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Machine Vision Based Inspection of Textile Fabrics*

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Abstract

Several issues on automatic inspection of textile fabrics are discussed in this paper. To avoid the intense computation for real time inspection, we suggest a parallel pyramid hardware architecture consisting of several channels with CCD cameras in different resolutions working simultaneously. In inspection algorithms, we use a hierarchy of improved BP neural networks which demonstrate a tree structure in the progress of defect detection and classification. Attention is also directed to the system cost and viability under practical industry conditions. Preliminary experiment results show that our suggested hardware and software structures are very promising.

1. Introduction

In the textile industry, inspection of fabric surfaces is obviously an important task to improve the product quality and reduce the cost. The traditional human inspection is not only very inefficient because of the need of great labor intensity, but also unreliable because of the workers' fatigue caused by a long time of staring. Therefore, many attempts and efforts have been made to developed computerized and/or automatic inspection systems for textile fabrics. However, up to now, little progress has been achieved [4].

We believe that there are three major difficulties for the development of the automatic inspection systems. The first is from the most crucial requirement, that is, the real time operation. During a very short time interval, the surface defects must be detected and classified. This gives rise to the problem of intense computing capability and speed. The second difficulty is to increase the robustness of the inspection. In the real factory conditions, the precision the cloth speed pulled by the mechanical pulling equipment can hardly be guaranteed, and the position of the optic-electrical device cannot be accurately maintained. In other words, a high level of background noise may be introduced to the signal. Therefore, the developed inspection system must be quite robust to meet the real operation requirement. The last but not the least important problem is related to the cost of the system. A practical system should be affordable.

Previous research and development on automatic textile inspection systems can be classified as the two basic categories: processing signals from laser beams [8] or using machine vision techniques on CCD images [1][2][5][6]. A typical laser inspection system requires very intense computation (2~4 million pixels per second) with great difficulties in defect classification and a high system cost (more than one million US dollars for hardware only). Previous visual inspection (CCD camera) systems generally require special VLSI [1] or high-cost parallel hardware [2]. Most previous inspection algorithms are designed only for defect detection and few seriously considered the problem of defect classification, which is at least equally or even more important than the defect detection. Defect classification sometimes contributes more to the determination of the textile products' quality level.

In this paper, we will describe our machine vision based automatic inspection system for on-line textile fabrics inspection. The system can perform not only defect detection, but also defect classification in order to determine the quality level of the textile products.

2. Suggested Configuration

Our suggested system introduces the concept of hardware pyramid. Although we currently only consider the use of a single process unit to inspect a small strip of the cloth, we plan to use several parallel processing units to cover the whole width of the cloth. Our suggested processing unit has multiple channels with several CCD cameras connected to each channel. All channels in a processing unit are supposed to be integrated on an image board which has the function of grabbing, digitizing and temporally storing the captured images in each channel. The CCD cameras with low resolution will capture the full-view image of their responsible area of the cloth. Low resolution images are used to locate the regions with defects. CCD cameras with high resolution are used to

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capture fine images. Processing on the high resolution image areas, the computer will determine that an area is "good" (without defects) or "bad". An area is "bad" when the computer algorithm suspects that there is a defect in the area. Then "good" areas are discarded from the high resolution images, but "bad" areas are kept for further processing. The defect classification algorithm employs a hierarchy of neural networks to classify the defect in "bad" areas. We also propose that the system produces a statistical report after a certain length of cloth has been inspected.

As the first step for the system development, we assume that we deal with the inspection of combed polyester cotton gray fabrics. The cloth is one to two meters wide and moves at the speed of 60 meters per minute. We plan to use image board ITEX 100 [3] as the image acquisition unit needed, which has three isolated channels, each connected with a CCD camera. A frame CCD camera with the resolution of 512 x 512 pixels will be connected to the first channel of the board to capture the full-view image; each pixel corresponds to a 2mm x 2mm small area of the cloth. The other two channels will be used for line CCD cameras with the resolution of 1024 lines to capture both half-view images; each pixel corresponds to a 1mm x 1mm small area of the cloth. The three channels will work synchronously so that correspondences among the three images of different resolutions can be easily achieved without any difficulty.

3. Defect Detection

Benefiting from the hardware pyramid described above, the computation intensity required by laser-beam-based inspection systems is greatly reduced. We obtain the full-view image of cloth at a coarse resolution which is only clear enough to discriminate "bad" areas. Ordinary threshold methodology is applied to the coarse image to separate "bad" areas from the "good" background. Experiments show that the brightness of defect areas is quite different from good areas. Therefore, segmentation can be done by simple thresholding. Of course, the suspected areas are marked in the coarse image. On the basis of the correspondence, the areas in the suspicious areas in the fine images from the two other channels are also marked. As explained before, the "good" areas in the fine images will be discarded and the "bad" areas will be kept for further processing.

