Research On Neural Network Quality Prediction Model Based On Genetic Algorithm

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Abstract. In industrial production process, it is difficult to predict product quality in advance. Traditional prediction methods are mostly based on complex mechanism models, and the prediction accuracy is not high. This paper uses the historical data of industrial production to forecast, constructs the quality prediction model of neural network, and uses genetic algorithm to optimize the network parameters, so as to avoid the neural network falling into local optimum. This paper takes the data of hot rolling production line as an example and adopts the method to predict the quality index of steel plate. The simulation result shows that the quality prediction model of neural network based on genetic algorithm has better prediction ability. This method has important theoretical value and practical significance for production workers to improve product quality.

1. Introduction
Quality prediction is also called soft measurement technology. According to the mathematical relationship between auxiliary variables and dominant variables, various mathematical calculation and estimation methods are used to realize the prediction of the predicted variables [1]. With the increasing competition in the market and the increasing complexity and high coupling direction of industrial production, further improvement of product quality is particularly important. Before the completion of the product manufacturing, the predicted value of the quality prediction can be used as the control parameter of the control system or the process parameters of the reaction process, provide control and decision information for the industrial production process, thereby it improves product quality and enhances the competitiveness of the enterprise. At present, quality prediction has become the focus of research in the field of industrial processes. For this reason, many scholars adopt different methods to establish quality prediction models to improve the accuracy of prediction, and obtain rich research results.

Wang Meiqi and others [2] built a mechanism model based on the heat balance effect and heat transfer theory to predict the temperature of the grate cooler effectively. Feng Shaowei and others [3] established a dynamic analysis model to obtain the dynamic response characteristics of the rocket booster, which provides reference and theoretical support for the engineering application of the rocket booster. Wang Fang and others [4] established the mechanism model of corn stalk and anaerobic fermentation biogas residue, which provided theoretical basis for the industrial application of biofuel preparation. Using statistical regression method to establish mathematical models is also one of the most commonly used methods for quality prediction. Xu Yingchao and others [5] established a regression model to accurately predict the reducing sugar content in Potato by multiple nonlinear regression analysis of experimental data. Meng Xiangde and others [6] used the method of paired comparison to study the subjective evaluation of diesel engine sound quality. The prediction model of
diesel engine sound quality was established based on the theory of multiple linear regression. The experiment proved that the prediction value of multiple linear regression model had little difference from the actual value of subjective evaluation, and could effectively predict the sound quality. With the rapid development of machine learning methods, support vector machines, artificial neural networks, fuzzy control and other methods are widely used in the field of quality prediction. Ge Yulong and others [7] used the finite element model to fully excavate the factors that affect the forming quality from the sample data, and then used the radial basis function neural network to establish a prediction model that predict the degree of tube NC bending. Dong Hua and others [8] used membership function to blur the samples, and established a prediction model of fuzzy least squares support vector based on time domain description membership. The model is mainly based on current process parameters, weakening the influence of historical parameters. Compared with the traditional prediction model, the model has higher accuracy.

Artificial neural network (ANN) is widely used in the field of quality prediction because of its good nonlinear function approximation ability, parallel distributed operation, fault tolerance, generalization and adaptability. But the neural network is easy to fall into the local minimum in the training process [9], and genetic algorithm has a strong ability of global optimization and it is often used in model optimization. Therefore, this paper uses genetic algorithm to optimize the weights and thresholds of the network. so that it can better approximate the global minimum. In this paper, a neural network quality prediction model based on genetic algorithm is established by using historical data.

2. Genetic algorithm

Genetic algorithm is a kind of population intelligence optimization algorithm, which simulates the mechanism of population genetic evolution. Its core idea embodies the biological evolution principle of "survival of the fittest in natural selection" [10]. In genetic algorithm, all possible solutions of the problem to be optimized are compared to the biological population, each possible solution of the problem is compared to each individual in the population, and each element of the possible solution is compared to a gene on the chromosome. After selection, crossover and mutation, the fitness value of each individual in the population is calculated according to the fitness calculation rules. The individuals with good fitness value are retained and the individuals with poor fitness value are eliminated. Finally, the algorithm obtains the optimal individual through continuous iteration. The basic operation of genetic algorithm is as follows:

(1) Selection operation refers to the selection of individuals from the previous generation of biological population or new individuals generated by crossover to the next generation of population through individual fitness value. The better the fitness of an individual, the greater the probability that the individual will be selected.

(2) The main purpose of crossover operation is to generate new individuals by randomly exchanging and combining the chromosome information of two individuals in a population. Randomization refers to the uncertainty of the location and length of chromosome crossover. The specific operation is shown in the figure 1.

(3) The purpose of mutation operation is to produce excellent individuals by randomly selecting a point in the individual chromosome information to mutate. The specific operation is shown in the figure 2.

The basic steps of genetic algorithm are as follows:
1) The possible solution of the problem is coded and the mapping relationship between phenotype and genotype is established;
2) Random initialization population;
3) Calculate the individual fitness;
4) Individuals form new populations through selection, crossover and mutation;
5) It is judged whether the algorithm satisfies the termination condition, and if it is satisfied, the algorithm ends, otherwise it returns (3).

3. Neural network predicting model
Artificial neural network is a research hotspot in the field of artificial intelligence. It processes information through abstract human brain neuron network, and forms different networks according to different connections of neurons.

