Application of ANN Model Based Simulated Annealing to Analyzing the Rice Flood Loss

Qiang Fu[1, 2], Nan Sun[2], Wei Zu[2]

1. Doctoral Working Station of Beidahuang Company, General Bureau of Agricultural in Heilongjiang, Harbin, Heilongjiang 150040, China; fuqiang100@371.net
2. School of Water Conservancy & Civil Engineering, Northeast Agriculture University, Harbin, Heilongjiang 150030, China

Abstract: Through improving the error back propagation artificial neural networks, a kind of new model of back-propagation artificial neural networks based on simulated annealing algorithm was built. The new model can overcome the disadvantage of traditional BP, which are slower convergence velocity, lower accuracy and easily fall into the local optimum. Through using the new model to analyzing the rice flood loss, it was showed that there are several advantages such as fast convergence velocity, good whole optimum, and strong practicability. The new improved model can be used in some other correlative research area. [Nature and Science. 2005;3(2):22-27].

Key Words: simulated annealing (SA); artificial neural networks (ANN); flood loss

1 Preface

In the flood disaster evaluation system, the model of flood disaster loss r is a response function to the factors and environment of disaster. The model has an important position in flood evaluation. It can be used in many aspects during the course of monitor natural disaster due to the nonlinearity, dynamic and multidimensional. So, building the suitable model become difficulty and hotspot in the research area of flood disaster.

In order to study the model and its application, the author take the rice disaster loss caused by flood as an example. Thus, the back-propagation artificial neural networks based on simulated annealing algorithm has been used.

It shows that the yield of rice is influenced by different growth stage, inundated deep, inundated diachronic (Zhu, 1990). The model of rice flood loss is to study the relationship between the rate of rice reduction of output and some influenced factors. The research work has great significance to ascertain the standard of water logging control, seek optimize control model, and improve economic benefit of reducing disaster reasonably. Obviously, neural networks model is an efficient approach to settle the approximating function. Jin put forward a kind of networks and it is feasible to built the rice flood loss model，but the training time of the networks is excessively long (Jin, 2000). Thus, a new method of training the networks named SA was put forward to improve the original networks.

2 Back Propagation Networks Based on Simulated Annealing Algorithm Model (SABP)

Because simulated annealing algorithm originates from annealing process and simulation it adopts Metropolis rule, which can avoid the local optimizing trap (Li, 2000). It can be combined with BP model. Thus, a new algorithm of BP named SABP (back propagation networks based on simulated annealing algorithm) has been put forward. When BP algorithm run into local optimization, SA algorithm can help BP model to handle the problem. Therefore, an arithmometer should be designed.

2.1 SABP Modeling

First, a function of SABP should be defined. That is FUNCTION SABP (W, B). The steps of modeling are as follows.

Step 1: Initialization weight matrix ($W^{(0)}$) and threshold value matrix ($B^{(0)}$).

Step 2: Initialization parameter ($\xi > 0$) of precision controls and preset circle times ($M > 0$).

Step 3: Define the initial error $SSE(k) = \xi + 0.5$.

Step 4: While $SSE(k) > \xi$ and $n < M$, then,

(1) Initialization the total error. Let $E = 0$, $n = 1$, $Count = Const$, $Number = 0$.

(2) Select a pair of sample random (X_p, Y_p) . Firstly, the practical networks output O_p corresponding to X_p should be calculated. Secondly, the error of output layer E_p should be calculated. Thirdly, calculate the accumulative total error $E = E + E_p$. Fourthly, the new weight value $W^{(1)}$ and new threshold value $B^{(1)}$ can be calculated by rectifying. At last, let $p = P - 1$ and $n = n + 1$. Then, if p equals zero, the program is over. Otherwise, the program should calculate the next pairs of sample.

(3) Calculate the output error of all samples. $SSE(k+1) = E/2$. If $SSE(k+1) < \xi$, the precision is satisfied. Otherwise, the program will run into the next step to train the networks continually. It cannot stop until the precision is satisfied.

