A Comparison Study of the Performance of the Fourier Transform Based Algorithm and the Artificial Neural Network Based Algorithm in Detecting Fabric Texture Defect

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Abstract

Two methods, based on digital image processing technique, for detecting fabric texture defect have been developed. In the first method, the detection was based on the statistics of the Fourier spectrum. The statistics used were: the average, the highest pixel count, the standard deviation, the skewness and the kurtosis. The FFT algorithm was used for computing the Fourier spectrum. In the second method, the defect was detected using the artificial neural network. The method employs feed forward neural network with sigmoid transfer function. Initially the network was trained to "understand" fabric with no defect and defective fabric. Edge detection and edge linking were applied to the image of the fabric before the image was fed to the network. These processes were needed to keep the network simple.

The two methods were tested using 60 and 70 images of both defective and good fabrics. The Fourier transform based method gives a success rate of 95 %, whereas the artificial neural network based method gives a success rate of 98.6%.

Keywords: *fabric texture defect, Fourier spectrum, artificial neural network*

1 Introduction

Competition forces textile industries to produce high quality fabric that meets requirements already specified. This situation forces the industries to apply a quality control system to ensure that the product meets the requirements, which means that the company must ensure that their product were not defective. Fabric defect can be categorized into two: texture defect and color defect (Grover, 1969).

One way of detecting fabric defect is by visually inspecting at the fabric while it is being produced. This has the drawback as human eyes are quickly becoming tired and tend to make error (Gonzalez and Woods, 1992). This drawback may be overcome by replacing the human every 30 minutes (Aristianto, 1995). Unfortunately, this requires the company to employ a number of persons with special skill of visually inspecting fabric defect.

This paper proposes a method for detecting fabric texture defect by using a computer system equipped with a video camera and a suitable software. The main advantage of the proposed method being that the method is not affected by fatigue as with the human eyes. The fabric texture detection methods developed in this research were based on the fact that fabric texture defect appears as high frequency components in the images of the fabric. Thus the detection of fabric texture defect can be carried out by detecting high frequency components of the image of the fabric.

In this paper two methods for detecting fabric texture defect are reported. The first method is based on the analysis of the statistics of the Fourier spectrum whereas the second method is based on the artificial neural network. The first method is selected for its ability to nicely represent images of fabric as frequency distribution in the form of the Fourier spectrum. The second method is selected for its ability to learn patterns in the images of defective and non defective fabrics.

For the purpose of detecting the high frequency components, the images of the fabric needs to be represented in different way, not as color distribution as it would normally. In the first method, the image is represented as frequency distribution (spectrum). In the second method the low frequency components were filtered out leaving the high frequency components. The artificial neural network is then applied to the filtered image.

2 Image Processing System for Detecting Fabric Texture Defect

The system for detecting fabric texture defect consists of four modules as shown in Figure 1.

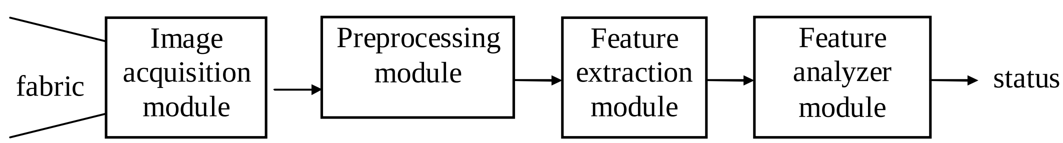

Figure 1. Block diagram of the system for detecting fabric texture defect.

The modules of the system perform the following processing

1. **Image acquisition module**. The image acquisition module takes the image of the fabric to be analyzed as defective or not defective. In this research the Matrox Meteor frame grabber was used. Only monochrome images were acquired since monochrome images were considered sufficient for detecting fabric texture defect.

