Fault Diagnosis Study of C^3I System Based on ANN

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Abstract: Artificial neural networks (ANN) are an information-processing method of a simulation of the structure for biological neurons. C^3I system as a modern combat unit can control and command the army action and can communicate to others. This paper makes a research on the approach of the artificial neural network for fault diagnosis of C^3I system and constructs a fault diagnosis system of C^3I system with ANN. And the system can analyze fault phenomena and detect C^3I system fault. It will greatly improve the response to the C^3I system fault diagnosis and maintenance efficiency.

Keywords: artificial neural networks; back propagation; C^3I system; fault diagnosis

1 Introduction

Artificial neural networks (ANN) are the natures of non-linear characteristics, parallel processing, adaptive learning ability, associative memory, fault-tolerance and robustness with neuronal activation function and other characteristics. Mathematics has proved that the artificial neural network can approximate all functions; this means that the artificial neural network can approximate those function which can depict a sample data in accordance with the law, and the more complex of the system function forms, the more obvious of the artificial neural network characteristics. ANN provides a new theory and technology means of fault diagnosis for modern complex systems, C^3I system fault diagnosis is a very complicated nonlinear system, objectively it need establish nonlinear model. It is difficult to use traditional methods reflect the changes of the dependent variable accurately and also affect the fitting model ultimately. Artificial neural network creates the right C^3I system fault diagnosis system and theoretical research. [1]

2 Artificial Neural Networks

An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information. The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems. ANN, like people, learns by example. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons. [2]

Much is still unknown about how the brain trains itself to process information, so theories abound. In the human brain, a typical neuron collects signals from others through a host of fine structures called dendrites. The neuron sends out spikes of electrical activity through a long, thin stand known as an axon, which splits into thousands of branches. At the end of each branch, a structure called a synapse converts the activity from the axon into electrical effects that inhibit or excite activity from the axon into electrical effects that inhibit or excite activity in the connected neurons. When a neuron receives excitatory input that is sufficiently large compared with its inhibitory input, it sends a spike of electrical activity down its axon. Learning occurs by changing the effectiveness of the synapses so that the influence of one neuron on another changes. The most basic unit of artificial neural network is the neuron. The basic neural network model is shown in **Figure 1**.

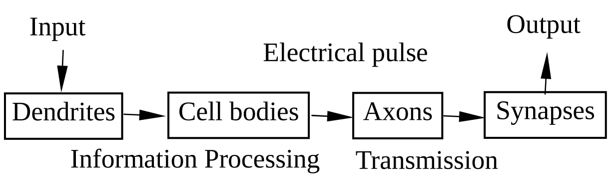

Figure 1: Basic Neural Network Model

3 Error Back Propagation Training Algorithm

There are many algorithms of ANN models, a typical algorithm is error back propagation training algorithm, also known as BP algorithm. BP neural network model is the most commonly used and the most mature one of models. Essentially, BP model uses samples to establish models; on mathematics, BP model is a method which uses functions to fit curves or surfaces, it will be converted into a non-linear optimization problem to solve. [3].

3.1 Features of BP Algorithm Model

1) Non-Linear Mapping Capability: BP neural network

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can approximate any nonlinear continuous function accurately. In the process of modeling the many models are highly nonlinear.

2) Self-Organization: An ANN can create its own organization or representation of the information it receives during learning time.

3) Adaptive Learning: An ability to learn how to do tasks based on the data given for training or initial experience.

4) Real Time Operation: ANN computations may be carried out in parallel, and special hardware devices are being designed and manufactured which take advantage of this capability.

5) Fault Tolerance via Redundant Information Coding: Partial destruction of a network leads to the corresponding degradation of performance. However, some network capabilities may be retained even with major network damage. [4]

3.2 BP Algorithm Model

BP algorithm is a Feed-forward network, Feed-forward networks allow signals to travel one way only; from input to output. There is no feedback (loops) *i.e.* the output of any layer does not affect that same layer. Feed-forward networks tend to be straight forward networks that associate inputs with outputs. This type of organization is also referred to as bottom-up or top-down.

The most common type of artificial neural network (Feed-forward network) consists of three groups, or layers, of units: a layer of "input" units is connected to a layer of "hidden" units, which is connected to a layer of "output" units. The activity of the input units represents the raw information that is fed into the network. The activity of each hidden unit is determined by the activities of the input units and the weights on the connections between the input and the hidden units. The behavior of the output units depends on the activity of the hidden units and the weights between the hidden and output units. This simple type of network is important because the hidden units are free to construct their own re presentations of the input. The weights between the input and hidden units determine when each hidden unit is active, and so by modifying these weights, a hidden unit can choose what it represents.

