Application of RBF Neural Network in Intelligent Fault Diagnosis System

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Abstract With the problem of large-scale system safety and stability increasingly prominently, intelligent fault diagnosis is becoming very important, and this paper puts forward the application of neural network in fault diagnosis system and analyzes in detail the principle, structure model, learning algorithm of radial basis function (RBF) neural network based on the basic principle of neural network knowledge. At last, taking the numerical control (NC) module in a system as an example, combined with the specific characteristics of NC module, this paper gives the structure of neural network diagnosis system and builds the RBF network model for simulation, training, and learning, the result of which shows that the intelligent fault diagnosis method can improve the back-propagation (BP) neural network, is feasible, and has a strong practical value.

Keywords Neural network · Fault diagnosis · RBF neural network · BP neural network

1 Introduction

With the development of computer science and control technology, the scale and complexity of all kinds of system has been increased rapidly, the safety and reliability of equipments is becoming more and more serious, some tiny fault of the system cannot be detected and excluded in time, the whole system may be failed, and even disastrous consequences may be caused. Therefore, fault warning and diagnosis is more important. The fault diagnosis system means to identify causes or properties which cause the system dysfunctional in a certain

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environment, judge parts or components that the deterioration state occurs in, and predict the development trend of the deterioration state, and so on [1]. The significance of the fault diagnosis technology is mainly in reducing the accident rate, decreasing repair costs, cutting the repair time, and increasing the running time. The existing fault diagnosis methods can be divided generally into three categories: (1) based on signal processing; (2) based on analytical model; and (3) based on knowledge. Among them, the diagnosis method based on knowledge is a new theoretical foundation that the computer artificial intelligence technique provides for the fault diagnosis. Because this method does not need precise mathematical model of the object, but has some “smart” characteristics, it is a method with great vitality. The fault diagnosis method of neural network is an important branch of the fault diagnosis method based on knowledge. The author used back-propagation (BP) neural network to construct intelligent fault diagnosis system, and the analysis of the experimental results proves that the BP neural network can play an important role in fault diagnosis, but the BP neural network is easy to fall into local minimum in the application, the radial basis function (RBF) proposed in recent years solves the above problems effectively, and the theory proposes that the RBF is more suitable for fault diagnosis, but lacks empirical. Therefore, the author established the RBF network model, which can be used in the simulation with the same data as [2] to determine its effectiveness in fault diagnosis.

2 The Basic Principle of the Neural Network Knowledge

Simply put, the neural network is an artificial system, which can simulate the structure and function of the human brain with a physical device, system or existing computer. It consists of a large number of simple neurons extensively interconnected to constitute a computational structure, which can simulate the working process of biological neural systems of the human brain in a way.

2.1 RBF Neural Network Theory

RBF neural network uses the RBF as the “base” to build the space of the hidden layer, which can map directly the input vectors to the hidden layer space. When the center point of the RBF is determined, the nonlinear mapping relationship can be defined. The output of the network is the linear weighted sum of the output of the hidden layer unit, and the weights of the network can be obtained directly from the linear equation or least mean square (LMS) method, thus greatly accelerating the speed of learning and avoiding the problem of local minimum.

2.2 RBF Neural Network Structure

The topological structure of RBF neural network is similar to that of multilayer feedforward network, and it is a kind of three-layer feedforward neural network. The nodes of RBF network's input layer transmit only the input signal to the hidden layer, the hidden layer nodes are constituted by radial functions such as Gauss function, and the output layer nodes usually are simple linear functions. The functions (kernel function) of the hidden layer nodes respond to the input signal in local, i.e., when the input signal is near the central range of the nuclear function, the hidden layer nodes will produce larger output. The nodes of the input layer, the hidden layer, and the output layer are, respectively, X, Y, and Z. The function of the hidden layer unit is to transform the input pattern, making the input data from a low-dimensional space into a high-dimensional one in order to classify and recognize in the output layer. The transformation role of hidden units actually can be regarded as extracting the features of the input data, and the transfer function of hidden units of the RBF network is the Gauss kernel.

2.3 Learning Algorithm of RBF Neural Network

The RBF network has three parameters to learn, which are as follows: the center of the basic function Ci, the variance σi, and the weight between the hidden layer and the output layer ωi. According to the selection method of the RBF center, the most common learning methods are self-organizing selection center method, orthogonal least square method, and so on. The method of organizational learning to determine Ci and σi is the clustering method. The clustering method is to cluster the samples into several classes, taking the center of the class as the center of the RBF function, and the common method is k-mean clustering method. Learning algorithm of LMS method is used to learn the weight ωi, and the pseudo-inverse method or least square method can also be used directly. The adjustment rule of LMS weight ω is as follows:

$$e(n) = d(n) - X^T(n)\,\omega(n);\ \omega(n+1) = \omega(n) + \eta X(n)\,e(n)$$

where $X(n)$ is the output of the hidden layer; $\omega(n)$ is the weight vector; $d(n)$ is the desired output; η is the learning rate; and n is the number of iterations. The structure of the RBF neural network is simple, and the design of it needs less time than the other general feedforward network training. If the number of neurons in the hidden layer is enough, and each layer's weight and threshold are correct, then the RBF function network can accurately approximate any function [3].