2. **Preprocessing module**. The images acquired in the above step were preprocessed using digital image processing methods suitable for feature extraction, such as histogram equalization (Gonzales and Woods, 1992; Pitas, 1993).
3. **Feature extraction module**. This module extracts suitable features of the images that have been preprocessed in the preprocessing module. Features extracted in this module may include edges present in the image, color distribution, spectrum etc. (Brigham, 1988).
4. **Feature analyzer module**. Analysis of the features extracted in the feature extraction module was carried out in this module. The method used for analyzing the extracted features depends on the features selected. Analysis may be as simple as counting pixel with certain color to designing, training and employing artificial neural network for determining whether or not extracted features are representing defective fabric.

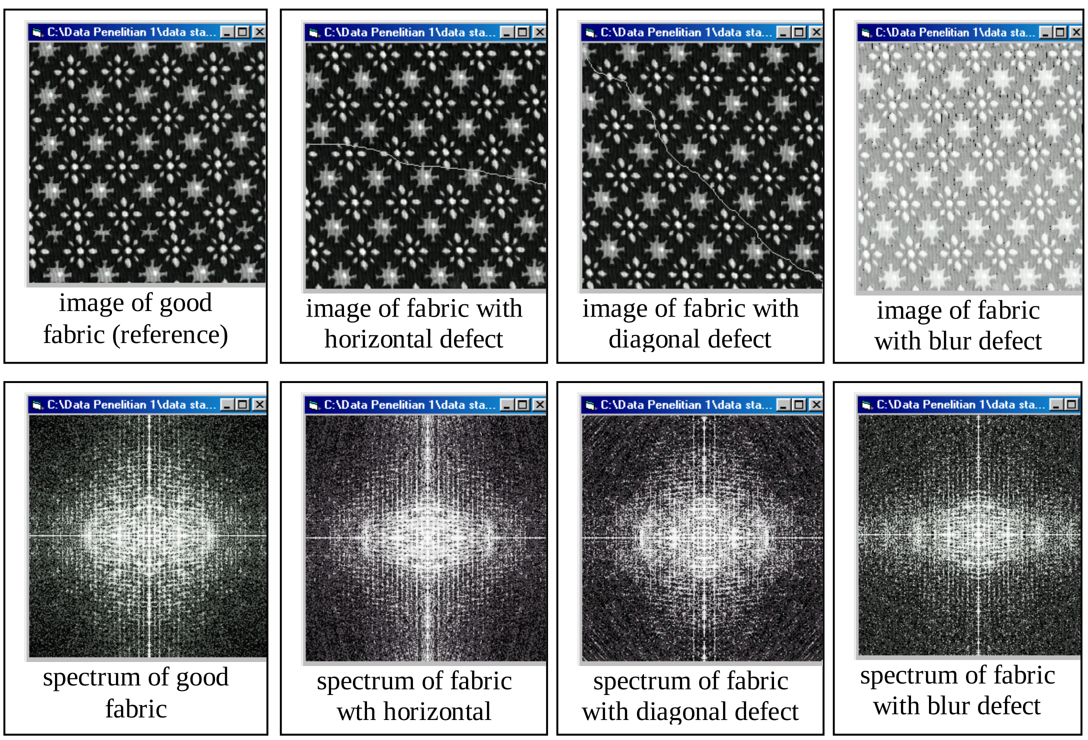

Figure 2. Examples of images for testing the methods and their spectrum.

3 Results and Discussion

In order to evaluate the performance of the proposed methods, computer program were developed. The program was written in Visual Basic, since this language is supported by the Matrox Meteor frame grabber. For this research the camera was set to auto focus and the diaphragm opening was set to automatic. Examples of images used for testing the methods are shown in Figure 2. Section 3.1 and 3.2 discuss each detection method and their performance.

3.1 Detection Fabric Defect Using the Statistics of the Fourier Spectrum

As mentioned before, the fabric texture defect detection method developed was based on the fact that fabric texture defect appears as high frequency components in the images of the fabric. This observation simplifies the detection of fabric texture defect as detection of high frequency components of the image of the fabric. In this particular method, the image is represented as frequency distribution (spectrum). The fast Fourier transform is employed for computing the spectrum of the image (Brigham, 1988; Gonzales and Woods, 1992). A number of values were calculated from the resulting spectrum. These values are used as an indicator for the occurrence of the high frequency components. These values, called statistic parameters, are the average, the highest pixel count, the standard deviation, *skewness* and *kurtosis*. Since fabric which is not defective may have high frequency components resulted from certain color pattern, statistic values from known good fabric were required as references. The statistic parameters calculated from these images are called reference statistic parameters. The statistic parameters of the image of a fabric are compared with the reference statistic parameters to determine if the fabric is defective.

