The Dynamic Model Prediction Study of the Forest Disease, Insect Pest and Rat Based on BP Neural Networks

Wang Yong
College of Forestry, Sichuan Agriculture University, Cheng'du 611130, China
Tel: 86-135-4134-9946 E-mail: 383777166@qq.com

Wang Gang (Corresponding author)
College of Forestry, Sichuan Agriculture University, Cheng'du 611130, China
Tel: 86-139-0800-0519 E-mail: 13908000519@qq.com

Shengjing Feng
College of Forestry, Sichuan Agriculture University, Cheng'du 611130, China
Tel: 86-136-7805-5965 E-mail: 512534978@qq.com

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Abstract

This paper introduced BP neural networks, and constructed a dynamic predict model, based on it to predict forest disease and insect and rat pest. Then analyzing and simulating the states in recent ten years with the data produced by the BP neural network model. The result indicates that the BP neural network model is reliable for predicting the forest disease and insect and rat pest.

Keywords: Forest Disease, Insect and rat pest, Forecast, ANN

1. Introduction

Currently forest disease, insect pest and rat belong to the first-class smokeless fire, which called one of "three evils" in the forestry of our country, causing direct economic losses amounted to nearly 30 billion yuan every year. With the historical transformation from emphasising timber production into ecological benefit and more attention on greening in city in the construction of our forestry, the measurement and control of the insect and rat pest are very important, in order to reduce the forest yield losses caused by the disease. Phytopathologists'traditional method uses regression statistics and the mathematical model of mechanism (e.g. logistic growth model) to learn the perniciousness of forest by forest disease, insect and rat pest. Based on the various index relationships, these models are mainly to describe the major influences of Forest Pathology. With this approach, the description of mathematical relations in the course of each simulation system must be grasped precisely. If any process deviates, the entire Forest Pathology model will have a larger error, while artificial neural network can evade the problem effectively. Neural network is a intelligent system which simulates human brain's biological process and has self-organizing, self-learning and strong nonlinear mapping ability. It can adjust the threshold value and weight factors through a variety of learning algorithm, and a comparatively ideal result can be automatically concluded from the data structure without any prior formula. Neural network has its unique superiority on learning the complex uncertainty judgment, recognition, inference and classification of causality.

The author innovates the existing prediction methods of forest disease, insect pest and rat, according to the special advantages of artificial neural network, making dynamic prediction on forest disease, pest and rat factor by using BP neural network model. In this way it provides a more scientific method for our forest resource management and offers scientific proofs in forest operation administration and full functional forest ecological system.

2. The collection and collation of original data

In view of major present forest disease, insect pest and rat in our country, forestry and related departments have established 1000 national forest disease, pest and rat forecasting points throughout of the country, which monitoring the main forest insect pest and rat as a major test object systematically. This paper is based on "Yearbook of China", "Chinese Forestry Statistics Yearbook", "National Forestry Statistic Information" and other statistical investigation data of forest resources to study and forecast the forest disease, insect pest and rat in China. This study has collected nearly ten years (2000-2009) survey datas of rodent pest to meet the requirement of computer training and simulation by relevant process, the specific data statistics see chart below:

<Table 1-3>

3. BP neural network

3.1 Bpneural network structure

BP(back propagation) neural network has good self-learning, adaptive capacity. Neural network consists of input layer, output layer and hidden layer (network topology structure shown in Figure 1), determining the network parameters by learning and training in a certain sample size. The working principle of BP network practically includes two repeated alternating process of information forward propagation and error back propagation. The basic idea of error back propagation algorithm is the least square method, which uses the gradient search technique, to obtain the minimal value of means-square error between the actual output and the expected output.