It should be noted that mean-filtering is used to reduce the effect of noise on the defect detection. However, our strategy is whether the suspicious points in the coarse image are the actual defect areas or just random noises, the corresponding fine image area is stored in a defect buffer for further processing to determine the suspicious defect type. Note that "good" will be also a type of the suspicious defect. Therefore, if a mistake is made in the defect detection, it may be corrected during the defect classification.

4. Defect Classification

Defect classification is the most complicated part for inspection system. It involves illumination compensation, Fourier transform, feature extraction, and pattern recognition.

To eliminate the effect of lighting variation on the image brightness (optical density), we need to mend the gray value of image pixels. A simple smoothing is used to the data stored in the defect buffer.

After lighting mending, FFT (Fast Fourier Transform) is performed on the data in the buffer. Then features are extracted from the power spectrum of FFT which has the expected property of shift-invariance. This property is crucial for our system. Rotational and/or scaling invariance is not required for textile inspection system.

The resulting FFT power spectrum is used as the input to a hierarchy of well-trained neural networks for classification. The neural networks are of the model of feed forward multi-layered network with two hidden layers. We use an improved back propagation algorithm for learning [7]. Each neural network accomplishes a certain task in the classification forming a tree structure in the classification progress. After repeated training from a well-selected prototype set of combed polyester cotton gray fabrics, the group of neural networks can accomplish the task of defect classification. This strategy greatly reduces the complexity in the neural network design.

We also plan that a statistical report will be produced after a certain length of cloth is inspected. The report will help to determine the quality level of this part of cloth.

5. Experimental Results

Preliminary experiments are performed in the computer vision lab of the department of computer science and technology, Tsinghua University. Samples of "good" areas and "bad" areas are imaged for defect detection. The trained neural network group can classify main types of cloth surface defects with a low classification error rate. The results show that our suggested method for defect detection and classification is promising.

Some experiment results are shown in Figure 1 to 4. They are the fully tested on three types of fabric defects including no defect. The ITEX 100 image board is used to grab image frame, digitize it, temporally store it and output the result image to the graphics monitor. The tasks of defect detection and classification are performed on IBM compatible 486/50, all implemented by software. The group of neural networks have learned eight classes of fabric defects by now: good, dirty area, hole, loose threads, jump line, bamboo node, rough area and discontinued thread. The average tolerance is satisfying for the good properties of FFT power spectrum. And the discrimination power is also high above the ordinary power of a single neural network because of our tree structure of neural network group.

Figure 1 shows a coarse (low resolution) image of a cloth area. A suspected area was found and the fine (high resolution) image of the area is shown in Figure 2(a), where a dirty spot can be seen. Figure 2(b) is the FFT power spectrum of Figure 2(a). Figure 3 shows a rough (uneven) area and the corresponding FFT power spectrum. For comparison, we show an image of a good cloth area in Figure 4(a), and its FFT power spectrum is shown in Figure 4(b).

More experiments are certainly needed to evaluate our method in a statistical base.

