PREDICTION OF MACHINE TOOL ROUGHNESS BASED ON ANN

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Abstract: This paper presents a method based on ANN to predict the surface roughness of parts in machining process. The mathematical simulation software MATLAB is used to establish the ANN model, and it is found that the error between the predicted value and the actual data is very small, between 6% and 15%. This method can combine artificial neural network with machinery, which is instructive for future research. This method has low operation threshold, does not need too complex geometric operation, only need a lot of data can get good results. Therefore, the ANN method can be used to predict and control the surface roughness of the workpiece.

1.INTRODUCTION
Surface roughness is a kind of geometric shape error whose wave distance is less than 1mm. The excellent degree of surface roughness will affect the fatigue strength, stability and interchangeability of mechanical parts. The control of surface roughness is an important process to ensure the smooth operation of the machine and improve and prolong the service life of the machine. Therefore, in many parts with high design accuracy, the precision of surface roughness will be strictly controlled. Only high precision surface roughness can achieve internal control objectives. In recent years, China’s machinery manufacturing industry has been actively seeking cooperation and exchanges with foreign machinery manufacturers, thus greatly improving product quality and performance. However, the processing of precision parts is still a major challenge in the development of China’s machinery industry.

AI technology is a kind of technology which is widely valued in the field of computer. The computer parses the external data through the algorithm given by human beings, and learns from the deconstructed data to flexibly adapt to the environment, realize the goal and solve the task. Therefore, in the field of machinery, AI technology can play a decisive role in improving precision machining technology. Researchers have made relevant application studies for this purpose. For example, Lo proposed an ANFIS model when predicting the surface roughness of the workpiece in the end face milling process. The model uses two middle functions to describe the membership of these inputs. One is a triangular function, and the other is a trapezoidal function. The former can make the average error only maintain at 4% and the accuracy is 96% when predicting the surface roughness. The latter has only 93.3% accuracy and 6.7% average error.

Ho and his team got similar results to Lo’s ANFIS model based on trigonometric function when controlling the surface roughness of parts. They combined ANFIS with GA to keep the prediction error of workpiece surface roughness at 4.06%.

When Sharkawy controls and predicts the surface roughness studied, three AI methods are used for modeling to control the average error within 4-5%.
Dong et al. proposed a modeling method based on LOO-CV when predicting the surface roughness in the machining process of parts. Average error controlled at 3.62%.

Ali M team applied ANFIS to predict surface roughness. This adaptive neuro-fuzzy inference system has high precision, which can maintain the average error at 3.47% - 3.49%.

Based on the above researchers, this paper proposes a method based on ANN as the basic linguistic logic model to predict and control the surface roughness in the production process, which is a convenient and accurate prediction method for model construction. ANN model construction needs to divide input and output data into rule areas. The input data and output data are imported into the input layer and the output layer, respectively, as the input and output of the machine. The operator sets different numbers of hidden layers and hidden neurons to make the machine for deep learning. At runtime, the model will capture, learn, verify and predict the random data, and finally get the complete machine learning results by computing. Note that the number of hidden layers and neurons in different hidden layers will affect the accuracy and error of the final results. Through continuous simulation, a machine learning model with high accuracy and stable and reliable model is finally obtained, which is a necessary means to reduce the risk of excessive error value.

The objective of this experiment is to give machine intelligence, to predict surface roughness quickly and conveniently with the lowest working cost, and to control the prediction results by using new processing technology. The ANN prediction model proposed by researchers is a simple operation structure and low operation difficulty method, which can combine machinery with artificial neural network, and has certain enlightening significance for future related research. At the same time, the proposed model does not require too complex geometric operations, and only needs to provide abundant data sets to obtain reliable prediction results. This article will describe the theoretical background of ANN in the next section. The third section shows the reliable data obtained by researchers. Finally, the conclusions are discussed and the results are evaluated.

2. ARTIFICIAL NEURAL NETWORK (ANN)

Artificial neural network is a widely used information processing system. It simulates the thinking mode of biology, abstracts the signal generated by human brain after external excitation and its organizational structure and operation mechanism, and simplifies it. Finally, a series of input data are simulated by the internal mathematical model to obtain the output of the neural network. Note here that the input and output values are standardized results, is a nonlinear functional correspondence. By setting different weights of neurons, the expected results are also different. This process is the training process of neural network. The entire artificial neural network model can obtain an abstract mapping between the two by learning the input data samples and the set model structure as samples. This process realizes the human experience thinking mode.

ANN has two classifications of multi-layer and single-layer, and each has several neurons. In general, the input layer and output layer of ANN network structure are determined by the input data set collected by the controller and the ideal output set obtained by the controller. Input how many eigenvalues, should set how many input layer neurons. The ideal number of output data that the operator wants should also be consistent with the number of neurons in the output layer. The middle is the hidden layer, including hidden neurons. Setting different number of hidden neurons can get different prediction results. According to the empirical formula, the number of neurons in the hidden layer should maintain such relationship with the input neurons:

$$A = 2 \times B + 1$$  \hspace{1cm} (1)

$$A = \text{Number of hidden layer neurons}$$
$$B = \text{Number of neurons in input layer}$$