Insert Fig 1 here

Input model vector: $A_k = (a_1,a_2,\ldots a_n)$

Expect input vector: $Y_k = (y_1,y_2,\ldots y_q)$

Hidden layer each unit input vector: $S_k = (s_1,s_2,\ldots s_p)$

Hidden layer each unit output vector: $B_k = (b_1,b_2,\ldots b_p)$

Output layer each unit input vector: $L_k = (l_1,l_2,\ldots l_q)$

Output layer each unit output vector: $C_k = (c_1,c_2,\ldots c_q)$

Input to inter layer connection weight: $\{_{ij}\}$,i=1,2,…,n,j =1,2,…p

Inter layer to output connection weight: $\{_t\}$,j=1,2,…,p,t =1,2,…q

Inter layer each unti output threshold: $\{_j\}$,j=1,2,…,p

Output each unit output threshold: $\{_t\}$,t=1,2,…,q

3.2 BP network structure iterative training algorithm

BP network responding function——The important character of the S function, Its function can be used to represent itself, The S function expression:

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

First derivative:

$$f'(x) = (\frac{1}{1+e^{-x}})' = \frac{e^{-x}}{(1+e^{-x})^2} = \frac{1+e^{-x}-1}{(1+e^{-x})^2} = \frac{1}{1+e^{-x}} - \frac{1}{(1+e^{-x})^2} = f(x)[1-f(x)]$$

With regarding to K learning model, The differences of network's prospect output and actual output is:

$$\delta_t^k = y_t^k - C_t^k, t = 1,2,\cdots,q$$

δ_t^k Mean square value:

$$E_k = \sum_{t=1}^{q} \frac{(y_t^k - C_t^k)^2}{2} = \sum_{t=1}^{q} \frac{(\delta_t^k)^2}{2}$$

In order to calculate E_k , With the revised connection weights according to the gradient descent. Need calculate E_k to networks, the Partial derivative of actual output: $\{C_t\}$

$$\frac{\partial E_k}{\partial C_t} = -(y_t^k - C_t^k) = -\delta_t^k$$

ω_{ij}

The Connection weight of ting changes, the influence of the first k learning mode in the mean square error, that is:

$$\frac{\partial E_k}{\partial \omega_{ij}} = [\sum_{t=1}^{q} \frac{\partial E_k}{\partial L_t} \cdot \frac{\partial L_t}{\partial b_j}] \cdot \frac{\partial b_j}{\partial s_j} \cdot \frac{\partial s_j}{\partial w_{ij}} = [\sum_{t=1}^{q} (-d_t^k) v_{jt}] \cdot f'(S_j) \cdot a_i$$

$$= -[\sum_{t=1}^{q} d_t^k v_{jt}] b_j (1-b_j) \cdot a_i$$

$$i = 1,2,\cdots,n;\ j = 1,2,\cdots,p$$

The Generalition error of the inter layer each unit:

$$\{e_j^k\},\ j = 1,2,\cdots,p; k = 1,2,\cdots,m$$

For e_j^k Definition E_k to inter layer input Negative Partial derivative, s_j :

$$e_j^k = \frac{\partial E_k}{\partial S_j} = -[\sum_{t=1}^{q} \frac{\partial E_k}{\partial L_t} \cdot \frac{\partial L_t}{\partial b_j}] \cdot \frac{\partial b_j}{\partial S_j} = [\sum_{t=1}^{q} d_t^k \cdot \frac{\partial L_t}{\partial b_j}] \cdot \frac{\partial b_j}{\partial S_j} = [\sum_{t=1}^{q} d_t \cdot v_{jt}] \cdot b_j (1-b_j)$$

Connection weight ω_{ij} adjustment quantity:

$$\frac{\partial E_k}{\partial \omega_{ij}} = -e_j^k \cdot a_i, i = 1,2,\cdots,n;\ j = 1,2,\cdots,p$$

$$\Delta \omega_{ij} = -\beta \frac{\partial E_k}{\partial \omega_{ij}} = -\beta \cdot e_j^k \cdot a_i, i = 1,2,\cdots,n;\ j = 1,2,\cdots,p$$

Threshold $\{\gamma_t\}$ adjustment quantity:

$$\Delta \gamma_t = \alpha \cdot d_t^k \qquad t = 1,2,\cdots,q$$

$$\Delta \theta_j = \beta \cdot e_j^k \qquad j = 1,2,\cdots,p$$

The BP network's global error:

$$E = \sum_{k=1}^{m} E_k = \sum_{k=1}^{m} \sum_{t=1}^{q} \frac{(y_t^k - C_t^k)^2}{2}$$

4. The establishment of the BP neural network

4.1 The establishment of related parameters set of the BP neural network

[PN, minp, maxp, TN, mint, maxt] = premnmx(P,T);

PR = minmax(PN);

Net = newff(PR [n 1] ,{‘tansig’‘ purelin’} ,‘trainlm’)；

net.trainParam. lr = 0.01;

net.trainParam. epochs = 5 00;

net.trainParam. goal = 0.001;

net.trainParam. show = 50;

Y = sim(net,P);

Y1 = postmnmx(Y, mint, maxt).

