Parts Surface Structure Image Classification Detection System Design

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Abstract

In order to accomplish the automatic nondestructive testing, a parts surface structure image classification detection system is designed. A series of parts surface texture images have been obtained from different processing methods for feature analysis and the combination of pre-processing method by MATLAB image processing toolbox has been put forward, using statistical analysis method for feature extraction. Based on the established BP neural network training optimization identification system, this paper realized the recognition of parts surface resulted from four kinds of processing methods: turning, milling, planning and grinding. The research results show that the deficit value of gray level co-occurrence matrix and the histogram matrix variance value can be regarded as characteristic parts of the surface texture structure value, providing foundations for further development of parts surface structure detection.

Keywords: Surface structure, image detection, feature extraction, BP neural network, classification and recognition

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1. Introduction

Parts surface structure is composed of contour superposition with geometric features such as surface roughness, waviness and form error. Because the machining parameters such as cutting tool, cutting speed, feed, depth, turning trajectory are different, parts surface texture characterizations of geometric feature are also different. Each image texture not only represents the common attributes of a specific object or a certain type of objects, but also has its unique properties and characteristics. This paper analyzed the characteristics of surface structure of parts resulted from four processing methods, turning, milling, planning, and grinding, and propose an image preprocessing method based on MATLAB image toolkit. The Research purpose is to extract characteristic value of parts surface structure by statistical analysis, and on this basis, to further determine the recognition classifier in order to realize the identification of parts of the surface structure of image. The results of the study will lay a foundation for further promoting parts surface structure detection, and provide references for the construction of parts online detection system [1-5].

2. The Overall Design of the Detection System

The detection system design flow chart is shown in Figure 1. The sample images and the images to be detected are obtained through the CCD camera aforespand. The left part of the plot is the “nerve center” of the classification system. First the multi sample images (such as standard sample input image) are inputted in order, and after image preprocessing, feature extraction, and BP neural network training, the training results regarded as the classifier are shown as output on the designed GUI interface. The right part is the working part of the classification system. All needed is to input the texture image to be detected, and via the image data processing, image classification and recognition, the classification results can be obtained. This system uses AM413ZT digital microscope (Polarizer) as the image acquisition hardware equipment with the optical resolution of 1280*1024dpi [6, 7].

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3. Image Preprocessing

Pretreatment of image has four steps: image type conversion, image background subtraction, histogram equalization, and median filter [8, 9].

First of all, load the collected part machining surface texture color image into the system, and use the custom weighted average method for gray conversion, as shown in the formula (1), with R, G, B in the formula representing the input RGB tricolor matrix image. Experiments show that this method saves more information with the gray level image than directly calling the rgb2gray function.

\[ f(x, y) = 0.299R(x, y) + 0.578G(x, y) + 0.114B(x, y) \]  \hspace{1cm} (1)

In order to eliminate the uneven illumination of the image, we use diamond scanning, rectangular scanning, and circular scanning on the gray image for background subtraction. By comparison, diamond scanning method does not satisfactorily eliminate the original uneven illumination of the image; while the rectangular scanning method eliminates the original uneven illumination of the image, the image becomes very dark and loses most of its information. Only the circular scanning method successfully solves the uneven illumination problems of the original image, and nicely retains most information of the original image at the same time.

Histogram equalization is a method to realize image enhancement by changing the distribution of the pixels of the image histogram, as shown in Figure 2 and Figure 3. Using “adapthisteq” equalization processing to limit the contrast, not only retains most of the original information, but also eliminates the unnecessary noise, so that the image quality can be improved to a large extent.
Images obtained via image acquisition usually contain a lot of noise. In order to get the accurate image information, prior to image analysis the unwanted noise must be removed through the filter. Experimental results show that while the traditional medfilt2 median filtering method decreases the noise of the image, the image is more blurred and the overall quality decreased. Using two-dimensional statistical order ordfilt2 filtering processing, not only is the image noise eliminated, but also the image quality is greatly improved.

