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Research on evaluation indicator system and methods of ecological environment quality of irrigation areas

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ABSTRACT

Evaluating ecological environment quality of irrigation areas plays a key role in ecological environment protection and is a research hotspot and difficulty for the researcher related. Firstly, the paper designs a new indicator system for ecological environment quality evaluation of irrigation areas; Then, a new algorithm structure is constructed and different learning methods are chosen to design a new fuzzy Back-propagation (BP) neural network algorithm to help it get its global optimum and speed up its calculation; Finally, the designed evaluation indicator system and improved algorithm are realized to evaluate ecological environment quality of irrigation areas, taking three irrigation areas for experimental sample and the experimental results indicates that the improved algorithm has great superiorities, such as fast convergence speed, high evaluation accuracy, simple algorithm process, etc.

KEYWORDS

Ecological environment quality evaluation; Fuzzy BP neural network algorithm; Evaluation indicator system; Irrigation areas.

INTRODUCTION

China is a large agricultural country, also is a big irrigation country. Irrigation Areas plays an important role in the national economic development and eco-environment protection. However, in the wake of the rapid national economic development and human activity intensity, In irrigation development and construction process, a series of ecological problems have appeared, like, excessive extraction of underground water, irrigation water pollution, soil salinization and so on, which directly affected the normal irrigation efficiency. Therefore, attention must be given to irrigation eco-environment, understanding of irrigation eco-environmental quality, in order to take appropriate treatment measures, ultimately achieve economic harmony with the environment and healthy development. This paper, on the basis of refer to the large number of domestic and foreign research results, researches on evaluating ecological environment quality of irrigation areas which is also a hot research topic for the researchers related.

LITERATURE REVIEW

Following methods are wildly used in evaluating ecological environment quality of irrigation areas.

(1)Analytic hierarchy process(AHP) effectively combines qualitative analysis with quantitative analysis, not only able to guarantee the systematicness and rationality of model, but also able to let decision makers make full use of valuable experience and judgment, so as to provide powerful decision-making support for lots of regulatory decision making problems. The method has such strengths as clear structure and simple computation, but due to its strong subjective judgment, the method also has shortcomings like low evaluation accuracy [2].

(2)Multi-hierarchy comprehensive evaluation of fuzzy mathematics, its principle of is to firstly evaluate various kinds of factors of the same thing, dividing into several big factors according to certain attribute; Then carry out initial hierarchical comprehensive evaluation on certain big factor, and carry out high hierarchical comprehensive evaluation on the result of initial hierarchical comprehensive evaluation based on that. The key of successful application lies in correctly specifying the factor set of fuzzy evaluation and reasonably form fuzzy evaluation matrix, obtaining evaluation result according to matrix calculation result. Make use of fuzzy comprehensive evaluation method can obtain the value grade of evaluated object or mutual precedence relationship; however, the method requires to establish appropriate evaluation matrix of evaluation object, which will obtain different evaluation matrixes due to the inconformity of different experts, leading to the inconformity of final evaluation results [3].

(3)Data envelopment analysis (DEA), starting from the perspective of relative efficiency, evaluates each decision-making unit, and the indicators selected are only relied on input and output. As it doesn't rely on specific production function, it is effective for dealing with the evaluation with various kinds of input and output indicators, suitable for the analysis of benefit, scale economy and industry dynamics. But it is complicated in computational method, subject to certain limitations in application[4].

(4)BP neural network method; BP neural network learning algorithm adopts gradient search technology so as to minimize the error mean square value between actual output value and desired output value; the method is adept in the processing of uncertain information. If the input mode is close to training sample, the evaluation system is able to provide correct reasoning conclusion. The method has such advantages as wide applicability and high evaluation accuracy, but it also has some disadvantages like easy to fall into local minimum in the computation, low rate of convergence, and etc[5].

BP neural network evaluation algorithm are wildly used in evaluating ecological environment quality of irrigation areas for their own advantages, but they also have their own disadvantages in practice, such as like easy to fall into local minimum in the computation, low rate of convergence. The paper redesigns a new fuzzy neural network evaluation algorithm to overcome their own questions and bring their superiorities into full play. In doing so a new algorithm for evaluating complex system is advanced.

