x 768 pixels. Brodatz includes 112 types of fabric images with 640 x 640 pixels.

Figure 3 shows a defective fabric textile of Tilda database and the filtered image in part (a) and (b) respectively. The wavelet coefficients of each quarter was optimized by GA while the fitness function of GA was entropy. This Figure shows that the entropy function has good quality, because the background is monotonic and defects are appeared clearly.



(a) (b)

FIGURE 3 : (a) a defective fabric textile, (b) filtered image by suitable coefficients for each quarter

In this experiment, first a perfect image from each fabric used for training phase and a suitable subset of its wavelet coefficients for each quarter was obtained. Figure 4 shows the histogram of quarter 4 of Figure 3-(b). this Figure shows a normal distribution. Most of pixels that are related to background are placed in the middle of distribution but defects are shown in the end of each littoral. So by selecting two thresholds in proximity of these two littoral, we can perform a thresholding process on the image and obtain a clear image for place detection of defects. The image can be more clear by applying some denoising and normalization processes on it.

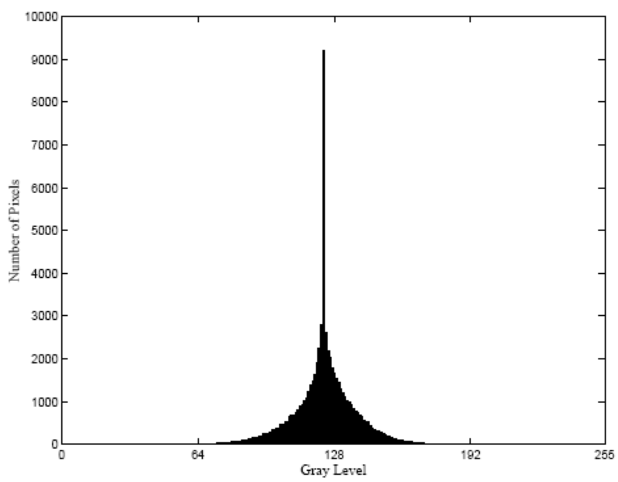


FIGURE 4: histogram of quarter 4 of Figure 3-(b)

Figure 5-(a) is a fabric textile with diagonal defects. Part (b) of this Figure shows quarter 4 of the filtered image that diagonal defects was appeared in it. Part (c) and (d) show the result of applying thresholding and denoising processes on part (b) and (c) respectively. Now part (d) of Figure 5 has suitable quality for defect detection.