(4) If border upon two circle total error $\Delta SSE = abs(SSE(k+1) - SSE(k)) < \varepsilon$, then set $Number = Number + 1$; When $Number = Const$, the Simulated Annealing Algorithm should be used. $SSE(k+1) = SA(W, B)$.

2.2 SA Algorithm of Simulated Annealing Algorithm

FUNCTION SSE = $SA(W, B, SSE, P, O)$. Where, W, B, SSE, P, O are weight value, threshold value matrix, input sample and expectation output sample.

Step 1: set original temperature ($T(0) = T_0$) and, iteration time ($k = 0$).

Step 2: According to the certain random process, a little-sized weight value disturbance σ will be gained. The weight value and threshold value will be revised.

$W1 = W + \sigma$; $B1 = B + \sigma$. Then, the total error of the networks $E1$ can be calculated.

Step 3: If $E1 < SSE$, let $SSE = E1, W = W1, B = B1$.

Step 4: If $E1 \geq SSE$, it should be revised according to Metropolis rule.

At first，calculate probability $p = \exp[-\Delta E / kT(t)]$, $T(t)$ is temporal temporality, then bring a random decimal fraction $\gamma = random(0,1)$, if $p > \gamma$, receive this revise： $SSE = E1$, $W = W1$, $B = B1$; otherwise, estimate weight value disturbance time, which whether exceed preset value or not，if not transfer step 2.

Step 5: $t = t + 1$, let $T = T_0 / \log(1 + t)$.

Step 6: If the temperature falls into the minimum temperature, then the total error cab is calculated. $SSE = E1$; IF the temperature hasn't reached the minimum temperature, the program runs into step 2.

In order to handle the disadvantage of original method of BP-ANN, such as slower convergence speed and longtime of training, the author put forward a new method to handle the problem (Fu, 2002; Zhou, 2000).

The improved BP algorithm named SABP.

3 Application of the SABP Algorithm

Rice yield is influenced by different generating process, inundated deep and inundate last a period time. The model of rice flood loss is a mapping problem of multi-dimension and nonlinear function. So, it is suitable to handle by BP-ANN model.

Table 1 shows the result of reduction in yield of rice (Zhou, 2000). In Table 1, when the first column value is one, it represents rice early tillering stage. When the second column value is one, it represents rice middle of tillering. When the third column value is one, it represents rice late tillering stage. When the forth column value is one, it represents rice booting stage. When the fifth column value is one, it represents rice spiking and blooming stage. When the sixth column value is one, it represents rice milk stage. When the seventh column value is one, it represents stage of yellow ripeness. The eighth column value represents rice flooded period (unit：day), the ninth column value represents quotient of flooded deep to plant height, and the tenth column value represents lapserate. The positive one shows rice increasing in crop yield and the negative one shows rice drop in crop yield. There are 105 groups of training samples, the last seven rows represent test sample.

Thus, the nerve cell of ANN input layer is 9，that are from the first column to the ninth column in Table 1. The output nerve cell is 1 and the nerve cell in hidden layer 1s 14. The network has three layers. At last, the frame of networks is 9-14-1.

Through training 3213 times, the networks convergence. Now, the minimum of network energy function is 7.2953×10^{-4}. The total error of all the 105 groups of training sample is 309.201 and the average error is 2.945. The output value of each sample sees also to the eleventh column in the Table 3—1. The last seven rows represent test sample, and the network forecast overall error is 19.538. The data of the twelfth column is the results of reference calculated by MAGA-BP Algorithm (Zhou, 2000). The total error summation is 133.823, average error is 1.2475 and the total error of forecasting sample t is 21.037 (Table 1, Table 2).

