Application of neural network method in engineering prediction

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Abstract. Data mining is widely used in engineering. Neural network method is one of the methods of data mining. It has obvious advantages in engineering prediction and numerical estimation. Based on the analysis of neural network algorithm, this paper uses neural network algorithm to predict the moisture content of used sand in casting production, and obtains an effective method to judge the moisture content by voltage.

1. Introduction
A large amount of data is stored in database and data warehouse. In a sense, at present, we are not lack of information, but are submerged by information, especially in engineering. The current database system can efficiently realize the functions of data entry, modification, statistics and query, but it can not find the relationships and rules in the data, and lacks the knowledge and means hidden behind the mining data, resulting in the phenomenon of "data explosion but poor knowledge". Therefore, people need new Effective means to mine a large number of data in order to give full play to its potential. For engineering data, data mining is produced and developed rapidly in this demand environment. It provides a means to automatically and intelligently transform massive data into useful information and knowledge.

From the current engineering problems, the quality prediction in the manufacturing industry needs more advanced and effective methods, the fault diagnosis in production needs more methods to strengthen its accuracy, and the sales and market analysis involved in the project needs more and more advanced analysis tools. In recent years, the application of data mining technology in quality prediction has been improved day by day, and is playing a more and more important role [1].

2. Data mining prediction principle
The problem of prediction in data mining is to scientifically estimate the possible results of an event or object. It is a model that can be used to extract important data sets and predict future data trends. Prediction is used to predict continuous values of data objects. The working principle of data mining for prediction is to summarize a prediction model by analyzing the historical data of known classification information [2].

If the accuracy of the first mock exam is considered acceptable after testing, then it can be used to classify future data records or objects. Compared with the classification learning method, the prediction method can be regarded as predicting the data records of unknown categories or the category values of objects by using the model obtained by learning. From this point of view, classification and regression
are two main prediction forms. The former is used to predict discrete target variables, and the latter is used to predict continuous target variables. Mining data must be prepared before prediction mining.

3. Data mining prediction principle

Usually, the data mining process based on neural network consists of three stages: data preparation, rule extraction and rule evaluation.

3.1. Data preparation

Having data is a necessary condition for data mining, but only having data is not enough. Therefore, it is necessary to prepare data before implementing data mining. Data preparation generally includes four steps: data cleaning, data selection, data preprocessing and data representation. After the data used to train the neural network is cleaned and loaded into the data warehouse, the data to be used for this mining will be selected. The first is the selection of column or parameter dimension, which is a part of data mining process; The second is the selection of rows or records, which is based on the values of each field [3].

Data preprocessing is the process of enhancing the selected data. Data preprocessing usually includes the following steps: calculating attributes, scale transformation, regularization, symbol mapping and class hierarchy, conversion from symbol data to numerical data, etc.

Relational database supports many data types, most of which can be simply reduced to three data types: continuous numerical data, discrete numerical data and symbolic data. Generally speaking, the more explicit the data representation is, the easier the neural network is to learn, and the more complex the neural network structure is.

3.2. Rule extraction

Practice has proved that determining the order of rules in advance plays an important role in the application of rules. However, the process of extracting rules from neural networks does not give any information about the order of rules, but it can be implemented on the basis of the following three measures: robustness measure, completeness measure and error vigilance measure [4].

![Flow chart of BP neural network digital recognition.](image_url)
4. Algorithm idea of artificial neural network

Neural network method is a method to simulate human brain neurons based on the structure and function of biological nervous system. Based on MP model and Hebb learning rules, three types of neural network can be established.

**Table 1. Three types of neural network.**

| Category               | Purpose                                                                 |
|------------------------|--------------------------------------------------------------------------|
| Feedforward network    | Represented by perceptron, back propagation model and functional network, it can be used in prediction, pattern recognition and so on. |
| Feedback network       | Represented by hopfield's discrete model and continuous model, they are used for associative memory and optimization calculation respectively. |
| Self organizing network| Represented by art model and koholon model, it is used for clustering. Data classification based on neural network usually has small classification error and noise. |

4.1. BP neural network

BP neural network is an artificial neural network technology proposed by a team of scientists led by Rumelhart and McClelland in 1986. Its basic idea is to use the error back propagation algorithm to train the multilayer feedforward network.

4.1.1. Basic principle of BP neural network. BP neural network algorithm consists of two parts: forward calculation of data information flow, that is, forward transmission of forward information flow and reverse feedback of error information. When the information flow is transmitted forward, its transmission direction is the order from the input layer to the hidden layer and then to the output layer. The state of neurons in each layer will only affect the state of neurons in the next layer. If the ideal output information is not obtained in the last output layer, the reverse feedback process of error information should be entered immediately.