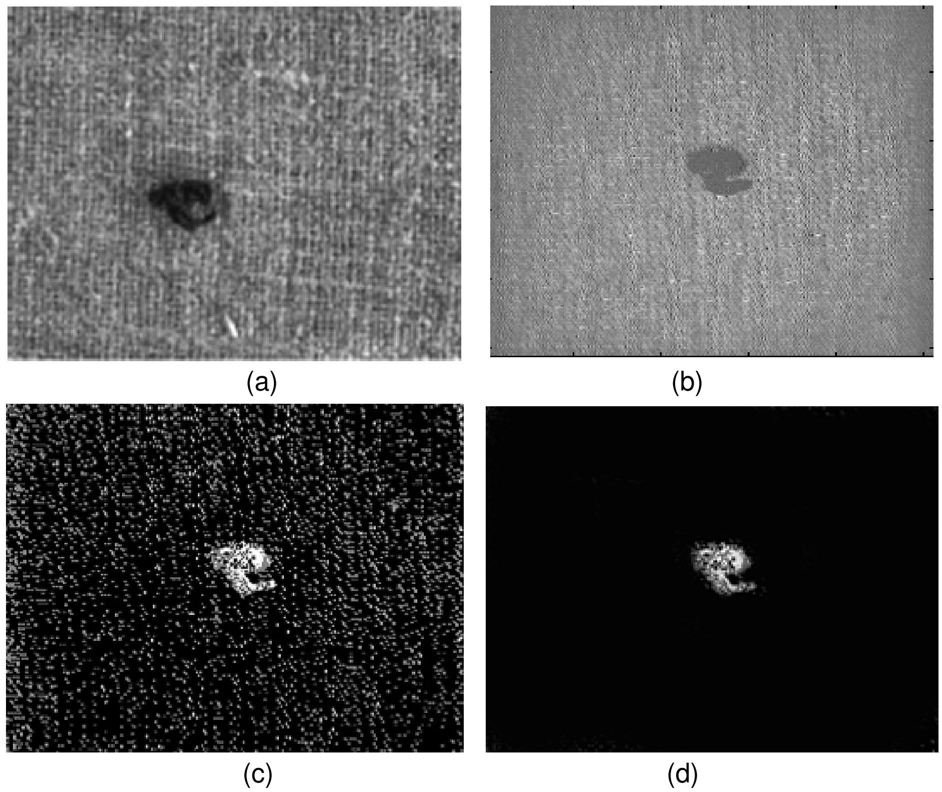


FIGURE 5: (a) a fabric with diagonal defects, (b) the quarter 4 of filtered image, (c) the result of applying thresholding process on part (b), (d) the result of applying denoising process on part (c)

Figure 6-(a) is a fabric textile with horizontal defects. Part (b) of this Figure shows quarter 3 of the filtered image that horizontal defects was appeared in it. Part (c) shows the result of applying thresholding on part (b), but this result is not suitable for denoising because the size of noise and defect areas are same nearly. So in this example we applied sliding window method on image in part (b) of Figure 6. This method builds 2 windows with size 17×17 and 9×9 for each pixel of image, Then calculates the standard deviation of each window and assignes the result of Equation (11) to central pixel as new value of it. In this Equation T is a suitable threshold.

$$\text{New value of Central pixel} = \begin{cases} if \quad \frac{\text{Standard Deviation of small window}}{\text{Standard Deviation of large window}} < T & 1 \\ otherwis & 0 \end{cases} \tag{11}$$

Part (d) of Figure 6 shows this result. In this image, size of defect areas are very larger than size of noise areas. So denoising process can be done on part (d). the result of denoising process is shown in part (e). Now part (e) of Figure 6 has suitable quality for defect detection.

