Methods of recognizing chips’ shape based on neural net

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ABSTRACT

Aiming at the problem of process monitoring on chip generating in automatic machining, methods of recognizing chips’ shape based on neural net are researched in this paper. The conception of area ratio of the chip image to the located window is defined, the area ratio feature has been proposed because the size of all windows and the direction of chips are respectively same. At the same time, the Euler number characteristic and disperse degree characteristic of the chip image have been worked out. The above geometry characteristics of the chip image are chosen as input vectors of neural network, and the 50 various images of each type such as C shape, spiral shape and disorderly shape are chosen as training sample, the recursion least square law is used to train network. The recognition rate and training time of the BP network are compared with those of the RBF network, so the conclusion that the RBF network is superior to the BP network at the aspect of chip shape recognition has got, and the relevant computer program has been developed, which possess good real-time application and adaptability by way of the experiment certification. The recognition rate achieves more than 90%.

Keywords: Recognizing chips’ shape, neural net, automatic machining, image analysis.

1. INTRODUCTION

The metal cutting owns the great proportion in modern manufacturing. The good or bad of chips’ shape influences the whole automation process system, that the chips break ineffectively will result in chips wrapping workpieces and tools, which not only reduce the quality of the machined surface and productivity, but also put tools, lathe and operator in danger. Now, the method which applied in machining system is using many kinds of sensors to test the factors which affect cutting process, such as cutting force, cutting heat, cutting vibration etc. so the chips’ shape and tool state is monitored, and these will ascertain the normality of the system and can process qualified products, but can not in the very wide scope very effective. In this paper, the artificial neural network is used to recognize chips’ shape. The chips’ images are obtained by video camera, then are conveyed to the computer, and then are transformed into digital images, so their Characteristics are acquired as input. The chips’ shape is recognized in the minimal error scope, after learning and training. The advantage of the method is visual and rapid, and it is very valuable for recognizing chips’ shape in the future.

2. DEFINITION OF CHARACTERISTIC PARAMETER OF CHIPS IMAGE

Under different processing conditions, such as different cutting depth, feed rate, cutting speed or workpiece material, it will generate various chips’ shape, like annular shape, annular-spiral shape, cone-spiral shape, tube shape, tube-spiral shape, and disorderly shape etc. C shape, spiral shape and disorderly shape are familiar forms under normal condition. In this paper, chips’ shape is divided into three types of typical shape, shown as Fig.1. Chips’ shapes are differ in thousands of way. Even to the congener shape, there is not a fixed characteristic parameter, which can differentiate one shape from other shape. So it
is necessary to research those characteristics, which can be used in classification and easily realized by program. In search of chips’ characteristics, we should take it into account that characteristic parameters are insensitive to different workpiece material, the chips’ bright and the image’s dimension etc. In terms of the classification of chips’ shape, characteristics of each type of chips are selected.

2.1. The characteristic of area ratio of chip

We can get the coordinates (x, y) of the top point of the chip by scanning the binary image \( g(i,j) \) of chips every row and every column. Change the start point and the direction of the scanning, repeating this process three times, then obtain the coordinate \((x_1, y_1)\) of the lowest, \((x_2, y_2)\) of the most left and \((x_3, y_3)\) of the most right respectively, at the same time get the inclination angle \( \gamma \) which is the chip opposite to the \( x \) axial. Adjust it to 45 degrees, and unify the image size. Scan again and obtain four peak coordinate \((X, Y), (X_1, Y_1), (X_2, Y_2), (X_3, Y_3)\), then crop the image with these coordinates. So the image which is tangency to the object chip and whose \( \gamma \) is unified can be gained. In order to minimize error, we should fill holes or hollows in image at the beginning of the program, but this operation has only affect disorderly type chip. We suppose \( A \) as the value of the area of chips and \( A_{all} \) as the value of the area of the window which the chips lie in, then the area ratio of the chip image to the whole image \( Q \) can be expressed as:

\[
Q = \frac{A}{A_{all}}
\]  

We can straightforwardly see that the area ratio of the disorderly type chip is the biggest, and the area ration of the other type chips is very small, so we can differentiate the disorderly type chip from the others.

2.2. Characteristics of Euler number

In the property of topological, the definition of Euler number and the operator of description region is the number of holes subtracted from the number of connected objects. \( H \) is taken as the number of holes of one image and \( C \) as the number of connected parts of the image. Euler number is defined as:

\[
E = C - H
\]  

The numbers of holes in the region is taken as the operator of topological description, so obviously this characteristic is not affected by stretch and revolving. In this paper, image (2) is obtained by rotating the original chip image (1) 180 degree on its axis, then image (1) and image (2) are proceeded with logical OR procession, finally two images are added and get image (3). The image (3) of C type chips has a hole, but that of spiral type chips has no hole, so we can differentiate the C type chips from the spiral type chips by calculating Euler number.

2.3. Characteristics of disperse degree

Suppose \( A \) as the area of subclass \( S \) of chip image and \( W \) as the width. \( A/W \) is defined as the disperse degree, namely making \( S \) disappear completely, the step contracted to the minimal that needs. The area \( A \) of the image has been calculated, the width \( W \) can be calculated by the position coordinate of up, down, left and right, then the disperse degree \( L \) can be deduced. Comparing with the three types of chips at the same area, the disperse degree of the spiral chip is the biggest.