In the process of using BP neural network, there is generalization. Therefore, in the actual process of predicting quality and process data, the convergence speed is very slow, the prediction error will fluctuate greatly, its stability is poor, and the parameters such as learning rate, momentum term coefficient and initial value are difficult to adjust, so it is not suitable for on-line learning and control [5].

The S-type function expression of the transfer function between the input layer and the hidden layer of BP artificial neural network is:

\[ f(x) = \frac{1}{1 + e^{-x}} \]  

4.1.2. Basic principle of L-M Neural Network. The commonly used BP is the gradient descent method. The parameters move in the opposite direction of the error gradient to reduce the error function until the minimum value is obtained. The computational complexity is mainly caused by the computational inverse. The linear convergence speed of this gradient descent method is very slow.

The full name of L-M algorithm is Levenberg maquardt algorithm, which is an improved form of Gauss Newton method. It has both the local characteristics of Gauss Newton method and the global characteristics of gradient method. Due to the use of approximate second-order derivative information, L-M algorithm is much faster than gradient method. The following is a brief description of L-M algorithm, which is set as follows:

\[ x = [\omega^i(1,1), \omega^2(1,2), \cdots \omega^i(s_i,r), b^i, \cdots b^i(s_i), \omega^2(1,1), \cdots b^2(s_M)]^T \]  

The change of weight and threshold can be regarded as \( \Delta x \):

\[ \Delta x = -\left[ \nabla^2 V(x) \right]^{-1} \nabla V(x) \]
In the formula, $\nabla V(x)$ is the Hessian matrix of the index function $V(x)$: $\nabla V(x)$ represents the gradient, and $S_M$ represents the number of neurons in layer M ($M = 1, 2, 3$). Hypothesis:

\[
V(x) = \sum_{i=1}^{N} e_i(x) \tag{4}
\]

\[
\nabla V(x) = J(x)e(x) \tag{5}
\]

\[
\nabla^2 V(x) = J(x)J(x) + S(x) \tag{6}
\]

\[
J(x) = \begin{bmatrix}
\frac{\partial e_1(x)}{\partial x_1} & \frac{\partial e_1(x)}{\partial x_2} & \cdots & \frac{\partial e_1(x)}{\partial x_n} \\
\frac{\partial e_2(x)}{\partial x_1} & \frac{\partial e_2(x)}{\partial x_2} & \cdots & \frac{\partial e_2(x)}{\partial x_n} \\
\vdots & \vdots & \ddots & \vdots \\
\frac{\partial e_M(x)}{\partial x_1} & \frac{\partial e_M(x)}{\partial x_2} & \cdots & \frac{\partial e_M(x)}{\partial x_n}
\end{bmatrix} \\
S(x) = \sum_{i=1}^{N} e_i(x)\nabla^2 e_i(x) \tag{7}
\]

For Gauss Newton's law:

\[
\Delta x = -\left[J^T(x)J(x)\right]^{-1}J(x)e(x) \tag{8}
\]

LM algorithm is an improvement of Gauss Newton method:

\[
\Delta x = -\left[J^T(x)J(x) + \mu I\right]^{-1}J(x)e(x) \tag{9}
\]

In the formula: $\mu > 0$ is a constant; $I$ is the identity matrix.

As can be seen from equation (9), if $\mu$ is very large, the LM algorithm approximates the closed gradient descent method, and if $\mu$ is 0, it is Gauss Newton method. Because using the second derivative information, the LM algorithm is much faster than the gradient method, and, $\left[J^T(X)J(X + \mu I)\right]$ is positive definite, the solution of equation (9) always exists.

In this sense, LM algorithm is better than Gauss Newton method, because for Gauss Newton method, whether $J^TJ$ is satisfied is still a potential problem. In practical operation, $\mu$ is a tentative parameter, for a given $\mu$, if you get $\Delta x$ can reduce the error function $V(x)$, then $\mu$ passive factor $\beta$ except; If the error function $V(x)$ increases, then $\mu$ Multiply by factor $\beta$. Therefore, when the efficiency of each iteration is significantly improved, its overall performance can be greatly improved, especially when the accuracy requirement is high.

Next, we will do experimental tests on BP and LM Neural Networks to find a more suitable algorithm in engineering data prediction.