Steps for detecting fabric texture defect based on the statistics of the spectrum of the image of a fabric and the modules where the steps are carried out are shown below.

1. **Acquisition module**. The detection process starts by acquiring the image of the fabric to be evaluated using the Matrox Meteor frame grabber.
2. Preprocessing module. The acquired image is enhanced using the histogram equalization technique (Gonzales and Woods, 1992; Pitas, 1993) to improve its contrast.
3. **Feature extraction module**. The fast Fourier transform (Brigham, 1988) is applied to the enhanced image resulted in the spectrum of the image. This step enables the detection of fabric texture defect as the detection of high frequency components.
4. **Feature analyzer module**. Statistic parameters were calculated from the spectrum of the image of the fabric to be evaluated. A fabric is said to be defective if its statistic parameters were significantly differ from the reference statistic parameters (calculated from known good fabric). For the detection purpose, a normalized weighted sum ($\Sigma\varepsilon'$) of the statistic parameters ($0 \leq \Sigma\varepsilon' \leq 1$) is then calculated. A fabric is said to be defective if its normalized weighted sum is greater or equal to 0.5 ($\Sigma\varepsilon' \geq 0,5$).

Table 1. Result of detecting fabric texture defect using one statistic parameter from 60 images.

Statistic parameter	Number of error (ε)
Average	3
Highest pixel count	3
Standard deviation	18
Skewness	4
Kurtosis	8

The weights used in the calculation of the normalized weighted sum were computed from an experiment with 60 known images. First, the spectrum of the 60 images were obtained and statistic parameters were calculated. Each statistic parameter is used to tell if the fabric from which the image is taken from is defective. The result is shown in Table 1. This result shows that each statistic parameter can be used as fabric defect indicator with different success rate.

In order to improve the success rate, all statistic parameters were combined in the form of a normalized weighted sum. The weight of a statistic parameter is calculated as the inverse of the number of error ε to reflect its detection accuracy. The weights of each parameter are shown in Table 2.

Table 2. Weights for the statistic parameters.

Statistic Parameter	Number of error (ε)	Weight (1/ε)	Normalized weight (ε')
Average	3	1/3	0.30
Highest pixel count	3	1/3	0.30
Standard deviation	18	1/18	0.05
Skewness	4	1/4	0.23
Kurtosis	8	1/8	0.12

Experimental result with 60 images shows that the detection method mistakenly classified three images which give an accuracy of 95%. It was observed that fabric with pattern presents more detection problem than fabric with no pattern. When defect appears in fabric with no or weak pattern, its effect can be easily identifed using statistic parameters. Defect in fabric with strong pattern poses problem in setting threshold for statistic parameters to tell if a fabric is defective. Setting threshold too low will cause non-defective fabric to be classified as defective. Setting threshold too high will cause defective fabric to be classififed as non-defective. The fabrics that were mistakenly classified are fabric with strong pattern with relatively small defect.

3.2 Detection of Fabric Texture Defect Using the Artificial Neural Network

As mentioned above, in the second method the low frequency components were filtered out leaving the high frequency components. A histogram is computed from the filtered image and an artificial neural network is then applied to the histogram to classify the corresponding fabric as defective or non defective. Steps for detecting fabric texture defect using the artificial neural network and the modules where the steps are carried out are shown below.

