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A New Fuzzy Neural Network Algorithm for Rural Public Service Performance Evaluation

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Abstract

The defects of BP neural network, such as low convergence speed, falling into local minimum easily, bad generalization ability, can depress the calculation accuracy of BP neural network and damage its practical effect. So the research of improving BP neural network has great theoretical and practical significance. The paper advances a new fuzzy neural network algorithm to overcome the defects of original BP neural network algorithm and evaluate rural public service performance. First, the paper designs a new calculation structure based on fuzzy and BP neural network theory, and selects new self-training methods for the improved fuzzy neural network algorithm; Second, the performance of the advanced algorithm is also analyzed form four aspects in theory; Finally, based on analyzing and constructing the evaluation indicator system, the improved fuzzy neural network algorithm is applied to evaluate rural public service performance and the experimental results show that the superiorities of the improved algorithm include high evaluation accuracy, fast convergence speed, small oscillation, simple algorithm process.

Keywords: *BP neural network algorithm, fuzzy neural network algorithm, performance evaluation, rural public service*

1. Introduction

Rural public service is an important part of the public service content, and plays a pivotal role in agricultural advancement and new rural construction. As an indispensable component of system analysis, performance evaluation needs future consideration and improvement in evaluation indicator system and methods design in application of rural public service, so the research on evaluation indicator system and methods for rural public service performance has become a hot topic for the researchers related and government at different levels [6].

Up to now, mathematical models adopted by evaluating rural public service performance mainly include the following categories. ① Analytic hierarchy process is a good method for quantitative evaluation via quantitative method, having the functions of establishing the ideal weight structure of evaluated object value and analyzing the weight structure of actually-built value by evaluated object; However, the method has strong limitations and subjectivity, with large personal error, not suitable for complicated system with lots of evaluation indicators [10]. ②Fuzzy comprehensive evaluation is a method carrying out comprehensive evaluation and decision on system through fuzzy set theory, the greatest advantage of which is that it works well on system evaluation of multi-factor and multi-level complicated problems. However, the membership of fuzzy evaluation method as well as the definition and calculation of membership function are too absolute, difficult to

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reflect the dynamics and intermediate transitivity of evaluation indicators of English course education performance [9]; ③ BP neural network evaluation method makes use of its strong capability in processing nonlinear problems to carry out evaluation of rural public service performance; The method has advantages like self-learning, strong fault tolerance and adaptability; however, the algorithm is easy to be trapped into defects like local minimum, over-learning, strong operation specialization [1].

Taking advantage of the positive effects of BP neural network algorithm of high evaluation accuracy, the paper overcomes the negative effects of original BP algorithm based on the fuzzy algorithm to improve the working principle of ordinary BP neural network algorithm to present a new fuzzy neural network algorithm for evaluating rural public service performance.

2. Materials and Methods

Designing calculation structure for fuzzy neural network algorithm: 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 [5].

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[2].

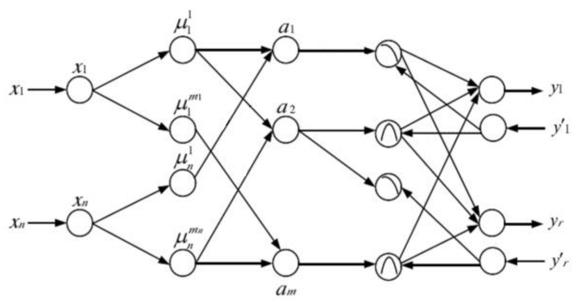

Figure 1. The Structure of the Improved Fuzzy BP Neural Network Algorithm

$$net - input = f(u_1^k, u_2^k, \ldots u_p^k; \omega_1^k, \omega_2^k, \ldots \omega_p^k) \tag{1}$$

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.

$$O_i^k = g(f) \tag{2}$$

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 kth input variable value. Link weight is $\omega_k^1 = 1$.

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

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 and Formula 5 is satisfied [4].

$$f_k^{(2)} = M_{xi}^{j}(m_{ij}, \sigma_{ij}) = \frac{(u_i^{(2)} - m_{ij}^{(2)})^2}{\sigma_{ij}^{(2)}} \tag{4}$$

$$g_k^{(2)} = e^{f_k^{(2)}} \tag{5}$$

In which, $1 \le k \le NN_2$, 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 6.

$$i = (k-1)/N_2 + 1, \qquad j = (k-1)\% N_2 + 1 \tag{6}$$

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 7 and Formula 8 is satisfied [8].

$$f_k^{(3)} = \min_{1 \le j \le NN_1}(u_{kj}^{(3)}) \tag{7}$$

$$g_k^{(3)} = f_k^{(3)} \tag{8}$$

In which $1 \le k \le NN_3$, $u_{kj}^{(3)}$ indicates the jth input of the kth node; link weight $\omega_k^{(3)} = 1$ [7].