3.3 Mathematical Model Based on BP Algorithm

Set a three-layer BP neural network, there are N neurons in the input layer, K neurons in the hidden layer, M neurons in the output layer (see **Figure 2**). y_{pm} is the value of the output layer and O_{pk} is the value of the hidden layer, $\omega 2_{km}$ is the weights of the hidden layer to the output layer and $\omega 1_{nk}$ is the weights of the input layer to the hidden layer, x_{pn} is the study sample of input, t_{pm} is the corresponding value of output.

Standard algorithm steps are as follows:

1) Initialization of the weights and set the learning rate μ, allowing error ε, the number of iterations i, set the cycle step $i = 0$.

2) Positive calculation: the first of p samples $\left(X_p = \{x_{p1}, \cdots, x_{pN}\}\right)$ input to the network in order, calculate O_{pk} and y_{pm} as follow equations:

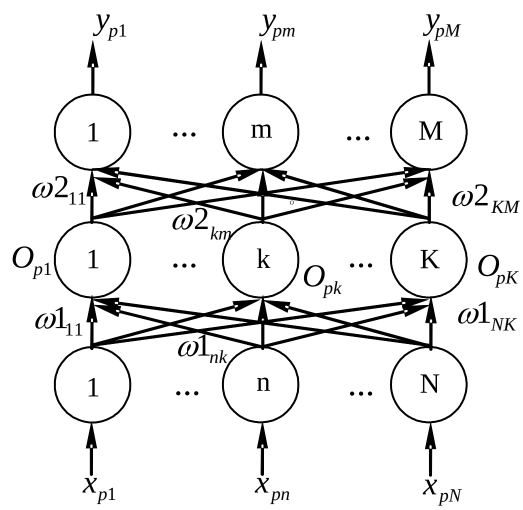

Fig.2: BP Neural Network Mathematical Model

$$O_{pk}(i) = f\left(\sum_{n=1}^{N} \omega 1_{nk}(i) x_{pn}\right) \quad (1)$$

$$y_{pm}(i) = f\left(\sum_{k=1}^{K} \omega 2_{km}(i) O_{pk}(i)\right) \quad (2)$$

Activation function usually uses the S-sigmoid function: $f(x) = 1/\left(1 + e^{-x}\right)$.

(3)Calculation means square error $E = \frac{1}{M}\sum_{m=1}^{M}\left(t_{pm} - y_{pm}\right)^2$, and if, so cease iteration; otherwise implement the next step.

(4)Reverse calculation: calculate the change of the weights. Equations are as follows:

$$\Delta\omega 1_{nk}(i+1) = \mu \sum_{p=1}^{P} \delta_{pk}(i) y_{pm} \quad (3)$$

$$\Delta\omega 2_{km}(i+1) = \mu \sum_{P=1}^{P} \bar{\delta}_{pm}(i) O_{pk}(i) \quad (4)$$

And

$$\bar{\delta}_{pm}(i) = \left(t_{pm} - y_{pm}(i)\right) y_{pm}(i)\left(1 - y_{pm}(i)\right) \quad (5)$$

$$\delta_{pk}(i) = O_{pk}(i)\left(1 - O_{pk}(i)\right)\sum_{m=1}^{M}\overline{\delta}_{pm}(i)\omega 2_{km}(i) \qquad (6)$$

Change the weights:

$$\omega 1_{nk}(i+1) = \omega 1_{nk}(i) + \Delta\omega 1_{nk}(i+1) \qquad (7)$$

$$\omega 2_{km}(i+1) = \omega 2_{km}(i) + \Delta\omega 2_{km}(i+1) \qquad (8)$$

(5)Set $i = i + 1$. Return (2). [5]

4 BP Neural Network Fault Diagnosis Model of C^{3}i System

4.1 Structure of the Model

C^{3}I system fault detection is positioning the fault when the C^{3}I system is in failure; our maintenance staffs usually repair the C^{3}I system under the table of fault or use experience which is accumulated in peacetime to judge the fault. While ANN fault diagnosis system uses through training and learning, it can more accurately determine the fault of the specific location of the components or the possibility of the fault. The trained neural network can not only have the right fault diagnosis, but also prevent the fault; it makes the fault diagnosis more simplistic, intelligent.

