ISSN: 2688-9323

Research on Complicated System Evaluation based on Fuzzy Neural Network

----- Taking Network Marketing Performance Evaluation for Example

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Abstract

The paper presents a new Back-propagation (BP) neural network algorithm to help it get its global optimum and apply it to evaluate complicated system. First the applicability of BP neural network to evaluate complicated system are analyzed; Second, based on the analyzing the working principle and source reasons of the defects of BP algorithm, the improvement including redesigning algorithm structure and reselecting learning algorithm are advanced to present a new fuzzy neural network algorithm, and the performance of the improved algorithm is also analyzed form four aspects. Finally the improved algorithm is applied to evaluate complicated system, taking network marketing performance for example and the datum from three network enterprises and the experimental results show that the improved algorithm has great superiorities, such as simple algorithm process, fast convergence speed, get out local minimum easily and high evaluation accuracy.

Keywords

Back-propagation (BP) neural network; fuzzy neural network algorithm; complicated system evaluation; network marketing performance.

1. Introduction

BP Neural Network, as an important subfield and quintessence of Artificial Neural Network, has accelerated the development in the field. Rumelhart and some other scholars advanced the theory of Error Back Propagation in 1985, and then the theory was improved by lots of scholars and applied in various fields. BP neural network has great advantages, such as explicit algorithmic process, integrated system, data identification and simulation function and excellent ability to solve nonlinear problem, therefore, so its practical value is great. Along with deep research, it also finds lots of defects of BP neural network, such as long training time, low convergence speed, bad generalization ability , falling into local minimum easily, few principle to build network structure. The above defects limit the application of the of BP neural network. So, how to overcome above defects and improve BP neural network has become a significant research topic in the field [1].

2. Applicability of BP Neural Network to Com Evaluation

BP neural network, with its non-linear mapping, learning classification and real-time optimization and other basic characteristics, opens up a new way for the study on pattern recognition and non-linear classification, and is widely used for the decision and analysis of non-linear, complicated and comprehensive problems. Basic principle of its application to comprehensive evaluation: take the information used for the description of evaluated objects' features as the input vector of neural network, and takes the values representing corresponding comprehensive evaluation as the output of neural network; then train the network with enough samples, making different input vectors obtaining different output value; if there are errors between output value and anticipated value, which exceed the stipulated error range, link weight and threshold of nodes of hidden layer and output layer among each layer of neural network shall be adjusted as to errors according to certain methods, until the system errors are acceptable; weight and threshold at this time shall no long change; thus, the weights and thresholds held by neural network are the correct internal representation obtained by network through adaptive learning; the trained neural network can be an effective tool for qualitative and quantitative combination, making comprehensive evaluation on the object system beyond sample mode[2].

Therefore, apply BP neural network to the comprehensive evaluation of complicated system, the basic ideas of which is that form the input vector of BP neural network with each evaluation indicator of neural network, and form the output vector of BP neural network with evaluation values (i.e. evaluation results of experts), reasonably designing network structure and training sample, inputting the training sample to the network to carry out calculation, until the system errors live up to the requirement; then the obtained network model is the neural network evaluation model needed.

BP neural network evaluation model application: The design idea in this paper is to divide the system into two categories; one is subsystem network and the other is integrated network; both of the networks adopt neural network for design. Each first-class indicator of comprehensive indicator system is a subsystem, and the corresponding second-class indicator is the input of subsystem. The output of each subsystem constitutes the input of comprehensive neural network; the output of comprehensive neural network is the final result of neural network evaluation, dividing into such five grades as excellent, good, medium, pass and fail. Each category has corresponding output value range of comprehensive neural network.

3. Derivation of Evaluation Algorithm

3.1. Root Analysis of the Defects of BP Neural Network Algorithm

The defects of the ordinary BP neural network resulted from the following.