Result and Analysis:

When establishing BP neural network, the “n” neuron has no uniform standard in hidden layer of newff function. Researchers made trials or relay on experiences to determine it in general. This paper uses network training to find out reasonable “n” neuron.

4.2 Emulated training and precision test of network

This paper evaluated “n” neuron of the occurrence area on forest disease to make trials. It relies on the model to choose 3,4,5,6,7,8 etc. as the number of neuron in the hidden layer ,producing the convergent speed is the fastest

and has a better network function after 315 trials. Its error curve was showed in picture 2. Above all, 5 neurons in the hidden layer of neural network are setted in this paper.

< Figure 2>

When it has 5 neurons, the weights and thresholds of input layer and hidden layer in the network are showed in table 4.

<Table 4>

After the number of neuron is determined, it makes emulating training of network on the occurrence area of forest disease, insect pest and rat. Using datas in 2000 to 2004, 2001 to 2005, 2002 to 2006, 2003 to 2007, 2004 to 2008, 2005 to 2009 in table 1 to 3 as the training samples inputted to the network, while using the dates in 2005, 2007, 2008, 2009 as the ideal output to make emulating training of BP neural network. The operational results in MATLAB7.0 followed in table 5.

<Table 5>

Draw a curve with the actual value and simulation value in 2005 to 2009 by MATLAB7.0 as showed in table 3: we can see that the error is relatively small, therefore the model is better.

< Figure 3>

4.3 The prediction analysis of insect and rat pest

Taking the history data in 2005-2009 as sample dates in BP neural network to predict pest and rat disease index in 2010 and using the prediction dates in 2006-2009,2010 as sample dates to predict the pest and rat disease in 2011 and so on, the forest pest and rat disease index can be predicted year after year. This paper predicts the occurrence areas and control areas of forest pest and rat disease in 2010-2014, the results are shown in table 6. It shows that our forest disease,insect pest and rat disease are declined in general, so it can be inferred that more attention and emphasis should be drawd on to the forest management in relevant departments. In the results, forest and rat disease has a clear trend of decline , the occurrence areas continue to decrease and the control areas continue to increase, so the situation is well controlled; while, forest pest disease of the occurrence area increased and control rate fell slowly, so the forest pest disease is the focus at present.

<Table 6>

5. Conclusion and Discussion

1). Using BP neural network to simulate and predict forest pest and rat disease, it will reduce errors between measured value and predicted value and have a higher reliability.

2). When using that model, the number of neurons depends on the specific task. The general principles are: when using multilayer or monolayer BP neural network to train and simulate in the neural network training with the identical simulation precision, a multi-layer BP neural network model usually has higher forecast accuracy.

3). Forest disease, insect pest and rat forecast are based on the transform discipline from past to now and use BP neural network to predict the future situation of them. Accurate forecast is the precondition to formulate and implement the measure of preventing and curing the forest disease, insect pest and rat. It makes efforts to guarantee the healthy growth of forest, consolidate afforestation achievement, increase forest resources, and make full use of the economic, social and ecological benefits of the forest.

4). The neural network forecast of forest disease, insect pest and rat also have some defects: because the weights of neural network relay on the first derivative (error negative gradient direction) of error function to correct, when solving space have several minimum parts, the weights of network setting improperly will leads to parts minimum. However, predicting the forest disease, insect pest and rat is a complex nonlinear problem; the better method remains to need further studies.

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Note

This paper's date come form Statistical yearbook of china, http://tongji.cnki.net/kns55/index.aspx.