3. STRUCTURE MODELS AND ALGORITHMS OF THE NEURAL NETWORK

Neural net comprises a group of mid-associated nerve cells, and every nerve cell has own transfer function. In other words, the output vector is equal to the sum of the input vector adds to the weighted value. For the model, it is necessary to ascertain a kind of link model, which is the arithmetic, to ascertain mid-layer's weighted value and transfer function. In this paper, we use Radial Basis Function (RBF) network of multi-layer feedback and local approach. Back-Propogation (BP) net is often used in pattern classification, and it is significance at most aspect. But when BP network is used in the approximation of function, adjust weight value according to the gradient descent law, so it exists some shortcoming of part extremely small and slow disappearing. RBF network is superior to BP network in approaching ability, categorized ability and study speed etc.
3.1. Model of RBF net

RBF net is a kind of typical part approach neural net. The transfer function of the neuron of RBF is radbas, and the output of radbas is the multiply of the distance between input vector and weight value vector by threshold value b. The RBF network includes two latent layers (namely radbas layer, includes S neuron) and output layer (namely pure line layer, includes S neuron). Fig. 2 is the structure chart of one RBF network.

3.2. Determination of input vector and output vector

The input layer of neural net only is a buffer, which transfers the input vector to the next layer. Because neural network can only deal with data, characteristic parameters of chips’ images should be calculated as input vectors. We respectively calculate area, perimeter, area ratio, Euler number, disperse degree and moment of the chip image, and take area ratio, disperse degree, Euler number as input vectors of this neural net.

We only need to recognize three types of chips, so we define 0 and 1 as the output variable of this neural net, and the output value may have four cases, namely 00, 01,10 and 11. The output of C type chip is defined as bits 00, accordingly, spiral type, disorderly type, and invalid state is defined as 10,11 and 01 respectively. If the bit 01 takes place in the course of recognizing, the network will be regarded as making mistakes and we should strengthen training network further and increase some data of edge to make network recognize critical state data well. The input vector of the neural net is shown as Table 1, and the output vector is shown as Table 2 by summarizing experiment data. We dispose of above-mentioned characteristics in the way of no dimension measures at the time of calculating.

<table>
<thead>
<tr>
<th>Chip’s shape</th>
<th>Disperse degree</th>
<th>Area ratio</th>
<th>Euler number</th>
</tr>
</thead>
<tbody>
<tr>
<td>C shape</td>
<td>0.2~0.4</td>
<td>0.3~0.42</td>
<td>0</td>
</tr>
<tr>
<td>Spiral shape</td>
<td>0.08~0.09</td>
<td>0.14~0.18</td>
<td>1</td>
</tr>
<tr>
<td>Disorderly</td>
<td>0.4~0.7</td>
<td>0.45~0.5</td>
<td>Uncertainly</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chip’s shape</th>
<th>The state of output 1</th>
<th>The state of output 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>C shape</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Spiral shape</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Disorderly</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

3.3. The training and studying algorithm of RBF network

The interaction of different neuron of neural net is shown as “touch value”, and the learning process of neural net is adjusting the ‘touch value’ constantly until to make the actual output of the network approach to the expected output. It is impossible for us to train all chips’ images, so we choose typical and favorable to the learning of neural net as the sample for training the neural net, which ensure the network to training to all categorized modes. After the network reach the permitted error by training for some time or after all sample learned by the neural net, the training finishes. Verify the capability of the neural net with experiment data, and analysis the result to see if it fulfills requirements.
In this paper, algorithm RLS (recursion least square) is shown as follows:

1) Supply \( W_{0-M} \) (initial weight matrix) value, and train \( \hat{P}(0) \) (the starting value of inverse correlation matrix of samples) and \( \varepsilon_{\text{min}} \) (the stopping value of iteration of error);

2) Randomly choose the center vector \( C_i \) of RBFN from the training sample, \( 1 \leq i \leq M \); 

3) Calculate the radial basis function;

4) Start iteration;

5) Calculate \( \hat{K}(n) \) and inverse correlation matrix \( \hat{P}(n) \) respectively according to the following formula:

\[
\hat{K}(n) = \frac{\hat{P}(n-1)Z(n)}{\hat{P}(n-1)Z(n) + \hat{P}(n-1)\hat{P}(n-1)Z(n)} \\
\hat{P}(n) = \frac{1}{\lambda} [\hat{P}(n-1) - \hat{K}(n)Z'(n)\hat{P}(n-1)] \\
\hat{W}(n) = \hat{W}(n-1) + \hat{K}(n)[d(n) - Z'(n)\hat{W}(n-1)]
\] (3)

6) Calculate the error signal

\[ E(n) = d(n) - Z'(n)\hat{W}(n-1) \] (4)

7) Calculate \( \hat{W}(n) \) according to the formula (3);

8) Calculate the accumulating error according to following formula:

\[ J(n) = \lambda J(n-1) + \frac{1}{2} \sum_{i=1}^{n} [d(n) - Z'(n)\hat{W}(n-1)]^2 \] (5)

9) If \( J(n) \geq \varepsilon_{\text{min}} \) then goes to the fifth step, or goes to the tenth step;

10) Training over.

### 4. RESULTS

During the course of experiment, 50 various images of each type such as C shape, spiral shape and disorderly shape are chosen as training sample. We increase critical image data for reducing ratio of fault recognition. The result of the test shows that RBF net can reach 10-2, the square of the minimal error of training, within 10 training steps, while BP net should take six times of RBF at least, sometimes even longer. The comparison between the errors of BP net and that of RBF net is show as Fig. 3.

![Fig. 3. The comparison between the errors of RBF net and that of BP net.](image-url)
5. CONCLUSIONS

The result of the experiment shows that the method of recognizing chips’ shape based on neural net has obvious advantages as following:

1) It’s easy to formulate complicated algorithms and program them with the MATLAB.
2) RBF network is superior to BP network in approaching ability, categorized ability and learning speed when it is used in chips’ shape recognition.
3) Area ratio, Euler number and disperse degree are defined as input vectors of the neural net.
4) The training time is within 10 steps and the recognition rate achieves more than 90%.

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