① Why the training of BP neural network is easy to fall into local extremum? From the perspective of algorithm structure, the reasons include: the nonlinear relation between output and input of BP algorithm result in the error of network; and the energy function of the model is a nonlinear space with many poles; while BP neural network model obtains a headlong pursuit of the monotonic decrease of energy function or network error, the BP model can only ensure the ability to "downgrade" rather than "climbing" to the network. For above two reasons, the BP model is easily falling into local extremum and can not break away, this will lead the model fail to got global extremum. So many experts say that BP model is too greedy to success [3].

② Why the learning process of BP model is too slow in rate of convergence? The reasons is the inertia factor α and fixed learning rate η in BP model. In essence, BP model is the sharpest descent algorithm based on gradient which take advantage of initial error derivative information to direct the adjustment direction of weight of the next round calculation to make the final error minimum. In order to speed up the convergence of BP model, the η should be less than certain value, otherwise it is impossible for BP model to realize the fast convergence rate[4].

③ Why the structure of BP model is difficult to be confirmed? The reason is that the most important issue is to confirm the best structure of the BP model. In application of BP model, the first job is determining the layers of the neural network and the number of nodes of every layer. The theoretical achievements at present are not enough to determine the number of nodes of every layer and the number of layers of BP model. Now the two number are always determine by the users' experience[5].

④ Why the generalization ability of BP model can not be ensured? The reason is that the factors, such as exert certain impact, are both qualitative and quantitative of BP model, quality and quantity of calculation samples, initial weight of different nodes, the complexity of objective function, learning time, the influence is complex, priori knowledge of objective function cause the difficulties to ensure the generalization ability of BP model[6].

3.2. Design of Fuzzy Neural Network Structure

Obviously complementary are the advantages and disadvantages of fuzzy system and neural network, and the common target of them is the imitation of human intelligence, which creates necessity and possibility for their organic combination. Fuzzy neural network is the product with the combination of fuzzy logic and neural network. At present, there are many scholars engaging in different fuzzy neural network models, applied in different fields. This paper, on the basis of fuzzy system model and neural network model, designs its own fuzzy neural network model, as shown in Figure 1.

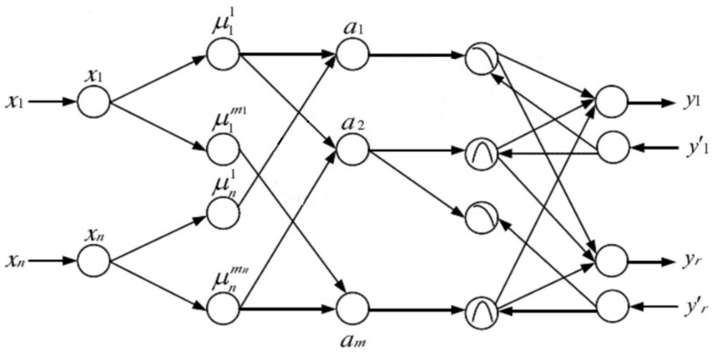

Figure 1 :The structure of the improved fuzzy BP neural network algorithm

The model defines the basic function of a node. A typical network is composed of a group of nodes which are fan-in nodes from other groups adding weighted quantity and fan-out nodes. What's related to a group of fan in is an integration function f , for the connection of information or data from other nodes. The function provides network input for the node as shown in Formula 1[7].

$$net-input = f(u_1^k, u_2^k, ...u_p^k; \omega_1^k, \omega_2^k, ...\omega_p^k) \quad (1)$$

In the formula, the superscript indicates number of layer. The second role of each node is to output activity value as the network output of the node as shown in Formula 2, in which $g(\cdot)$ is activation function. This paper adopts activation function with standard form[2,8].

$$O_i^k = g(f) \quad (2)$$

The 1st layer: input layer. This layer directly transfers the input value to the next layer; the number of neuron NN_1 is the number of input variable, as shown in Formula 3, in which $u_k^{(1)}$ is the k th input variable value. Link weight is $\omega_k^1 = 1$.

$$f_k^{(1)} = u_k^{(1)}, g_k^{(1)} = f_k^{(1)} \qquad (1 \le k \ge NN_1) \quad (3)$$