Table 1. Result of reduction in yield of rice analyzed by SABP

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	SABP	MAGABP
1	0	0	0	0	0	0	2	0.50	-5.850	-7.229	-5.842
1	0	0	0	0	0	0	2	0.75	-8.440	-8.534	-8.923
1	0	0	0	0	0	0	2	1.10	-13.490	-12.430	-16.115
1	0	0	0	0	0	0	4	0.50	-9.730	-4.704	-8.047
1	0	0	0	0	0	0	4	0.75	-10.130	-15.952	-10.255
1	0	0	0	0	0	0	4	1.10	-27.170	-28.275	-28.925
1	0	0	0	0	0	0	6	0.50	-9.100	-11.987	-9.316
1	0	0	0	0	0	0	6	0.75	-39.570	-31.829	-32.719
1	0	0	0	0	0	0	6	1.10	-55.670	-52.800	-55.635
1	0	0	0	0	0	0	8	0.50	-17.210	-17.688	-17.533
1	0	0	0	0	0	0	8	0.75	-33.260	-39.846	-29.488
1	0	0	0	0	0	0	8	1.10	-72.220	-74.058	-70.689
1	0	0	0	0	0	0	10	0.50	-18.460	-17.254	-13.239
1	0	0	0	0	0	0	10	0.75	-42.690	-38.738	-37.287
1	0	0	0	0	0	0	10	1.10	-89.950	-89.775	-90.547
0	1	0	0	0	0	0	2	0.50	-5.680	-7.167	-5.708
0	1	0	0	0	0	0	2	0.75	-15.710	-12.510	-11.559
0	1	0	0	0	0	0	2	1.10	-20.100	-21.654	-20.278
0	1	0	0	0	0	0	4	0.50	-10.290	-8.419	-7.335
0	1	0	0	0	0	0	4	0.75	-11.870	-13.097	-9.696
0	1	0	0	0	0	0	4	1.10	-15.450	-16.034	-15.465
0	1	0	0	0	0	0	6	0.50	-3.140	-8.637	-8.664
0	1	0	0	0	0	0	6	0.75	-9.710	-7.179	-9.874
0	1	0	0	0	0	0	6	1.10	-18.740	-14.793	19.497
0	1	0	0	0	0	0	8	0.50	-3.740	-2.013	-5.337
0	1	0	0	0	0	0	8	0.75	-1.530	-4.653	-1.986
0	1	0	0	0	0	0	8	1.10	-36.120	-39.584	-36.178
0	1	0	0	0	0	0	10	0.50	-3.320	-1.262	-9.932
0	1	0	0	0	0	0	10	0.75	-23.470	-26.035	-14.237
0	1	0	0	0	0	0	10	1.10	-98.440	-96.329	-95.241
0	0	1	0	0	0	0	2	0.50	0.060	-0.972	0.061
0	0	1	0	0	0	0	2	0.75	-0.020	7.508	-0.470
0	0	1	0	0	0	0	2	1.10	-5.080	-7.791	-4.198
0	0	1	0	0	0	0	4	0.50	19.040	12.171	-20.118
0	0	1	0	0	0	0	4	0.75	14.520	10.485	-11.759