In order to better explain the concept of ANN structure, this paper uses three completely different layers to describe the structural model of ANN. The first layer is the input layer, the second layer is the hidden layer, and the third layer is the output layer. When searching for the optimal prediction error with the smallest error, we can first set a hidden layer, and then compare the results after adding several hidden layers to obtain the optimal solution. Figure 1 shows the basic structure of ANN with four inputs.
3. RESULT AND DISCUSSION
In order to establish the artificial neural network model mentioned in this paper, the researchers refer to the relevant information of mechanical processing, and believe that many factors will affect the surface roughness of parts in the processing. The factors that can be controlled manually are usually concentrated in the following three aspects: depth of cut DEP, spindle speed SP and feed rate FE. Table 1 shows the input variable code used in this experiment. Table 2 shows the data sample used in this experiment, which is based on the data set of Ali M team survey. The purpose of this paper is to propose a simpler and more effective method to predict the results, which is also the reason why researchers use these four eigenvalues.

| Eigenvalue      | Code | Unit              |
|-----------------|------|-------------------|
| Depth of cut    | DEP  | Revolutions per minute |
| Spindle speed   | SP   | Inch per minute   |
| Feed rate       | FE   | Inch              |
| Roughness       | RA   | Micron inches     |

### Table 2: Experimental data

| Sequence | SP  | FE  | DEP  | RA  | Sequence | SP  | FE  | DEP  | RA  |
|----------|-----|-----|------|-----|----------|-----|-----|------|-----|
| 1        | 750 | 6   | 0.01 | 65  | 25       | 1250| 6   | 0.01 | 50  |
| 2        | 750 | 6   | 0.03 | 63  | 26       | 1250| 6   | 0.03 | 63  |
| 3        | 750 | 6   | 0.05 | 72  | 27       | 1250| 6   | 0.05 | 71  |
| 4        | 750 | 12  | 0.01 | 144 | 28       | 1250| 12  | 0.01 | 101 |
| 5        | 750 | 12  | 0.03 | 102 | 29       | 1250| 12  | 0.03 | 99  |
| 6        | 750 | 12  | 0.05 | 94  | 30       | 1250| 12  | 0.05 | 85  |
| 7        | 750 | 18  | 0.01 | 185 | 31       | 1250| 18  | 0.01 | 115 |
| 8        | 750 | 18  | 0.03 | 147 | 32       | 1250| 18  | 0.03 | 92  |
| 9        | 750 | 18  | 0.05 | 121 | 33       | 1250| 18  | 0.05 | 95  |
| 10       | 750 | 24  | 0.01 | 187 | 34       | 1250| 24  | 0.01 | 155 |

Fig 1 Basic structure of ANN model
After obtaining reliable data, researchers used neural network fitting App in mathematical simulation software MATLAB for the first simulation operation. After importing input and output data into the UI interface, 70% of the data is randomly selected for training, 15% of the data is used for verification, and the remaining 15% of the data is used for testing. The optimal number of hidden neurons can be calculated by formula (1) to be 7. Start training after setting. The results are shown in Fig. 2 and Fig. 3. It can be seen that the initial training results are very consistent with the original data. It has good research prospects.

![Error Histogram with 20 Bins](image)

**Fig. 2:** Error display calculated
Fig. 3: Error display calculated (2)

On this basis, the researchers set the model of artificial neural network, hoping to obtain the specific error value. In order to better evaluate the accuracy and practicality of this experiment. In Table 3, the researchers give the language rules for constructing this model.

| Table 3: Language rules |
|-------------------------|
| 1. inputs = input';     | 16. [net,tr] = train(net,inputs,targets); |
| 2. targets = output';   | 17. test_inputs = []; |
| 3. hiddenLayerSize = 7; | 18. test_targets = []; |
| 4. net = fitnet(hiddenLayerSize); |
| 5. net = fitnet(hiddenLayerSize); |
| 6. net.divideFcn = 'divideind'; |
| dividerand(48,0.8,0.1,0.1); |
| 9. net.divideParam.trainInd = trainInd; |
| 10. net.divideParam.valInd = valInd; |
| 11. net.divideParam.testInd = testInd; |
| 12. net.trainParam.epochs = 10000; |
| 13. net.layers{1}.transferFcn = 'logsig'; |
| 14. net.trainParam.min_grad = 1.0e-08; |
| 15. net.trainParam.epochs = 10000; |
| 16. net.trainParam.trainParam.epochs = 10000; |
| 17. test_inputs = []; |
| 18. test_targets = []; |
| 19. for i = 1:length(testInd) |
| 20. test_inputs(:,i)=inputs(:,testInd(i)); |
| 21. test_targets(:,i)=targets(:,testInd(i)); |
| 22. end |
| 23. test_outputs = net(test_inputs) |
| 24. errors = gsubtract(test_outputs,test_targets); |
| 25. relative_errors = errors./test_targets; |
| 26. mean_relative_error = mean(abs(relative_errors)); |
| 27. save('ann_fd2') |
| 28. Test the Network |
| 29. View the Network |
| 30. view(net) |

It is worth noting that the researchers re-set the training proportion. After the test, it is found that increasing the training proportion to 80% can improve the accuracy to a certain extent. Finally statistics the first eight error statistics. It is shown in Table 4.
This information can be obtained from the error statistics, that is, the error is between 6% and 15%. Through multiple training can make the accuracy not less than 90%. This means that the ANN model proposed in this paper can predict the surface roughness of parts in machining process with good accuracy and simple method.

4. Conclusions
In this paper, an ANN model inference system is proposed to predict and control the surface roughness of the workpiece during the machining process of the workpiece. The experimental results show good accuracy, and the average error is between 6% and 15%. This means that the proposed model can well predict the surface roughness of the workpiece to be processed, and the operation threshold is low and easy to implement. In the future development, the upgrading of the model needs further research.

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