Automatic Classification of Woven Fabric Structure by Using Learning Vector Quantization

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Abstract

Current procedure for classification of woven fabric structure in the textile industry is performed by human, which wastes manpower and time. This paper proposes an automatic woven fabric image extraction and classification method. To speed up the system running time, 2-D wavelet transform for fabric images is used firstly. Extracting the feature parameters of gray level co-occurrence matrix is a typical method for fabric texture image. Finally, identification and classification of the woven fabric structures exactly by using the learning vector quantization neural network. The experimental results show that focusing on learning vector quantization improves the classification performance as well as increases the computational efficiency.

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Keywords: Woven Fabric Structure; Two-dimensional Wavelet Transform; Gray Level Co-occurrence Matrix; Learning vector quantization neural network.

1. Introduction

In the current textile industry, the analysis and recognition of woven fabrics mostly rely on manual type. However, the reliability of manual inspection is limited due to fatigue and inattentiveness. Meanwhile, this manual operation costs a long time which is not beneficial for the industry. Therefore, this paper proposes an automatic and efficient recognition system for woven fabrics. Using this system not only

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recognizes woven fabrics automatically, but also improves productive efficiency. The first is taking the three basic woven fabrics as the research objects, plain, twill and satin weave. After using 2-D wavelet transform for the woven fabric images, the size of woven fabric images is reduced, but the main information of woven fabric images can be retained. Then extracting the gray level co-occurrence matrix's four feature parameters of the fabric image as learning vector quantization neural network's inputs. After establishment and training of network, the competitive layer weights are determinated. Finally, simulating the test samples and the trained network to realize the automatic recognition and classification of woven fabric structures. Compared with other methods, this automatic recognition system has a high accuracy.

2. Woven Fabrics Image Collection and Preprocessing

We use scanner CanonScan 9000F as the fabric image acquisition system. Under the same external condition, we scan the woven fabric images by 600 dpi, and then acquire 18 groups of woven fabric images about 300×300 size as samples, of which each basic woven fabric structure has 6. After gaining fabric image samples, it can use median filter and histogram equalization [1] to preprocess fabric image. Fig. 1(a) shows that original gray level image of a satin weave. To eliminate noise interference, we adopts the median filtering for a satin weave. The result shows as Fig. 1(b). Then we uses histogram equalization to automatically enhance the whole image contrast and minimize the uneven distribution of gray levels of pixels caused by local illumination. The equalization of a satin see Fig. 1(c).

![Fabric Image Preprocessing](image1.jpg)

Fig. 1. satin image preprocessing (a) a satin weave; (b) a satin weave after median filter; (c) a satin weave after equalization

3. Woven Fabrics image Processing Based on 2-D Wavelet Transform

Wavelet transform [2] is firstly presented by French scientist J. Morlet in 1974. In 1989, Mallat proposed the signal tower multi-resolution analysis decomposition and reconstruction fast algorithm, that is the famous Mallat algorithm. Wavelet transform is a local transform between time and frequency, which effectively extracts information from signal. The arithmetic functions of flexing and translation process multi-scale thining analysis for function and signal, and can solve the problem that Fourier transform cannot solve.

![Wavelet Transform](image2.jpg)

Fig. 2. a satin weave after 2-D wavelet transform decomposition (a) a satin weave; (b) a satin weave after 1st layer wavelet decomposition; (c) a satin weave after 2nd layer wavelet decomposition
2-D wavelet transform is made by twice interval sampling in the rows and columns after the inner product between an original image and a wavelet basis image. Each convolution can decompose the one-dimensional convolution on rows and columns, because scale functions and wavelet function are separable. After 1st layer of wavelet transform, the original image is broken into four subimages [3]: a low-frequency subimage $LL$ (display for approximate image); three high frequency detailed subimages, a high-frequency horizontal sub-image $HL$, a high-frequency vertical sub-image $LH$, a high-frequency diagonal subimage $HH$. In the next layer of wavelet decomposition, the low frequency part is decomposed only. Fig. 2(a) is the original image of satin weave. Fig. 2(b) shows that the satin weave is decomposed into four subimages by 1st layer two-dimensional wavelet. After 2nd layer two-dimensional wavelet, the satin weave is decomposed into seven subimages showed as Fig. 2(c).