3.1 Error Back-Propagation algorithm
The neural network consists of input layer, hidden layer and output layer. Each layer is composed of neurons. The neurons have N input signals. These input signals are transmitted through a weighted connection. The output of neurons is shown in the following formula.

\[ y = f(\sum_{i=1}^{n} \omega_i x_i - \theta) \]  

(1)

Error inverse propagation algorithm referred to as BP. For training set \( D=\{(x_1, y_1), (x_2, y_2), \ldots, (x_l, y_l)\} \) \( x_i \in \mathbb{R}^n, y_i \in \mathbb{R}^m \), The input \( x_i \) has N attribute descriptions, and the output \( y_i \) is an M dimensional vector. Taking single hidden layer neural network as an example, this paper introduces error back propagation algorithm. The neural network has n inputs, m outputs, p neurons in the hidden layer, \( \theta_i \) is the threshold of the i-th output layer neurons, \( \lambda_j \) is the threshold of the j-th hidden layer neurons, \( \omega_{ij} \) is the connection weight of the lth input layer neuron and the j-th hidden layer neuron, and \( \omega_{ji} \) is the connection weight of the j-th hidden layer neurons and the i-th output layer neurons.

For training set D, the output of the neural network is calculated as follows:

\[ \hat{y}_i = f(\beta - \theta) \]  

(2)

The calculation formula of the mean square error of the network is as follows:

\[ E = \frac{1}{2} \sum_{i=1}^{m} (\hat{y}_i - y_i)^2 \]  

(3)

The BP algorithm uses a gradient descent strategy to update the parameters in the direction of the negative gradient of the target. The formula is:

\[ \nu \leftarrow \nu + \Delta \nu \]  

(4)

Assuming that the weight update is performed on \( \omega_{ji} \), the derivation process is as follows:

The mean square error \( E \) of equation (3) has:

\[ \Delta \omega_{ji} = -\eta \frac{\partial E}{\partial \omega_{ji}} \]  

(5)

\[ \frac{\partial E}{\partial \omega_{ji}} = \frac{\partial E}{\partial \hat{y}_i} \frac{\partial \hat{y}_i}{\partial y_i} \frac{\partial y_i}{\partial \omega_{ji}} \]  

(6)

\[ \frac{\partial \hat{y}_i}{\partial \omega_{ji}} = b_j \]  

(7)

According to the nature of the Sigmoid function, the following formula can be obtained.

\[ g_i = \frac{\partial E}{\partial y_i} \frac{\partial \hat{y}_i}{\partial \beta} = (\hat{y}_i - y_i) f'(\beta - \theta) = \hat{y}_i (1-\hat{y}_i) (y_i - \hat{y}_i) \]  

(8)
Substituting (8) (7) into (6) and (5) can obtain the weight update formula of BP algorithm.

\[ \Delta \omega_{ij} = \eta g_i b_j \quad (9) \]

The error function of the neural network has a local minimum, that is, the neural network is easy to fall into the local optimum [11].

3.2 Neural network with genetic algorithm

Neural network is easy to fall into local optimum, slow convergence speed, and low prediction accuracy, so this paper uses genetic algorithm to optimize the structural parameters of the neural network (parameters include: input layer to hidden layer weight, hidden layer to output layer weight, hidden layer of each ganglion point threshold, output layer of each ganglion point threshold). The algorithm flow is shown in figure 3.

![Figure 3. The algorithmic flow of neural network based on genetic algorithms](image)

4. Experiment and simulation analysis

For the above method, the paper uses specific data to verify the model and selects the appropriate amount of data as training data and the remaining amount of data as prediction data. A quality prediction model is established.

4.1 Source and preparation of experimental data

Based on the data of hot rolling production line, this paper establishes a prediction model for predicting the quality of steel plates. The input parameters of the model are the factors that affect the quality of steel plate. The index of quality is the output parameter of the model. After determining the input and output of the model, the data is normalized to eliminate the order of magnitude difference between the data.

4.2 Experimental simulation

According to the number of input and output parameters, the neural network has 98 input layer nodes, 15 hidden layer nodes, one output layer nodes. There are 1485 weights and 16 thresholds, so the length...
of chromosome is 1501, that is, 1501 parameters of the neural network are optimized by genetic algorithm. The performance diagram of the neural network is shown in figure 4.

In Figure 4, the blue line represents the performance of MSE in the BP training process in each generation. The green line represents the performance of the MSE index in the BP cross validation process in each generation. The red line represents the performance of MSE in the BP test process in each generation. The best dotted line shows that when BP network is trained to the fourteenth generation, the result of BP training is the best.

The prediction results of the model are shown below. In figure 5, the red line represents the predicted value of the model. The blue line represents the actual value of the model. The prediction error of the model is less than 60 and the average prediction error is 2.35%. It shows that the model can predict the quality of steel plate effectively.
5. Conclusion

Nowadays, due to the diversification and complexity of industrial production process, it is particularly important to predict the quality of products in the production process, and put forward stricter requirements for the accuracy of quality prediction. On the basis of constructing neural network by using error back propagation algorithm, this paper introduces genetic algorithm to optimize the weight and threshold of neural network, avoiding it falling into local optimum and speeding up convergence.

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