5. Actual engineering data processing and results

In the cooling treatment of used sand, the water content test of used sand is the key link to ensure the quality of molding sand and castings. The water content of used sand is continuously detected on-line through special equipment on the actual molding line. These detection devices measure a series of voltages in time sequence through sensors, and the internal relationship between voltage and moisture content of old sand needs special treatment to calculate the corresponding moisture content.

Based on this consideration, it is decided to use neural network technology to estimate the operation results. The two algorithms used in neural network technology have been described in detail above, so
they can be used directly and their prediction results are compared. Table 2 shows some data involved in training, and some BP neural network prediction results and LM Neural Network prediction results are shown in Table 3.

Table 2. Partial data of training participation.

| NO. | M (%) | V1 | V2 | V3 | V4 | V5 | V6 | V7 | V8 | V9 | V10 | V11 | .... |
|-----|-------|----|----|----|----|----|----|----|----|----|-----|-----|------|
|     | 0     | 0.31 | 0.33 | 0.40 | 0.42 | 0.42 | 0.44 | 0.51 | 0.54 | 2.5 | 5.0 | 5.5 | .... |
|     | 1     | 1.5  | 1.87 | 1.88 | 1.89 | 1.9  | 2.1  | 2.07 | 2.10 | 3.04 | 3.74 | 3.77 | .... |
|     | 2     | 2.0  | 3.11 | 3.16 | 3.18 | 3.22 | 3.26 | 3.47 | 3.57 | 3.77 | 3.84 | 3.88 | .... |
|     | 3     | 2.5  | 3.64 | 3.73 | 3.77 | 3.77 | 3.78 | 3.84 | 3.86 | 3.82 | 3.90 | 3.94 | .... |
|     | 4     | 3.0  | 3.84 | 3.89 | 3.89 | 3.89 | 3.94 | 3.96 | 3.98 | 3.90 | 4.01 | 4.02 | .... |
|     | 5     | 3.5  | 3.92 | 3.95 | 3.90 | 3.91 | 3.94 | 4.03 | 4.03 | 3.82 | 4.01 | 4.02 | .... |
|     | 6     | 4.0  | 3.96 | 4.04 | 4.02 | 3.98 | 4.00 | 4.03 | 4.04 | 3.96 | 4.02 | 4.02 | .... |
|     | 7     | 4.5  | 4.05 | 4.40 | 4.02 | 4.02 | 4.00 | 4.03 | 4.04 | 4.02 | 4.00 | 4.02 | .... |
|     | 8     | 5.0  | 4.06 | 4.04 | 3.96 | 4.03 | 4.03 | 4.03 | 4.04 | 4.02 | 4.00 | 4.02 | .... |

Table 3. Operation results.

| NO. | V1 | V2 | V3 | V4 | V5 | V6 | V7 | V8 | Actual moisture content | LM predicted value% | BP forecast% |
|-----|----|----|----|----|----|----|----|----|--------------------------|---------------------|--------------|
| 1   | 3.56 | 3.63 | 3.76 | 3.77 | 3.77 | 3.78 | 3.84 | 3.84 | 2.5                      | 2.33840             | -7.0943      |
| 2   | 3.91 | 3.92 | 3.96 | 4.00 | 4.02 | 4.02 | 4.03 | 4.03 | 4.0                      | 4.2327             | -4.7452      |
| 3   | 0.11 | 0.12 | 0.12 | 0.11 | 0.12 | 0.12 | 0.11 | 0.5  | 0.5                      | 0.5743             | 0.6531       |

The actual water content in Table 2, that is, m in Table 1, refers to the calibrated value of water content, which is obtained by drying method. It can be seen from the results in Table 2 that the error of BP neural network when predicting the water content of 0.5 is basically 0.15, but in the other two items, there are even negative values, which shows that BP neural network has great instability. The instability caused by the generalization of BP neural network has been difficult to solve in recent years, and it often can not meet the needs after improvement in the engineering field. In the operation of this system, under the same conditions, LM Neural Network is obviously more stable and accurate than BP neural network. Therefore, in engineering data mining tools, LM Neural Network is selected as the algorithm to undertake the prediction task, which can effectively avoid the generalization problem of BP neural network [6].

6. Conclusion

Data mining is a process of using various analysis methods and tools to establish models and find the relationships between data in massive data. These models and relationships can be used to make decisions and predictions, so they have good applications in many fields.

Based on the analysis of neural network algorithm, this paper uses neural network algorithm to predict the moisture content of used sand in casting production, and obtains an effective method to judge the moisture content by voltage. Neural network method can also be used for prediction and numerical estimation of similar problems in engineering.

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