ANALYSIS AND ESTABLISHMENT OF EVALUATION INDICATOR SYSTEM

Evaluating ecological environment quality of irrigation areas needs to focus on ecological environment which is a special and complicated factors, the similarity of general environment quality and the specialty of the topic in this paper shall be combined to establish evaluation indicator system of ecological environment quality. Integrating the general idea of system evaluation, and combining existing research literature[6-8], this paper will, from such five aspects as evaluation of internal and external ecological environment quality, establish the evaluation indicator system of ecological environment quality of irrigation areas, which includes 3 hierarchies, 5 categories, 18 second-grade indicators; see TABLE 1 for details.

DERIVATION OF EVALUATION ALGORITHM

Fuzzy neural network structure design

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[9].

TABLE 1 : Evaluation indicator system

Target hierarchy	First -class indicator	Second -class indicator
Ecological environment quality of irrigation areas	Location conditions	The distance to highway
		The distance to villages and small towns
	The disaster situation	The drought
		The waterlogging
		The other disasters
	Topographic elements	Topographic unit
		Sea level elevation
	Irrigation conditions	Irrigation mode
		Water channel density
		Security days
	Soil elements	Effective soil layer thickness
		The Thickness of plough layer
		Water permeability
		The barrier layer of soil
		Soil texture
		The location of barrier layer
		Groundwater level
		Soil type

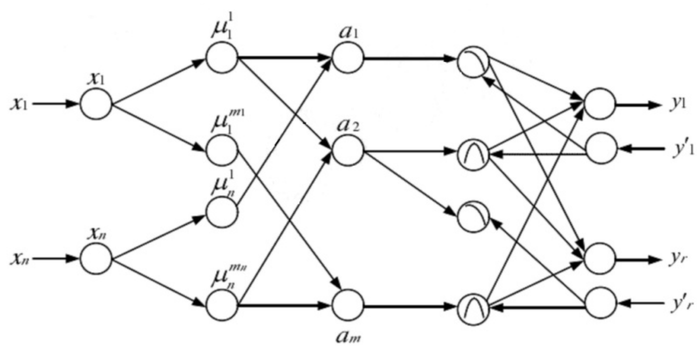

Figure 1 : The structure of the improved fuzzy BP neural network algorithm

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[10].

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

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.

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

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

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

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 is satisfied.

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

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.

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

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 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 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.

Selection of learning algorithms of the improved algorithm

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

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

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

 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.

 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.

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

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.

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

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.

Performance analysis of the improved algorithm

Analyzing from model building

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.

Analyzing from the input and output of the improved algorithm

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.

Analyzing from determining membership function and parameter identification

Analyzing 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.

EXPERIMENTAL RESULTS AND ANALYSIS

This paper adopts there irrigation areas in Jiangxi, China as detection sample called A, B and C respectively to realize the evaluation indicator system and the improved fuzzy BP neural network algorithm; due to limited space, here only list such secondary evaluation results and final comprehensive evaluation results, see TABLE 2.

TABLE 2 : Part evaluation results of different areas

	Location conditions	The disaster situation	Topographic elements	Irrigation conditions	Soil elements	Final evaluation
A	4.701	4.233	4.783	4.601	4.667	4.610
B	4.401	3.976	4.420	4.330	4.331	4.309
C	4.001	3.551	4.109	3.709	3.763	3.721

As for the performance of the presented algorithm, ordinary BP evaluation algorithm[5] and ordinary fuzzy evaluation algorithm[1] are also realized in the same calculation environment in the paper, evaluation performance of different algorithms can be seen in TABLE 3. The calculation environment of the calculation platform can be listed as follows: Intel i7 4510U, 4GB (4GB×1) DDR, AMD Radeon R5 M230 and 2GHz CPU, and windows 8.164. The TABLE 3 shows us clearly that the improved algorithm in the paper has greater value than that's of in evaluation accuracy and time consuming.

TABLE 3 : Evaluation performance comparison of different algorithms

	Algorithm in the paper	Ordinary fuzzy algorithm	Ordinary BP algorithm
Evaluation accuracy	93.89%	73.21%	82.33%
Calculation time(s)	12	11	703

CONCLUSION

It is indicated through empirical research that the improved algorithm for evaluating ecological environment quality of irrigation areas based on BP neural network established in this paper is practicable, effective and feasibility, and is able to effectively conquer some shortcomings of traditional evaluation models, as well as equipped with capabilities like self-learning, self-adaptation, strong fault tolerance and ability of expression, able to reduce some human subjective factors to the hilt, so as to improve the reliability in evaluating ecological environment quality of irrigation areas, making evaluation results more objective and accurate.

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