6. References

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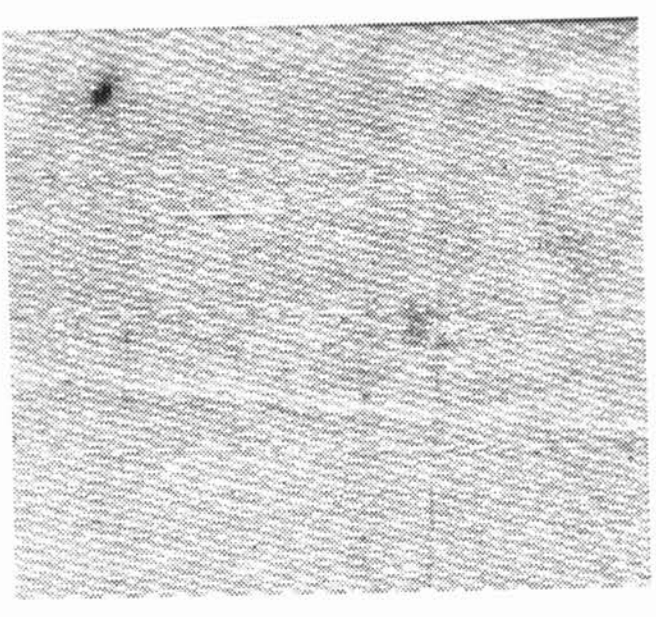
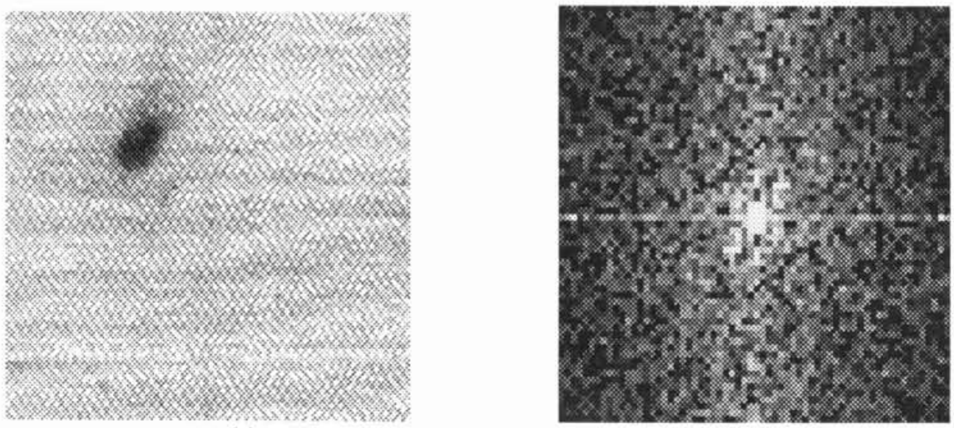
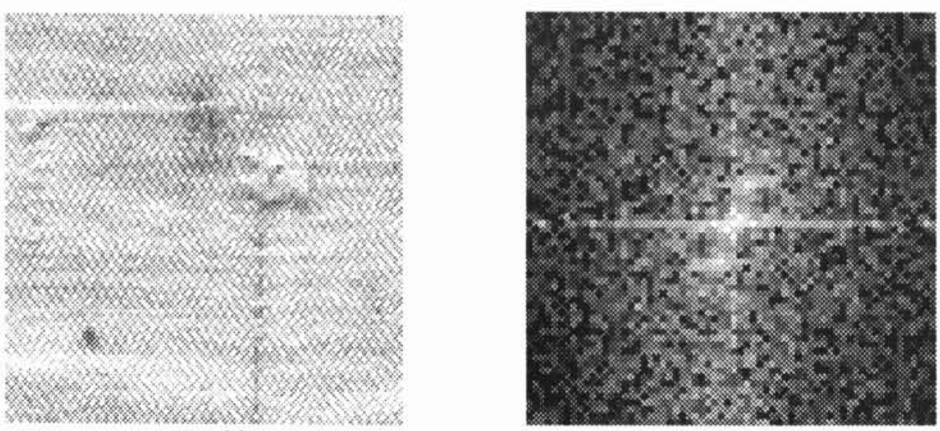


Figure 1. A coarse (low resolution) image of a cloth area.



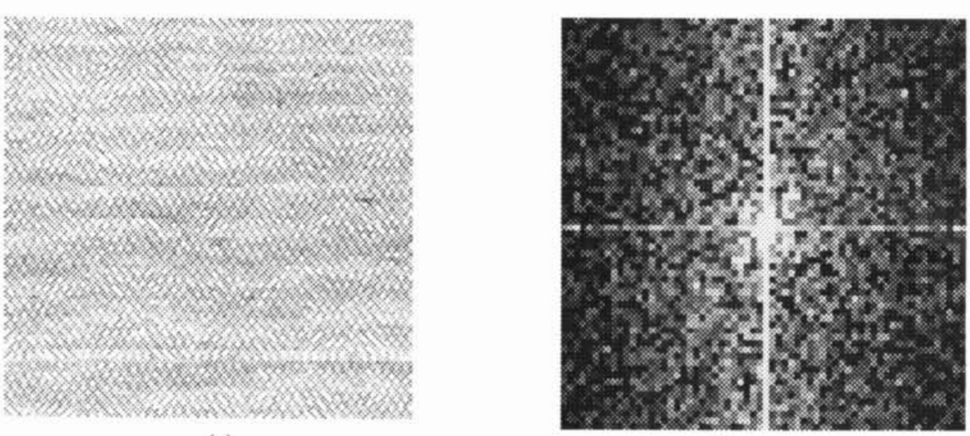
(a) (b)

Figure 2. The fine (high resolution) image of a dirty area (a); and its FFT power spectrum (b).



(a) (b)

Figure 3. The fine (high resolution) image of a rough area (a); and its FFT power spectrum (b).



(a) (b)

Figure 4. The fine (high resolution) image of a good area (a), and its FFT power spectrum (b).