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 9 and Formula 10 is satisfied.

$$f_k^{(4)} = \sum_{j=1}^{N_{4k}} u_{kj}^{(4)} \tag{9}$$

$$g_k^{(4)} = \min(1, f_k^{(4)}) \tag{10}$$

In which, $1 \le k \le NN_4, N_{4k}$ 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 kth 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 11 and Formula 12 are satisfied [8].

$$f_k^{(5)} = y_k^{(5)} \tag{11}$$

$$g_k^{(5)} = f_k^{(5)} \tag{12}$$

In which, $1 \le k \le NN_5$, $y_k^{(5)}$ 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].

Selecting learning methods for the improved algorithm: 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 13.

$$\begin{aligned} z = (\overline{w_1}x)p_1 + (\overline{w_1}y)q_1 + \overline{w_1}r_1 + (\overline{w_2}x)p_2 \\ + (\overline{w_2}y)q_2 + \overline{w_2}r_2 = A \cdot X \end{aligned} \tag{13}$$

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 14.

$$X^* = (A^T A)^{-1} A^{-1} z \tag{14}$$

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. Performance Analysis of the Improved Algorithm

Analysis based on 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.

Analysis based on input and output: 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.

Analysis based on determination 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. Results and Discussion

Evaluation indicator system construction: Evaluation indicator system construction is the first key step for evaluating system performance correctly and effectively, so does evaluating rural public service performance. And the indicator system for evaluating rural public service performance is constituted multiple elements and is a complex, dynamic, timely comprehensive system, in which the various subsystems and indicators coexist in different forms. Based on analyzing the unique characteristics of rural public service performance evaluation, combined with literatures and experts consultations, and according to connotation characteristics of common public service performance evaluation, this paper constructs a scientific and wide evaluation indicator system for evaluating rural public service performance, and the system includes 2 hierarchies, 2 categories, 9 first-grade indicators, 26 second-grade indicator, see table 1[1, 9-10].

Experimental results: Taking experimental data form 3 rural villages to create experimental database, the three rural villages are called corporation A, B and C respectively. For villager part data, 300 villagers of each rural village are investigated and the results are taken as the database for training and experimental verification in the paper, totally 900 villagers' data for experimental confirmation which come from practical visit and investigation. In order to make the selected data representatives, 300 villagers (100 villagers from each rural village) are more than 50 years old, 300 villagers are between 30 and 50 years old, 300 villagers (100 villagers from each rural village) are less than 30 years old.

In order to save paper space, here omits the intermediate evaluation results, only final comprehensive evaluation results and some secondary evaluation results and provided, see table 2.

As for the evaluation performance of the advanced algorithm, the ordinary BP neural network [1] and fuzzy evaluation [9] are also realized in the paper and the evaluation performance of different algorithms can been seen in table 3. In table 3, evaluation results of different 3 food network enterprises are chosen and compared with artificial evaluation to calculate the evaluation accuracy. The indicators of the calculation platform can be listed as follows Intel i3 2120, 2GB DDR3, AMD Radeon HD 7450 and 3.3GHz CPU, C programming language environment and windows XP operating system.

Table 1. Evaluation Indicator System of Rural Public Service Performance Evaluation

Target hierarchy	First -class indicator	Second-class indicator
Performance of rural public service	Elementary education	Average expenditure per student
		The ratio between teachers and students
		Education coverage
	Medical and health	Average expenditure per capita
		The number of doctors per thousand people have
		The coverage rate of cooperative medical service
	Public science and technology	Science and technology expenditure per capita
		The ratio of Agricultural science and technology personnel
	Social security	Social security expenditure per capita
		Unemployment insurance coverage
		Rural pension coverage
		Minimum living guarantee of rural coverage
		Disposable income ratio
	Public culture and sports	Expenditure per capita
		Cable TV coverage
	Public facilities	Road area per capita
		Green area per capita
	Ecological environment	Forest coverage
		Natural population growth rate
	Public security	The registered unemployment rate
		The satisfaction of social security
	Public Administration	Administrative expenses

		Public financial expenditure
		The administrative personnel ratio
		The satisfaction of government management satisfaction
		The cases of corruption

Table 2. Part Evaluation Results of Different Rural Villages

	Elementary education	Social security	Public facilities	Public security	Public administration	Final evaluation
Village A	3.017	3.298	3.665	3.761	3.641	3.234
Village B	3.471	3.901	4.081	3.981	4.279	3.803
Village C	4.002	4.508	3.989	4.612	4.793	4.408

Table 3. Evaluation Performance Comparison of Different Algorithms

Algorithm	Algorithm in this Paper	Ordinary BP Algorithm	Fuzzy Evaluation Algorithm
Accuracy Rate	93. 98%	83.98%	69.28%
Time Consuming(S)	11	561	11

5. Conclusion

At present evaluation of public service performance, especially for rural public service performance evaluation, lies in the core status in government performance management system and is an effective way to guarantee rural government performance. So the research on rural public service performance evaluation, including evaluation indicator system and methods has become a hot topic for the researcher related. Taking advantage of the positive effects of BP neural network and wavelet algorithm, the paper overcomes the negative sides and constructs a new evaluation indicator system for evaluating rural public service performance. The case study in the paper takes the data of three rural villages as an example to illustrate the preferable evaluation effects of the presented evaluation indicator system and method.

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