1. **Acquisition module**. The detection process starts by acquiring the image of the fabric to be evaluated.
2. Preprocessing module. The acquired image is enhanced using the histogram equalization technique (Gonzales and Woods, 1992; Pitas, 1993) to improve its contrast.
3. **Feature extraction module**. This module filter out the low frequency components leaving the high frequency components. The high frequency components contains information about the texture defect of the fabric, if exist. The Sobel operator (Gonzalez and Woods, 1992) is used to filter out the low frequency components. In order to improve the result of applying the Sobel operator, an edge linking operator (Gonzalez

and Woods, 1992) is further applied to the resulted image. Finally, the image is binarized and the histogram of the image, which is the feature looked after, is computed.

4. **Feature analyzer module**. The feature extracted in the feature extraction module is processed using an artificial neural network. The network act as a classifier to decide whether a fabric is defective or non defective. The artificial neural network is selected for its popularity and wide usage (Caviglia, 1989; Chang, 1990; Fu, 1994). A feed forward network is selected for its processing efficiency. A number of network topology were evaluated, but a network with four layers performs well. These layers are the input layer which consists of two nodes, two hidden layers with two nodes each and an output layer with one node. The network is shown in Figure 3. In this figure, W^k_{ij} represents weight factor of node j in layer k for node i in layer k+1, whereas b represent biases. The nodes between two consecutive layers are fully connected.

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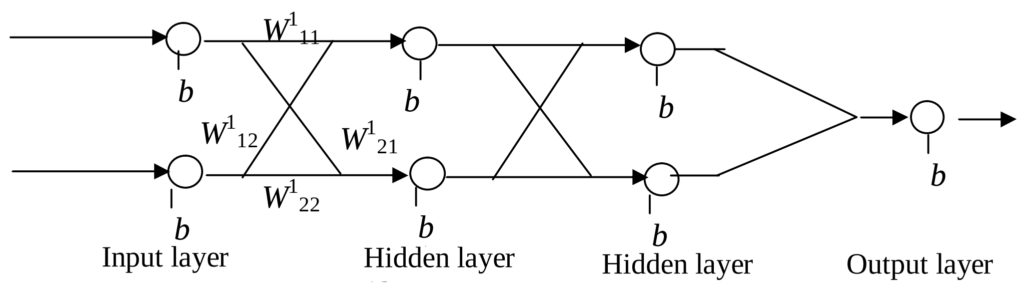

Figure 3. The artificial neural network topology used for detecting fabric texture defect.

The method has been tested on 70 images of defective and non defective fabric. The performance of the network is influenced by the learning rates and detection tolerance. The learning rate mainly affect the training time. The smaller the learning rate is the longer the time needed for training the network. The detection tolerance affects the detection accuracy. The smaller the detection tolerance is the more accurate the detection accuracy. The best performance of the network is found for learning rate 0.04 and detection tolerance 0.2 with only one image misclassified, which gives detection accuracy of 98.6%. The error occurs for fabric with strong pattern and small texture defect which is classified as non defective. It is noted that two images that were misclassified by the Fourier transform based method are correctly classified by this method. The artificial neural network based method classifies fabric as defective or non defective using a set of weight internal to the network. The weights are calculated from fabric used for training the network. When input is given to the network, the network gives a respone (the output of the network) using the weights computed from the training set. The response tells if the fabric is defective or non defective. Thus the network is autonomous in the sense that no human intervention is needed in making a decision (unlike the first method that relies on the threshold set by human). This is may be the reason why the second method is better than the first one.

4 Conclusion

This paper presents two methods for detecting fabric texture defect. One method is based on the analysis of the spectrum of an image of a fabric. The second method is based on the artificial neural network. The first method gives an accuracy of 95% whereas the second one gives an accuracy of 98.6%. The two methods have a common problem in detecting texture defect for fabric with strong pattern because strong pattern may appear as high frequency components and thus may be detected as texture defect. The difficulty with the first method lies in setting proper threshold for deciding if a fabric is defective. Setting threshold too low will cause non-defective fabric to be classified as defective. Setting threshold too high will cause defective fabric to be classififed as non-defective. As for the second method, there is no threshold that needs to be set. The second method makes decision based on a set of weights computed from the fabric used for training the network. This could be the reason why the artificial neural network based method performs better than the Fourier transform based method.

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