Table 1. 2000--2009 year statistics of Forest disease

Time	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Occurrence area (Million hectares)	93.45	80.5	74.5	75.75	75.79	101.2	103.87	110.95	116.83	103.12
Control area (Million hectareas)	61.95	58.29	57.12	55.25	56.71	70.62	71.8	85.88	90.48	81.88
Cure rate (%)	66.29	72.41	76.68	73	75	69.78	69.13	77.4	77.44	79.4

Table 2. 2000--2009 year statistics of Forest Insect Pest

Time	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Occurrence area (Million hectares)	669.28	668.38	679.23	718.46	744.03	726.09	829.87	887.72	843.19	850.3
Control area (Million hectareas)	456.59	459.27	451.23	463.33	494.85	498.51	557.2	604.53	590.23	638.14
Cure rate (%)	68.22	68.71	66.43	64	67	68.66	67.14	68.1	70	75.05

Table 3. 2000--2009 year statistics of Forest Insect Rat

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Occurrence area (Million hectares)	89.12	90.15	87.52	94.53	125.02	133.73	166.93	211.02	181.81	188.55
Control area (Million hectareas)	55.65	69.74	63.61	64.34	87.96	71.62	106.47	110.79	103.25	99.36
Cure rate (%)	62.44	77.35	72.68	68	70.36	53.56	63.78	52.5	56.79	52.7

Table 4. The weight and threshold after trained

Hiddenlayer node	1	2	3	4	5

Input node 1 to hidden layer node weight	0.0995	-1.2280	-0.3672	1.2024	1.0206
Input node 2 to hidden layer node weight	0.8672	0.7639	1.0282	-1.0586	0.1147
Input node 3 to hidden layer node weight	-0.0184	1.0315	1.1918	0.5369	0.9623
Input node 4 to hidden layer node weight	-0.2537	-0.7913	0.6158	-0.1123	-1.6084
Input node 5 to hidden layer node weight	-0.7427	-0.7277	1.1682	-0.8203	-0.5796
Hiddenlayer threshold	-1.8710	-1.0339	0.0146	-0.9614	-2.0701
Hidden layer node to output layer weight	0.7168	-0.5520	0.3906	-0.0053	0.4592
Output layer node threshold	0.2213				

Table 5. Result train of BP neural networks

Project	Index	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Forest disease	Actual value	93.45	80.5	74.5	75.75	75.79	101.2	103.87	110.95	116.83	103.12
	Simulation value						101.9	101.17	109.53	116.12	105.17
	Absolute error						-0.7	2.7	1.42	0.71	-2.05
	Relative error						-0.01	0．03	0.01	0.01	0.02
Forest insect pest	Actual value	669.28	668.38	679.23	718.46	744.03	726.09	829.87	887.72	843.19	850.3
	Simulation value						748.75	840.45	856.16	837.19	834.88
	Absolute error						-22.66	-10.58	31.56	6	15.42
	Relative error						-0.03	-0.01	0.04	0.01	0.02
Forest rat	Actual value	89.12	90.15	87.52	94.53	125.02	133.73	166.93	211.02	181.81	188.55
	Simulation value						142.63	158.59	205.09	190.58	191.95
	Absolute error						8.9	-8.34	-5.93	8.77	3.4
	Relative error						0.07	-0.05	-0.03	0.05	0.02

Table 6. Prediction of occurrence and control area of forest disease, insect pest and rat in 2010 to 2014

Time	Forest disease			Forest insect pest			Forest insect rat		
	Occurrence area (Million hectares)	Control area (million hectares)	Cure rate (%)	Occurrence area (Million hectares)	Occurrence area (Million hectares)	Cure rate (%)	Occurrence area (Million hectares)	Occurrence area (Million hectares)	Cure rate (%)
2010	115.2	81.95	71.14	887.25	696.54	78.5	189.12	155.65	82.3
2011	117.83	68.29	57.96	918.5	773.62	84.23	150.16	109.74	73.08
2012	130.34	87.12	66.84	844.87	663.67	78.55	167.57	133.61	79.73
2013	116.51	85.25	73.17	847.97	626.58	73.89	174.58	114.34	65.49
2014	104.09	86.83	83.42	914.13	632.98	69.24	155.46	127.96	82.31