0	0	1	0	0	0	0	4	1.10	-31.410	-28.066	-25.938
0	0	1	0	0	0	0	6	0.50	-3.240	1.887	-3.716
0	0	1	0	0	0	0	6	0.75	-5.510	-5.042	-5.512
0	0	1	0	0	0	0	6	1.10	-53.960	-56.206	-55.211
0	0	1	0	0	0	0	8	0.50	-16.700	-10.158	-12.486
0	0	1	0	0	0	0	8	0.75	-15.720	-22.174	-15.375
0	0	1	0	0	0	0	8	1.10	-84.080	-81.796	-82.198
0	0	1	0	0	0	0	10	0.50	-6.860	-11.627	-7.222
0	0	1	0	0	0	0	10	0.75	-36.870	-34.768	-37.745
0	0	1	0	0	0	0	10	1.10	-96.500	-98.573	-91.044
0	0	0	1	0	0	0	2	0.50	-47.760	-46.079	-47.637
0	0	0	1	0	0	0	2	0.75	-69.670	-71.001	-66.843
0	0	0	1	0	0	0	2	1.10	-77.150	-76.756	-74.652
0	0	0	1	0	0	0	4	0.50	-39.390	-42.77	-39.393
0	0	0	1	0	0	0	4	0.75	-76.070	-71.885	-75.284
0	0	0	1	0	0	0	4	1.10	-86.550	-85.137	-84.257
0	0	0	1	0	0	0	6	0.50	-69.400	-65.816	-68.732
0	0	0	1	0	0	0	6	0.75	-79.610	-88.125	-81.892
0	0	0	1	0	0	0	6	1.10	-95.740	-95.376	-94.547
0	0	0	1	0	0	0	8	0.50	-85.900	-84.916	-86.575
0	0	0	1	0	0	0	8	0.75	-97.100	-97.255	-93.809
0	0	0	1	0	0	0	8	1.10	-97.750	-99.645	-94.643
0	0	0	1	0	0	0	10	0.50	-86.370	-89.185	-82.263
0	0	0	1	0	0	0	10	0.75	-96.330	-95.038	-94.403
0	0	0	1	0	0	0	10	1.10	-100.00	-96.533	-94.675
0	0	0	0	1	0	0	2	0.50	-11.600	-10.350	-11.881
0	0	0	0	1	0	0	2	0.75	-40.780	-47.301	-40.601
0	0	0	0	1	0	0	2	1.10	-75.960	-78.550	-72.944
0	0	0	0	1	0	0	4	0.50	-10.260	-3.701	-10.726
0	0	0	0	1	0	0	4	0.75	-79.340	-65.618	-78.117
0	0	0	0	1	0	0	4	1.10	-98.200	-97.073	-93.855
0	0	0	0	1	0	0	6	0.50	-3.020	-25.760	-1.584
0	0	0	0	1	0	0	6	0.75	-85.710	-84.509	-86.281
0	0	0	0	1	0	0	6	1.10	-100.00	-103.860	-94.347
0	0	0	0	1	0	0	8	0.50	-71.430	-51.687	-71.022
0	0	0	0	1	0	0	8	0.75	-90.360	-92.589	-92.177
0	0	0	0	1	0	0	8	1.10	-100.00	-100.370	-94.567
0	0	0	0	1	0	0	10	0.50	-67.660	-75.256	-77.426
0	0	0	0	1	0	0	10	0.75	-100.00	-99.615	-93.895
0	0	0	0	1	0	0	10	1.10	-100.00	-98.539	-94.649
0	0	0	0	0	1	0	2	0.50	-18.380	-17.541	-18.380
0	0	0	0	0	1	0	2	0.75	-21.640	-21.253	-23.241
0	0	0	0	0	1	0	2	1.10	-25.710	-28.681	-25.732
0	0	0	0	0	1	0	4	0.50	-7.010	-5.945	-12.447
0	0	0	0	0	1	0	4	0.75	-13.390	-17.001	-17.493
0	0	0	0	00	1	0	4	1.10	-31.720	-25.84	-34.927
0	0	0	0	0	1	0	6	0.50	-0.060	-3.047	-1.834
0	0	0	0	0	1	0	6	0.75	-21.030	-15.327	-21.525