4. Texture Image Feature Extraction

In the 1980s, J • K • Hawkins proposed the three elements of a texture, i.e. the repeatability partial sequence of image data, the periodic of arranged sequence motifs, and the similarity of image data region structure size. Considering the machining parts surface texture features and experimental conditions, the statistical analysis method of gray level co-occurrence matrix (GLCM) and the histogram matrix are selected for texture analysis of image characteristic value extraction.

4.1. Extracting Feature Parameters of GLCM

The GLCM is a matrix function of pixel distance and angle, which calculates statistically the frequency of occurrence $p(i,j,d,\theta)$ that a pixel gray $i(position(x,y))$ and a pixel gray $j(position(x+dx,y+dy))$ occur synchronously, to reflect the comprehensive information of the image in the direction, interval, magnitude and speed of change. Its mathematical expression is:

$$p(i,j,d,\theta) = [f(x,y),(x+dx,y+dy)|f(x,y)=i,f(x+dx,y+dy)=j]$$

(2)
The GLCM eigenvalue of the textures images were calculated in four directions along 0°, 45°, 90° and 135° respectively. It includes six kinds of statistics such as Angular Second Moment (ASM), Entropy (ENT), Contrast (CON), Inverse Difference Moment (IDM), Dissimilarity (DIS) and Correlation (COR). Test results show the relationship between the statistics in different directions is similar, therefore only the eigenvalue of 0° is analyzed in this paper. Through the integration of induction sample images, we obtain the GLCM eigenvalue’s minimum and maximum values of various processing methods of training samples, and further to the eigenvalue data for visualization, get the GLCM curve feature value range, as shown in Figure 4.

From Figure 4(a), (c), (d) and (f), four methods of processing GLCM ASM, CON, COR and DIS, the two interference range is wide, as well as the data value of milling machine and planning machine is smaller than the lathes and grinding machine, if using this data as a characteristic value, the entire system can identify the two processing methods, so it does not meet the requirement of significant differences when selected eigenvalues. As shown in Figure 4. (b) and (e), although the ENT and IDM also generate pairwise interference phenomenon, four sets of data pairwise interference range is narrow, such data can be used as the characteristic value if the difference of eigenvalues is large.

![Figure 4. The GLCM feature curve of four kinds processing](image)

### 4.2. Extraction of the Feature Parameters of the Histogram Matrix

The histogram has a gray statistical result of single pixel image. The texture profile image is composed of a texture element through certain rules into the permutation and combination so through the analysis and calculation of the gray histogram, we can representation and identifies texture primitive permutation and combination of periodicity and directionality.

Through the integration of sample images, we draw the eigenvalues’ minimum and maximum of each histogram feature of training samples, further for data visualization processing, and get the histogram feature curve, as shown in Figure 5.
Figure 5. The histogram feature curve of four kinds processing

From Figure 5(a), the histogram matrix’s mean curve of four kinds processing methods occur pairwise interference phenomenon, and the data value of milling machine and planning machine are smaller than lathe and grinding machine, if using this data set as the feature value, the whole system can only recognize two kinds of processing methods so it does not accord with the feature value obvious difference in the selection of requirements. The histogram matrix energy (Figure 5(b)) and ENT (Figure 5(c)) have great interference. Therefore it is not suitable as a feature value of the classification system. While as shown as the Figure 5(d), histogram variance (VAR) is large difference, and less interference phenomenon occurs between data, when the four groups of data encounter little difference as its magnification, four kinds of processing methods of data can be distinguish greatly.

4.3. Extraction of System Features

Based on the above analysis, the NT and IDM of GLCM can be used as the feature value data, but for histogram data matrix only the variance can be taken as the feature value data, since these feature values have not significantly different in four processing method, they must be used synthetically for analysis. Among these three feature value, the histogram matrix’s variance should be the priority to choose for its smaller interference, in addition, because the GLCM ENT and IDM are antagonistic they cannot be used simultaneously and the histogram matrix variance in numerical milling and planning is far less than the turning and grinding, so the effect will be better if choose a feature of milling machine and planning data is greater than the turning and grinding data to work with. Thus, the final selection is to select and use IDM of GLCM values and the histogram matrix’s VAR as the feature value of this system.