ISSN: 2688-9323

The 2nd layer: input language variable lay, also called fuzzy layer. The function is to calculate the membership function of fuzzy set of each input component belonging to each language variable value. The number of neuron NN_2 is related to that of input variable NN_1 as well as that of fuzzy subset of each input variable. If choosing the same number of fuzzy subset of each input variable $(|T(x_i)| = N_2, i = 1,2,...,NN_1$, $NN_2 = NN_1 \times N_2$. Each neuron indicates one fuzzy subset. If choosing Gaussian function as membership function, Formula 4 is satisfied [8].

$$f_k^{(2)} = M_{xi}^{j}(m_{ij}, \sigma_{ij}) = \frac{(u_i^{(2)} - m_{ij}^{(2)})^2}{\sigma_{ij}^{(2)}}, \quad g_k^{(2)} = e^{f_k^{(2)}} \quad (1 \le k \le NN_2) \tag{4}$$

In which, m_{ij} and σ_{ij} is the center and width of the membership function of the jth fuzzy subset of the ith input variable of x. Link weight $\omega_k^2 = m_{ij}^{(2)}$. At this time, the relationship among i, j and k meets Formula 5.

$$i = (k-1)/N_2 + 1, \quad j = (k-1)\%N_2 + 1 \tag{5}$$

The 3rd Layer: rule layer. The connection of this layer is used for matching the preconditions for fuzzy logic rule; rule nodes have the function of “AND” operation. The number of neuron NN_3 is equal to that of rule, and the largest number of rule is $NN_2^{NN_1}$, then Formula 6 is satisfied[4].

$$f_k^{(3)} = \min_{1 \le j \le NN_1}(u_{kj}^{(3)}), \quad g_k^{(3)} = f_k^{(3)} \quad (1 \le k \le NN_3) \tag{6}$$

In which $u_{kj}^{(3)}$ indicates the jth input of the kth node; link weight $\omega_k^{(3)} = 1$.

The 4th layer: output language variable layer. The nodes of this layer have two working modes, transferring from left to right and from right to left. In the left-to-right mode, “OR” operation is implemented. The number of neuron is equal to the number of all fuzzy subsets of output variable, similar to the 2nd layer, $NN_4 = NN_5 \times N_5$. In which NN_5 is the number of network output variable, N_5 is the number of fuzzy subsets of each output variable $(|T(y_i)| = N_5, i = 1,2,...,NN_5$; Formula 7 is satisfied.

$$f_k^{(4)} = \sum_{j=1}^{N_{4k}} u_{kj}^{(4)} \quad g_k^{(4)} = \min(1, f_k^{(4)}) \quad (1 \le k \le NN_4) \tag{7}$$

In which N_{4k} is equal to the number of input linked with the kth node of this layer, and $u_{kj}^{(4)}$ indicates the jth input of the k th node. Weight value $\omega_k^{(4)} = 1$.

The 5th layer: output layer. There are two kinds of nodes in this layer. The first kind of nodes plays a right-to-left transferring role on the training data of feed-in network; the number of neuron of such kind of node is NN_5; Formula 8 and Formula 9 are satisfied.

$$f_k^{(5)} = y_k^{(5)} \quad g_k^{(5)} = f_k^{(5)}) \quad (1 \le k \le NN_5) \tag{8}$$

In which, $y_k^{(5)}$ is the kth output variable value; link weight $\omega_k^{(5)} = 1$. The second kind of nodes plays a left-to-right transferring role on decision signal.

3.3. Selection of Learning Algorithms of the Paper

In the actual calculation of fuzzy neural network mode of this paper, the following learning algorithms are adopted.

① Back propagation algorithm, rule antecedent and rule consequent parameters are updated via back propagation algorithm.

② Least square method, adopting least square method to update all the rule antecedent and rule consequent parameters.

③ Back propagation algorithm and primary least square method, only adopting least square method to update rule consequent parameters in the first iteration, and adopting back propagation algorithm to update other parameters.