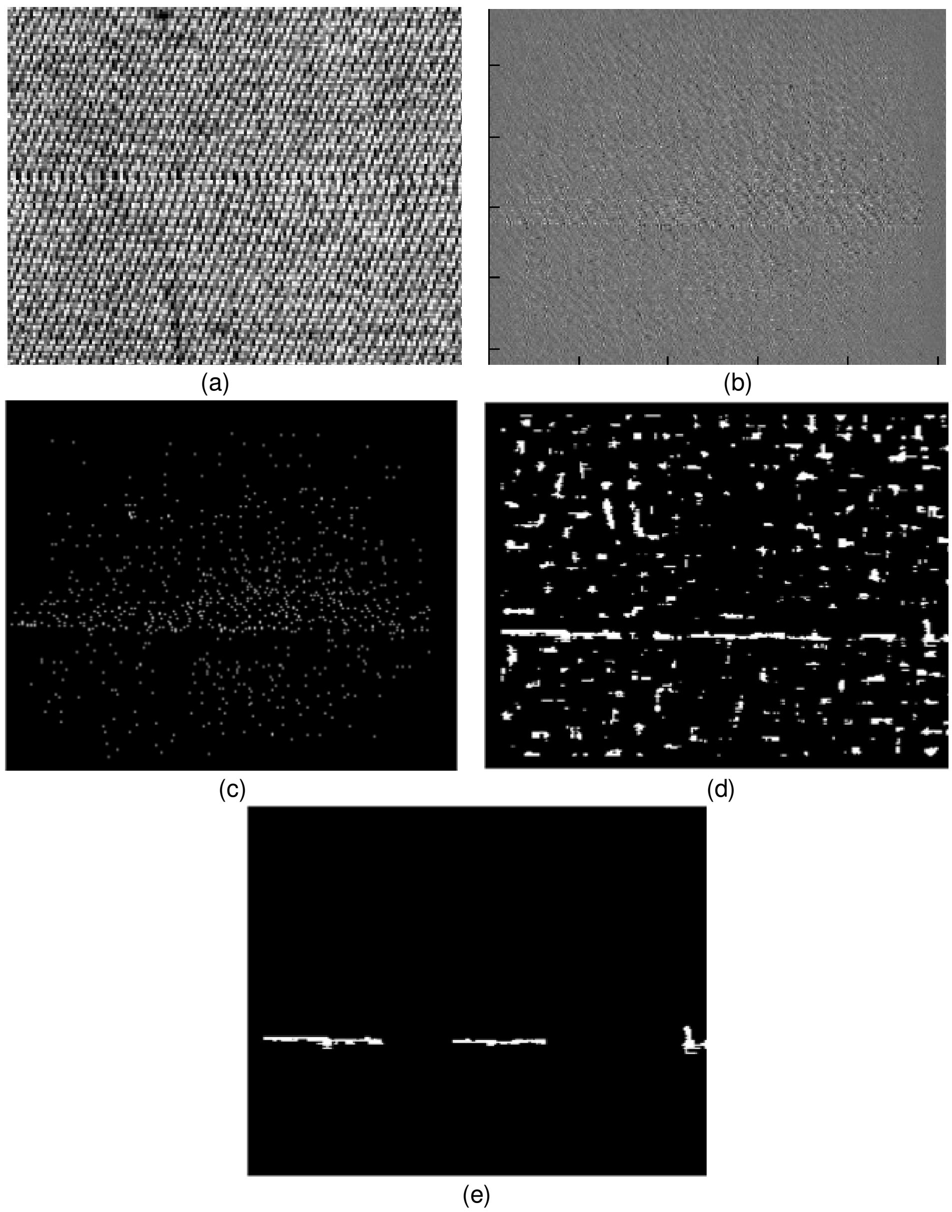


FIGURE 6: (a) a fabric with horizontal defects, (b) the quarter 3 of filtered image, (c) the result of applying thresholding process on part (b), (d) the result of applying sliding window method on part (b), (e) the result of applying denoising process on part (d)

In this experiment, first a perfect image from each fabric used for training phase and a suitable subset of its wavelet coefficients for each quarter, was obtained. Then in the test phase, the other perfect or defective images evaluated by our proposed technique. Table 1 and 2 show these results for Tilda and Brodatz databases, respectively. Since genetic algorithm starts with a random initial population, solutions that are produced by each population, must be same or close to each other. This characteristic is called repetition's capability. We tested this capability and its results were shown in Table3. In this table, for each quarter of two different fabric types, mean and standard deviation of ten runs with different initial populations were shown.

Fabric Type	Image number	Defective image number	Perfect image number	Detected defective image number	Detected perfect image number	Accuracy of correct detection
C1r1	18	12	6	11	6	94.4%
C1r2	22	14	8	14	7	95.4%
C2r3	20	16	4	15	4	95%

TABLE 1 : Fabric defect detection results for Tilda database

Fabric Type	Image number	Defective image number	Perfect image number	Detected defective image number	Detected perfect image number	Accuracy of correct detection
D77	100	23	77	19	76	95%
D79	100	27	73	23	70	93%
D105	100	56	44	51	39	90%

TABLE 2 : Fabric defect detection results for Brodatz database

Fabric type	Quarter number	Mean	Standard deviation
C1r1e3	2	5.9208	0.1092
C1r1e3	3	6.0158	0.1286
C1r1e3	4	5.9466	0.1297
C2r2e2	2	5.7401	0.1607
C2r2e2	3	5.8144	0.1707
C2r2e2	4	5.7530	0.1356

TABLE 3 : results of repetition's capability

6. CONCLUSION

As mentioned previously, in this paper we used a novel method for fabric textile defect detection. This process had two phases. the First phase includes extracting all wavelet coefficients from a perfect fabric image and the second one includes finding a suitable subset of all coefficients using genetic algorithm. The experimental results showed that our method have good accuracy for defect detection.

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