4. Feature Extraction Based on GLCM Method

The graylevel co-occurrence matrix (GLCM) of an image can reflect the comprehensive informations of image gray level [4], which are about directions, adjacent interval and rangeability. It has been proved a good method of texture analysis in theory and experiment. GLCM has been brought out in 1973 by Haralick. It describes the grey value $i$ and $j$, the 2 pixels' frequency correlation matrix $P(i,j,d,\theta)$ of the N-graylevel image in $\theta$ direction and distance $d$. $P(i,j,d,\theta)$, the $i$-row and $j$-column element of graylevel co-occurrence matrix, expresses all appeared probability of the grey value $i$ and $j$ in $\theta$ direction and distance $d$. $\theta$ is the angle of the x axis and the two pixels' line, and the angle of $\theta$ is $0^\circ, 45^\circ, 90^\circ, 135^\circ$. Distance $d$ is related to the image generally according to the test to determine. When calculating of two pixel grayscale appeared probability, GLCM should be normalized. Ulaby and others have found: although there are 14 texture features in GLCM, only 4 features [5] are not relevant, which are convenient for computation and can give a higher accuracy of classification. Generally people use these 4 common features to extract image texture characteristics: the angular second moment(energy), contrast, correlation and entropy.

- **Energy**
  \[ Q_1 = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} [C(i,j)]^2 \]
- **Contrast**
  \[ Q_2 = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} k^2 \cdot C(i,j) \quad k = |i - j| \]
- **Entropy**
  \[ Q_3 = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} C(i,j) \cdot \log_2 C(i,j) \]
- **correlation**
  \[ Q_4 = \frac{\sigma_x^2 \cdot \sigma_y^2}{\sigma_x^2 \cdot \sigma_y^2} \]

With

- $\mu_x = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} C(i,j)$
- $\mu_y = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} C(i,j)$
- $\sigma_x^2 = \sum_{i=0}^{N-1} (i - \mu_x)^2 \sum_{j=0}^{N-1} C(i,j)$
- $\sigma_y^2 = \sum_{j=0}^{N-1} (j - \mu_y)^2 \sum_{i=0}^{N-1} C(i,j)$
Taking the GLCM of satin for example, its results shown as table 1. When the value of $\theta$ is 0 °, 45 °, 90 °, 135°, and the distance (d) is 1, calculating four features (energy, contrast, correlation, entropy).

Table 1. A satin weave's features

| $\theta$  | Energy  | Contrast       | Correlation     | Entropy   |
|-----------|---------|----------------|-----------------|-----------|
| 0 °       | 0.000209| 3433.263063    | -73.816674      | 12.284601 |
| 45 °      | 0.000209| 11445.280314   | -73.981932      | 12.279230 |
| 90 °      | 0.000200| 7328.262523    | -0.705396       | 12.330470 |
| 135 °     | 0.000209| 5411.884405    | -74.029045      | 12.279326 |

5. Texture Classification Based on LVQ Neural Network

Learning vector quantization (LVQ) is an algorithm for training competition layer with supervision. A complete LVQ network [6] contains three layers of neurons: input layer, hidden layer and output layer. This network in input layer and the hidden layers is completely connection, while the network in hidden layer and output layer is partial connection. Each output neuron connects the different groups of hidden neurons, meanwhile the connective weights between hidden layer and output layer are fixed for 1. The connective weights between input layers and hidden layer establish the components of reference vector. By training network, these weights have been changed. When an input mode was sent to the network, hidden neurons reference vector closest to the input mode gets inspired and wins the competition, enabling it to produce "1", but other hidden neurons are forced to produce "0". Meanwhile, output neuron connecting with winning hidden neurons exports "1", other output neurons issue "0". The output neuron of "1" points out the class of input mode, each outputs is expressed as a different class.

![Fig.3. (a) Input vector and the network competitive layers' weights before training; (b) Input vector and the network competitive layers' weights after training](image-url)
The learning vector quantization does not need to normalize and orthogonalize the input vectors. It just need to calculate the distance between the input vector and the competition layer directly, to realize pattern recognition simply. After extracting features of GLCM, it can get 18 groups of features of fabric image, each group has 16 features (4 direction). Taking 5 groups of the plain, twill and satin as the training samples, and the rest as testing samples. 15 groups of 16 dimensions' features as LVQ neural network's input layer, making corresponding classification. The output layer has 3 class (plain, twill and satin weave). The network with 5 neurons is established, and network weights are 0 without training. Fig.3.(a) shows that the input vectors and the competitive layers' weights before training. We can see the competitive layer weights is the same value 0. After training, the network weights are changed. Fig.3.(b) shows that the input vectors and the competitive layer weights before training. Finally, simulating the three groups of test samples and the trained network, which gets the correct classification.

6. Conclusions

This paper uses LVQ neural network to supervise train woven fabrics, then it can realize these three basic woven fabric structure's identification and classification well. The four different features of gray level co-occurrence matrix can effectively reflect the texture characteristics of fabric. Using the two-dimensional wavelet transform for fabric image processing, not only can reduce the size of fabric image analysis, but also can shorten the time of texture analysis. This method can extract fabric structure characteristics quickly, to realize the automatic recognition and classification of fabric. In addition, it liberates the artificially Labours. With the development of computer technology, fabric image automatic identification and classification will have more prospects, promoting the development of textile industry.

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