0	0	0	0	0	1	0	6	1.10	-21.360	-25.325	-21.358
0	0	0	0	0	1	0	8	0.50	-5.040	-4.829	-9.514
0	0	0	0	0	1	0	8	0.75	-13.300	-15.331	-10.445
0	0	0	0	0	1	0	8	1.10	-31.860	-30.932	-34.709
0	0	0	0	0	1	0	10	0.50	-13.600	-12.811	-9.683
0	0	0	0	0	1	0	10	0.75	-22.040	-22.258	-11.752
0	0	0	0	0	1	0	10	1.10	-45.080	-45.668	-45.198
0	0	0	0	0	0	1	2	0.50	0.940	0.712	0.167
0	0	0	0	0	0	1	2	0.75	0.680	-1.299	0.167
0	0	0	0	0	0	1	2	1.10	0.530	0.995	0.167
0	0	0	0	0	0	1	4	0.50	-0.100	1.639	0.167
0	0	0	0	0	0	1	4	0.75	-0.050	0.192	0.167
0	0	0	0	0	0	1	4	1.10	-0.070	0.527	0.167
0	0	0	0	0	0	1	6	0.50	0.360	0.826	0.167
0	0	0	0	0	0	1	6	0.75	0.250	-0.891	0.167
0	0	0	0	0	0	1	6	1.10	0.530	-0.087	0.167
0	0	0	0	0	0	1	8	0.50	0.190	-0.426	0.167
0	0	0	0	0	0	1	8	0.75	0.340	0.699	0.167
0	0	0	0	0	0	1	8	1.10	0.470	2.320	0.167
0	0	0	0	0	0	1	10	0.50	-0.060	-0.403	0.167
0	0	0	0	0	0	1	10	0.75	-0.180	2.053	0.167
0	0	0	0	0	0	1	10	1.10	0.270	-0.366	0.167
1	0	0	0	0	0	0	5	0.75	-24.85	-23.752	-21.210
0	1	0	0	0	0	0	10	1.00	-77.02	-73.886	-72.729
0	0	1	0	0	0	0	6	0.60	-4.148	0.188	-1.706

0	0	0	1	0	0	0	3	0.75	-72.87	-67.586	-77.57
0	0	0	0	1	0	0	8	0.90	-94.49	-99.317	-94.004
0	0	0	0	0	1	0	7	1.10	-26.61	-26.901	-21.195
0	0	0	0	0	0	1	5	1.10	0.23	-0.339	0.167

Table 2. Precise comparison of different algorithm about reduction in yield of rice

Algorithm	Training times	Training sample total error	Training sample average error	Test sample total error
SABP	3213	309.201	2.945	19.538
AGABP	---	729.29	6.946	22.765

4 Conclusions

(1) From Table 2, it can be seen that the SABP algorithm is good on training time and forecasting precision. The new method can handle the disadvantage of the original BP algorithm. It is obvious that the rice inundated function in each growth period can be described by one ANN.

(2) Due to the application of SABP algorithm，it may form computer process. Thus it can extend conveniently to solve other water resources engineering in relate to analyzing and forecasting. So, it is significant practically to research the SABP application in water resources development.

Correspondence to:
Qiang Fu, Wei Zu
School of Water Conservancy & Civil Engineering
Northeast Agriculture University
Harbin, Heilongjiang 150030, China
fuqiang100@371.net

References

[1] Fu Q, Liang CH. Modeling and optimize technique of water saving irrigation system. Sichuan Technology Publishing Company, Chengdu, Sichuan, China. 2002;6:56-62.
[2] Fu Q, Song YF, Xiao JM. Forecast well irrigated paddy rice water demand based on artificial neural net. Northeast Hydraulic and Hydroelectric Publishing Company. 2002;5:38-40.
[3] Fu Q, Fu H. Applying PPE model based on RAGA in the investment decision-making of water saving irrigation project. Nature and Science 2003;1(1):57-61.
[4] Fu Q, Zu W. Using multi-dimension dynamic planning based on RAGA to optimize irrigation system under non-sufficient irrigation condition. The Journal of American Science 2005;1(1):68-74.
[5] Jin JL, Ding J. Heredity algorithm and application in water science.. Sichuan College Publishing Company. 2000:147-52.
[6] Kang LSH, Yun Xie. Simulated annealing algorithm. Technology Publishing Company. 2000:22.
[7] Ma XD, Fu Q. Applying self-organizing competition artificial neural networks to classify the soil. Nature and Science 2003;1(1):75-81.
[8] Zhu RL. Experiment research of paddy rice inundated grade influent on production. Downfold disaster and fathering experiment. Dalian Publishing Company. 1990:146-56.
[9] Zhou JL. Heredity algorithm and application in water science. Sichuan University Doctor Dissertation. 2000:93-5.