According to the actual C^{3}I system fault situation, with the materials and factory brochures, in this paper we consider the following types of malfunctions phenomena as the model initialization samples. Specific situations, as shown in **Table 1** (X_i stands for the code of fault phenomenon):

Table 1. Code of Fault Phenomenon

Code	Fault Phenomenon
X_1	Intelligence system failure
X_2	Communication system failure
X_3	Command and control system failure
X_4	General response system failure

And the reasons of the above fault phenomenon are shown in the **Table 2**. It has a special situation (the normal system). Y_i stands for the code of specific fault.

Table 2. Code of Specific Fault

Code	Fault Phenomenon
Y_1	Intelligence delay
Y_2	Intelligence capacity
Y_3	Communication BER
Y_4	Communication business
Y_5	Communication delay
Y_6	General information treatment time
Y_7	Total information quality
Y_8	Deciding time
Y_9	System survivability
Y_{10}	System hidden
Y_{11}	System interoperability
Y_{12}	Normal system

Establish a three-layer network, and take six species of faults as input layer nodes of the BP neural network, and nine reasons which cause the six faults as output layer nodes, while the hidden layer selects eight nodes, the input layer node is the value of the actual repair troops from the process of the large number of original data obtained according to the probability. Through a lot of samples on the network initialization training (that is the appropriate time to change the network linking the various weights) can import and export values between the values obtained in a relatively stable state, that is, each can create a clear reason for the failure, to achieve the purpose of fault diagnosis.

4.2 Simulation Test

BP neural network uses the software MATLAB neural network toolbox to modeling. MATLAB neural network toolbox can greatly facilitate weight training, reduce training workload and enhances efficiency. The procedures of MATLAB neural network model for fault diagnosis system are: net = newff (minmax (pn), [8,10], ('tansig' 'purelin'), 'trainlm'); newff () is the function of the BP neural network establishment, minmax (pn) that is the input range of pn value after the sample data pretreatment, [8,10] said that the hidden layer nodes are 8, the output nodes are 10, ('tansig' 'purelin') said that the hidden layer neurons use 'tansig' transfer function, the output layer uses 'purelin' function, 'trainlm' is the learning algorithm. Then the weights and thresholds initialization net=init (net); give random values of (-1, +1) to the connection weights IW{1,1}. LW{2,1} and threshold b{1}, b{2}. Learning process is [net, tr]=train (net, pn, tn); get the new network weights and thresholds according to the network study transmission error inverse algorithm. Finally is simulation an=sim (net, pn); a = poststd (an, meant, stdt); According to the trained network and the input vector the BP network will output simulation results, which are shown in **Table 3** and **Table 4**. [6]

Table 3. Results of ANN Input

ANN INPUT			
X1	X2	X3	X4
0	0	0	0
0.93	0.19	0	0
0	0.96	0	0
0	0.12	0.95	0
0	0	0	0.89

Table 4. Results of ANN Output

ANN OUTPUT											
Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12
0	0	0	0	0	0	0	0	0	0	0	1
0.41	0.37	0.08	0.09	0.05	0	0	0	0	0	0	0
0	0	0.67	0.13	0.2	0	0	0	0	0	0	0
0	0	0.09	0.03	0.05	0.17	0.55	0.11	0	0	0	0
0	0	0	0	0	0	0	0	0.37	0.22	0.41	0

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Input nodes in the input layer are the faults phenomena, and make various faults normalize, make the numbers of X_i in [0, 1], the numbers always are the faults magnitude, where 0 is no fault which X_i represents, 1 is a fault that can not be repaired. And output node in the output layer is the specific fault, the output value represents the possibility of fault occurred in this part. When multiple simultaneous faults appear, the bigger the output value, the greater possibility that the fault occurs in this part; instead, the smaller the output value, the less possibility that the fault occurs in this part. For example, when all of the input values are 0, there is no fault in C^3I system. So network output values are 0; when the result of communication BER is not up to standard and communication business likely imprecise and the possibility of communication system fault is 0.96, it will most likely breakdown.

5 Conclusions

After the tests of the C^3I system fault diagnosis of BP neural network model, the results are similar to the predicted ones and those of daily repairs; showing the feasibility to diagnose the C^3I system fault with BP neural network. However artificial neural network is a mathematical method, it is not a theory to be applied to the practical training, in addition there are often some drawbacks in practice by using. The C^3I system fault diagnosis has a lot to gain from neural networks. Their ability to learn by example makes them very flexible and powerful. Furthermore there is no need to devise an algorithm in order to perform a specific task; i.e. there is no need to understand the internal mechanisms of that task. They are also very well suited for real time systems because of their fast response and computational times which are due to their parallel architecture. We would also like to combine the actual equipment support requirements for C^3I system maintenance and upkeep.

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