④ Blended learning algorithm is a kind of learning algorithm combining least square method with gradient descent method, able to reduce the dimensionality of search space in the back propagation algorithm and improve the rate of convergence. For each time of sample training, blended learning algorithm has two process of forward and back propagation. In the entire training iteration, adopting least square method to update rule consequent parameters and adopting back propagation algorithm to update rule antecedent parameters. First, fixing antecedent parameters, antecedently transferring the input variable to the 4th layer of model, at this time, total system output can be indicated as linear combination of consequent parameter, i.e. Formula 9.

$$z = (\overline{w_1}x)p_1 + (\overline{w_1}y)q_1 + \overline{w_1}r_1 + (\overline{w_2}x)p_2 + (\overline{w_2}y)q_2 + \overline{w_2}r_2 = A \cdot X \tag{9}$$

In the formula, $\{p_1, q_1, r_1, p_2, q_2, r_2\}$ consists of vector X; A, X and z are matrix, dimensionalities are respectively $p \times 6$, 6×1, $p \times 1$; p is the number of groups of training data. Using back propagation algorithm to update antecedent parameters, and changing the shape of membership function, as Formula 10.

$$X^* = (A^T A)^{-1} A^{-1} z \tag{10}$$

The selection of the above algorithms mainly takes the complexity of time and space into consideration. In terms of space complexity, back propagation algorithm is the best. From the perspective of time complexity, least square method is the best. In the realization of this paper, algorithm 4 is adopted (blended learning algorithm). In the entire learning iteration, back propagation algorithm and least square method are jointly adopted.

3.4. Performance Analysis of the Improved Algorithm

① Analyzing from model building

From the fuzzy network model structure of this paper, we can see that the model in this paper is the optimization of fuzzy system of an established rule, the learning process of which is the process of continuous updating and optimizing of above-mentioned parameters.

The fuzzy rules include input and output variables of system, division of input and output sample space and number of fuzzy rules. These factors determine the specific structure of model. However, in practice, these rules are not an easy thing indeed; global rule (rule enumeration) is generally adopted for determining processing rule base. In establishing actual model, after the sample data are determined, such two major tasks are needed to be finished for establishing models as structure identification, i.e. setting network structure, and parameter identification, i.e. model parameter adjustment.

Structure identification is setting network structure, mainly including the following aspects: determining the input and output variables of models, obtaining optimal input and output variable combination; determining input and output space division, the number of if-then rules and the number of membership function, as well as the initial parameters of membership function.

Parameter identification is the identification of a group of parameters under determined structure, adjusting each parameter in the model to obtain the optimal model parameter of the system. Parameter identification in the model mainly includes membership function and rule consequent parameter; in the process of parameter identification, network training is mainly relied on to judge training error. The learning of model is actually a process of parameter identification.

From the above analysis, we can see that the establishment of the model in the paper is a part of the standard fuzzy neural network algorithm (parameter identification); the design of network structure (structure identification) always plays a more important role. Actually, it is difficult to determine first-order fuzzy system of absolute optimal structure, so the model target of the paper is to obtain a fuzzy model structure approximate to the optimal one.

② Analyzing from the input and output of the improved algorithm

Input and output are main interface of model application, closely related to specific application. Output variable is determined by model establishment purpose, generally easy. Difficulty generally lies in the selection of input variable.

There are two methods to determine input variable; one is to consult experts' experience, asking experts to offer factors influencing models. The other is to analyze sample data via other statistical method or algorithm to determine the factors closely related to output as the input of model. Besides, the establishment of the model of the paper is based on fuzzy neural network model of T-S model, which is only able to process multiple inputs and single output (MISO) model, for other multiple inputs and multiple outputs (MIMO) models, it only needs to transfer them into several multiple inputs and single output models.

③Analyzing from determining membership function and parameter identification

After division of input space, the main task is to choose appropriate fuzzy membership functions of proper types for each fuzzy division. Commonly-used membership functions are triangle, trapezoid, Gaussian function, and etc. Membership functions adopted by the models of the paper are Gaussian function and bell shaped function.