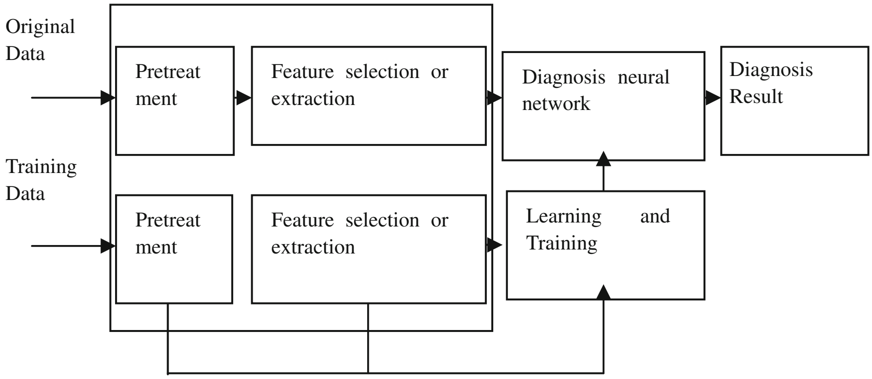

Fig. 1 Structure of the diagnosis system

3 Structure of Diagnosis System

The structure of the diagnosis system based on RBF neural network is shown in Fig. 1.

4 Application Examples and Simulation

This paper takes the numerical control (NC) module fault diagnosis of some equipment as example and applies the RBF neural network knowledge into fault diagnosis and simulation. Output of neurons corresponding to fault types is as shown in Table 1. The RBF model uses one hidden layer structure. The number of nodes in the hidden layer and the center of the hidden layer are determined by the k-means clustering method on the actual output sample data. We mainly focus on the learning accuracy of the network and the generalization ability of it, from which the performance of the network can be measured.

The RBF network is trained by adjusting three parameters, namely the center of the basic function Ci, the variance σi, and the weight between the hidden layer and the output layer ωi, to make the performance tend to optimum, satisfying the requirements of the error and accuracy. This paper uses the orthogonal least square OSL to train the RBF network. Through training the network continuously, finally it is determined that the number of hidden layer neurons is one hundred.

After the RBF neural network is trained using MATLAB, the RBF neural network model containing one hundred neurons is obtained, the function between the input layer and the hidden layer of the model is the Gauss function, and the

Table 1 Output of neurons corresponding to the type of fault

Type of fault	Output of neurons expected				
	Y1	Y2	Y3	Y4	Y5
Transmission fault of spindle	1	0	0	0	0
Power fault of spindle	0	1	0	0	0
Fault of cooling motor	0	0	1	0	0
Fault of digital transfer board A, B	0	0	0	1	0
Disconnection of intermediate cables	0	0	0	0	1

Table 2 Actual simulation data of test samples

Number of the sample	Actual simulation data of the RBF network				
1	1.0000	0.0009	0.0044	0.0066	0.0000
2	0.0000	0.8945	0.0007	0.0020	0.0006
3	1.0000	0.0436	0.0008	0.0015	0.0099
4	0.0000	0.0004	0.9856	0.0090	0.0097
5	0.0000	0.0000	0.0089	0.0058	1.0004
6	0.0000	0.0660	0.0000	0.0037	0.0008
7	0.0000	0.0038	0.0025	0.0000	0.0007
8	0.0000	0.0069	0.0078	1.0000	1.0008
9	0.0000	0.06843	0.0034	1.0000	1.0000
10	0.0000	0.0061	0.9987	0.9984	1.0000

number of training steps is one hundred. The simulation results of the RBF network with MATLAB are shown in Table 2. Through the data comparison, the accurate rate of fault diagnosis based on the RBF neural network is up to 92.8 %.

5 Conclusions

This paper, based on the theory of neural network and the study of the RBF neural network, puts forward the fault diagnosis expert system model based on the RBF neural network knowledge, through simulation in the application process of concrete instance, proves that this method has the advantages of simple structure, easy method, short training time, low error, and high accuracy of the diagnostic results, and overcomes the shortcomings of the BP neural network that is easy to fall into local minimum, especially suits to the system diagnosis that the expert knowledge is difficult to organize and represent. However, RBF remains to be further improved in the treatment of multiple faults; in the future, if we can combine the RBF neural network and other fault diagnosis methods such as the expert system, the diagnosis ability of the system will improve certainly, which will be the next research.

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