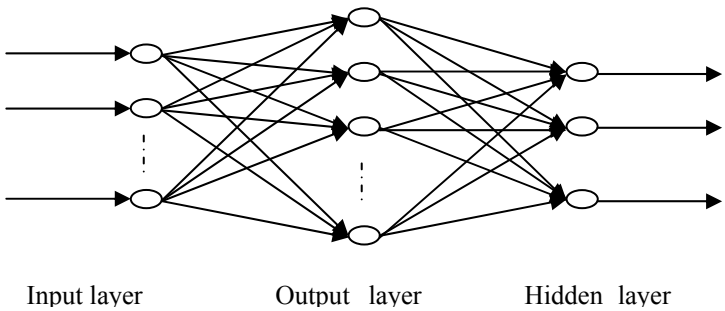

Figure1. The topological structure of BP neural network

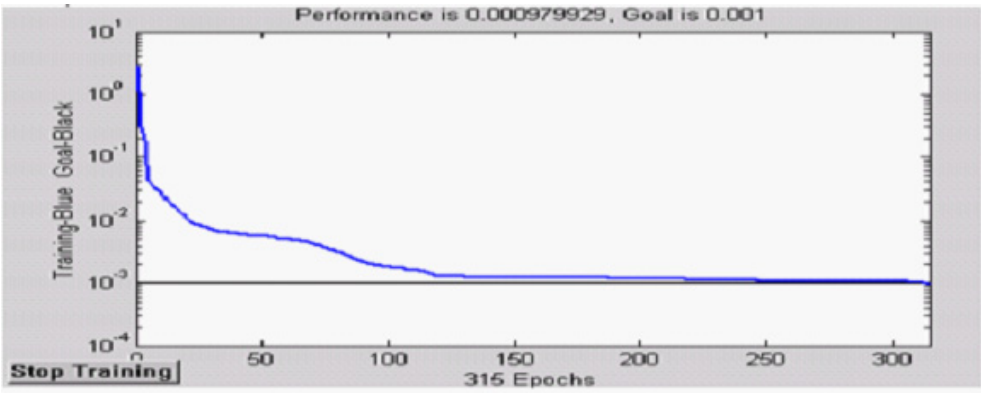

Figure 2. Convergence curve of networks consisting of 5 neurons in hidden layer respectively

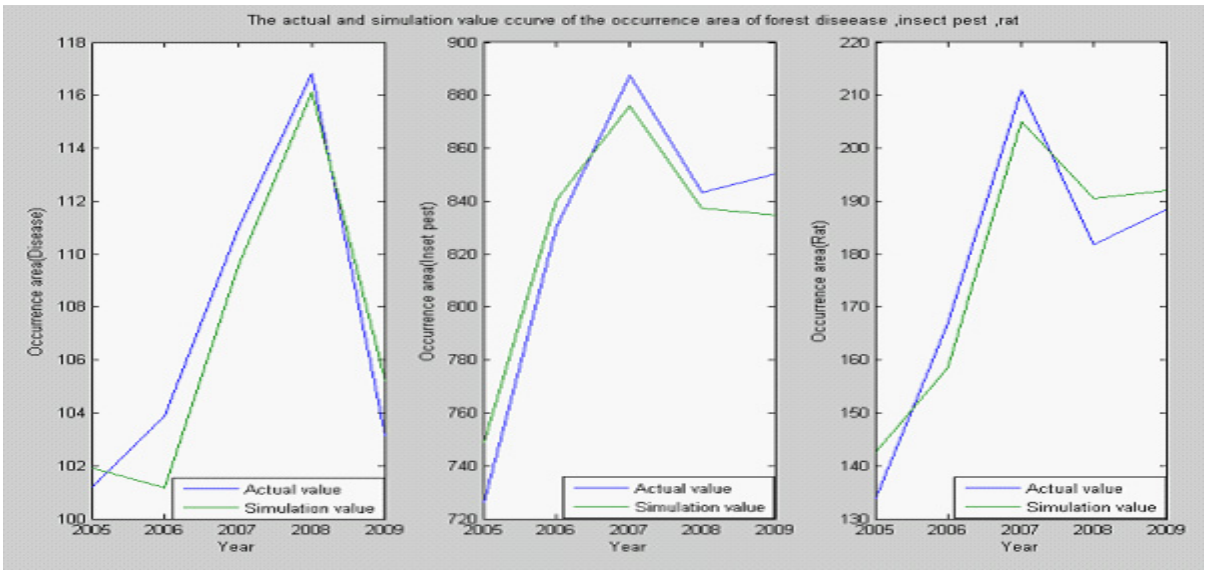

Figure 3. The actual value and simulation value ccurve of the occurrence area of forest disease, insect pest and rat