Through the foregoing steps, model network of the paper has been determined. Structure identification process is also finished. Parameter identification mainly includes setting network initial parameters, setting training parameters, network training and network detection. Network training and detection in parameter identification is a continuously repeated process. Train network with training sample and detect network with detection sample. Stop when the detection accuracy reaching certain requirement. Otherwise, network designing and detection shall be carried out again until reaching detection requirement.

4. Experiment Confirmation

4.1. Analysis and Establishment of Evaluation Indicator System

Complicated system evaluation, here takes network marketing performance evaluation for example which is a complicated comprehensive operation system consisted of multiple indicators, the numerous indicators and subsystems of the system exist with different forms, jointly assembly and forming competitiveness. The paper, according to analyzing the principle of network consumer behavior of network enterprises, on the basis of analyzing advantages of experts consultations, in the light of connotation characteristics of competitiveness network marketing performance evaluation, especially referring to existed literatures, establishes a scientific and widely concerned evaluation indicator system to evaluate network marketing performance[9,10]. The established system includes four hierarchies and three categories and seven second-grade indicator and thirty third-grade indicator. The three categories are enterprise performance, website performance and customer relationship. In order to save paper space, the thirty third-grade indicators and seven second-grade indicators are not listed here one by one.

ISSN: 2688-9323

4.2. Experimental Results and Analysis

Here take data from database of three network enterprises for experimental sample and three enterprises are called corporation A, B and C respectively. For data of customer part, 300 consumers of each network enterprises are chosen as the for data training and experimental verification in the paper, totally 900 consumers' data for training input that come from practical visit and investigation. In order to make the selected consumers' data representatives, 300 learners(100 learner from each university) with more than 1 years network buying experience, 300 consumers with half year buying experience, 300 learners with less than half years buying experience.

To save paper space, here omits the evaluation of intermediate results, only lists final comprehensive evaluation results and some secondary evaluation results, see in Table 1.

Table 1: Part evaluation results of different network enterprises

	Website performance	Enterprise performance	Customer relationship	Final evaluation
Corp. A	3.286	4.219	4.221	3.821
Corp. B	3.651	4.309	4.521	4.087
Corp.C	4.138	4.486	4.798	4.462

In order to illustrate the performance of the presented algorithm, the ordinary BP neural network [6], and fuzzy evaluation [9] are also realized in the paper, the evaluation performance of three algorithms are indicated in table 2. In Table 2 evaluation results of training effects of different network trade enterprises are selected and compared with artificial evaluation to calculate the evaluation accuracy. And the calculation platform can be listed as follows: hardware is V1000 FHD-ISE with Intel i3 4010U processor, 500 hard disk, 4G memory; software platform is C programming language and Windows XP operating system environment.

Table 2: Evaluation Performance Comparison of Different Algorithms

Algorithm	Algorithm in This Paper	BP Neural Network Algorithm	Comprehensive Fuzzy Algorithm
Accuracy Rate	94.18 %	85.41%	66.74%
Time Consuming(S)	12	421	14

5. Conclusion

BP neural network is a typical algorithm in the artificial intelligence network for its strong nonlinear mapping capability and its outstanding ring in solving some nonlinear problems. Therefore, the application of BP neural network becomes more extensive, and it has become a wildly used algorithms in various fields. also BP algorithm has many disadvantages which limits the application of the algorithm. This paper takes advantage of the positive aspects of BP algorithm and overcome the its defects through simplifying algorithm structure and improving algorithm calculation efficiency based on fuzzy theory. Finally the paper also takes the data of three network enterprises for experimental examples and the experimental results show the improved BP algorithm presented in the paper can be used for evaluation network marketing performance effectively and can be a good reference for analyzing and evaluating other complicated systems.

ISSN: 2688-9323

Acknowledgements

This work is supported by scientific research project of the education department of Jiangxi Province (GJJ13300) and 52nd Chinese Postdoctoral Fund under the grant No. 2012M521284.

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