5. BP Neural Network Design

| Table 1. Design parameters of BP neural network |
|-----------------------------------------------|
| **Parameter type** | **Parameter name** | **Parameter value** |
| BP neural network structure parameter          | The input layer | 2 |
| | The hidden layer | 25 |
| | The output layer | 1 |
| | The hidden layer transfer function | logsig |
| | The output layer transfer function | purelin |
| | The training function | traingdx |
| | The weight learning function | Learngdm |
| BP neural network training parameter           | Epochs | 20000 |
| | Show | 25 |
| | Goal | 0.01 |
| | Learning rate | 0.001 |

Data for 104 samples eigenvalues series are processed to neural network design. In order to improve the system of training accuracy, the number of hidden layer is to conducted many experiments, experiments show that, when the number of hidden layer is 25, the value of
training can achieve the target value, the design parameters of the neural network are listed in Table 1, as surface texture recognition classifier are processed by different methods.

6. Graphical User Interface Design

MATLAB GUI interface is also known as the software graphical user interface, It can be through menus, windows, controls, and text and other items constitute a custom-designed software interface, users can through the project you have already set up , using the mouse, keyboard and other input devices to easily achieve the overall operation of the system.

Design of the software interface is shown in Figure 6 including two modules sample training area and system identification zone.

In the sample training area, click on the "Sample collection" button, the system will collect the sample image, and data collected are grayscale conversion, background subtraction, histogram equalization, median filtering, feature extraction, preservation data and other steps, at the same time, the new interface will appear a "Running waiting box", when all the above steps are completed, waiting for the box will be automatically shut down. Click "BP network training" button, the system will carry on the training of BP neural network on the sample data store, and store the results of training output, as the working area of the classifier.

In the system identification area, click the "Import texture image" button, the system will pops up the picture dialog box to select the picture, according to the instruction is completed, the image will be displayed in the GUI interface on the coordinate axis.

Click "Export gray image" button, the system will process image type conversion from the entered texture image, the conversion from the original RGB image into a gray image, and preprocess the image, and display the processed image.

Click "Show eigenvalues" button, the system will automatically calculate the eigenvalues of the image and displays a histogram variance matrix and GLCM IDM value in the text box.

Click "Export results" button, the system will through the classifier and combine extracted eigenvalues to simulate, and finally show the classification results in the text box.

Figure 6. The software interface
7. Results and Analysis

By turning, milling, planning and grinding four processing methods to produce a surface roughness Ra in the range of 0.8 ~ 12.5µm standard specimen for image acquisition, a total of 104 images samples were collected for BP neural network training, forming the central classifier, and then classifying inspection of parts surface texture image generated by the above four kinds of processing methods, then the reliability of system is obtained. The statistical results of the test are shown in Table 2.

| Texture type | The image number with training | The image number with test | Accurate identification number | Recognition rate |
|--------------|-------------------------------|---------------------------|--------------------------------|------------------|
| turning      | 26                            | 26                        | 26                             | 100.00%          |
| milling      | 26                            | 26                        | 23                             | 88.46%           |
| planning     | 26                            | 26                        | 21                             | 80.77%           |
| grinding     | 26                            | 26                        | 25                             | 96.15%           |
| total        | 104                           | 104                       | 95                             | 91.35%           |

A total of 104 test images through the classification system can accurately identify a total of 95 images, the system overall recognition rate reach 91.35%, in which the turning and grinding parts have higher degree of texture recognition. Statistical analysis showed that use the images GLCM IDM and its histogram matrix VAR as the characteristic value, can be a good process for turning and grinding texture classification, but for milling and planning parts, especially processing flat parts processing, because of the cutting tool angle and cutting conditions is a more consistent, so that the texture recognition is slightly lower, but generally it does not affect the reliability of the classification system.

8. Conclusion

In this paper, turning, milling, planning, grinding four basic parts machining methods were designed texture image classification system, through contrast experiment of image preprocessing, feature extraction and neural network design and other aspects in the design process, finding out using image GLCM IDM and histogram matrix VAR as a combined feature, and using the BP neural network training, constructing the recognition classifier, gets one-to-one correspondence with various processing texture image, thus realizing the purpose of processing method of parts classification, and to determine the reliability of algorithm through experimental statistics.

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