An Evaluation Model of Water Quality Based on DSA-ELM Method

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ABSTRACT

The evaluation technology of water quality is of great significance for monitoring and management of surface water quality. In this paper, the Extreme Learning Machine algorithm was optimized with the Dolphin Swarm Algorithm. Optimal weight and threshold of Extreme Learning Machine algorithm was searched by the process of creating a virtual team and seeking the best position of Dolphin Swarm. Four parameters of Ph, dissolved oxygen(DO), Potassium permanganate index（CODMn） and ammonia-nitrogen(NH3-N) were chosen to evaluate the level of the water and the Extreme Learning Machine algorithm optimized by Dolphin Swarm Algorithm (DSA-ELM) was used as the evaluation model of the water quality. In this paper, the water quality of 18 monitoring sites of Huai river was evaluated by DSA-ELM and ELM method. Compared the ELM algorithm model, the DSA-ELM model has the advantage of high accuracy and good stability.

Keywords: *Extreme Learning Machine, Dolphin Swarm Algorithm, surface water, water evaluation*

1. INTRODUCTION

With the development of industry, water resources are seriously polluted. In the process of water quality monitoring and pollution controlling, the accuracy of water quality evaluation is crucial. There are many ways to evaluate water quality now, but the water environment system is a complex system consisting of multiple factors and water quality is affected by many factors.

The relationship of evaluation parameters and the evaluation standard grade of water quality are complex and nonlinear, so there is no uniform evaluation method. At present, the common evaluation methods are single factor evaluation, comprehensive index evaluation, principal component analysis, grey correlation method, fuzzy identification method, and neural network method [1]. The neural network method has the characteristics of self-study, uncertainty and non-linearity, which is very suitable for establishing water quality evaluation model. In this paper, DSA-ELM model and ELM model was used to evaluated the water quality of 18 monitoring sites of Huai river and applicability of DSA-ELM in the evaluation of water quality was demonstrated.

2. BASIC THOUGHT AND ALGORITHM IMPLEMENTATION OF DSA-ELM

2.1 ELM algorithm

The ELM algorithm can generate the weights between input layer and hidden layer and the threshold of hidden layer[2]. The optimum weight and threshold are obtained by adjusting the number of hidden layer merely. The structure diagram is shown as Fig.1.

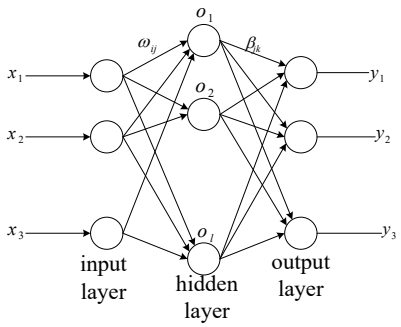

Fig.1 Structure diagram of ELM

2.2 Algorithm thought of DSA

The algorithm thought of DSA is as follow:

(1) Generating Dolphin populations randomly: in the D dimension search space, the dolphin swarm generate randomly: $\boldsymbol{X} = [\boldsymbol{x_1}, \cdots, \boldsymbol{x_n}]$, and the size of dolphin

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swarm is n. The location of dolphin i is $\boldsymbol{x_i} = [x_{i1}, \cdots, x_{id}, \cdots, x_{iD}]^T$, $x_{id} = x_{min} + rand(x_{max} - x_{min})$, in which $i = 1,2,\cdots,N$, $d = 1,2,\cdots,D$, and rand is random number evenly distributed in [0,1]. x_{max} and x_{min} are the upper and lower limits of search space. The dimension $D = ml + l + lk + k$, where m is the node number of input layer, l is the node number of hidden layer, and K is the node number of output layer.

(2) Creating a virtual team: each dolphin is as the center, and calculates the distance d_{ij}. $d_{ij} = \sqrt{(\boldsymbol{x_i} - \boldsymbol{x_j})^2}$ is the distance between dolphin $\boldsymbol{x_j}$ ($j = 1,2,\cdots,n$) and dolphin $\boldsymbol{x_i}$. The nearer t dolphins were selected as the virtual team of dolphin $\boldsymbol{x_i}$.

(3) Determine dolphin's role: calculating the fitness value of each dolphin according to fitness function. Each dolphin will compare the fitness to other dolphins in the virtual team and decides its role as a leader or an common member. If a dolphin is the optimal position of the virtual team, it is the leader. Each dolphin has its own $\boldsymbol{nbest_i}$ by communicating with others.

(4) Update dolphin's location: as to a member of the virtual team, the update formula of location is: $\boldsymbol{x_i(t+1) = x_i(t) + c_1 r_1 (p_{xi} - x_i) + c_2 r_2 (p_{ni} - x_i)}$, where $\boldsymbol{p_{xi}}$ is the $\boldsymbol{xbest_i}$ position of dolphin i, $\boldsymbol{p_{ni}}$ is the $\boldsymbol{nbest_i}$ position. The update will stop until iteration condition is met[3].

2.3 Algorithm implementation of DSA-ELM

Searching the optimal weight and threshold by role, communication, tracking and exploration of dolphins swim, the Extreme Learning Machine algorithm was optimized.

The steps of DSA-ELM are shown as follow:

(1) Choose the learning sample: select the appropriate number of training samples including the input vector and the expected output vector.

(2) Establish the DSA-ELM neural network: confirm the number of input layer, hidden layer and output layer and the activation function.

(3) Generate Dolphin populations: the dolphin population is the weight and threshold of Extreme Learning Machine and initialize location of dolphin swarm. The dolphins create a virtual team by confirming the range of searching the optimal value and the range of weight and threshold.

(4) Determine the appropriate parameters: Given the maximum of iterations, T = 500, dolphin populations M = 20, learning factor $c_1 = c_2 = 2$, and dimension D.

(5) Explore optimal value: the root-mean-square error of learning sample was used as the fitness function, then the fitness function of dolphin populations were calculated and compared to confirm the optimal position of the virtual team.

(6) Update the iteration: update the dolphin's location until reach the maximum iteration number or the minimum error.

The working flow chart is shown as Fig.2

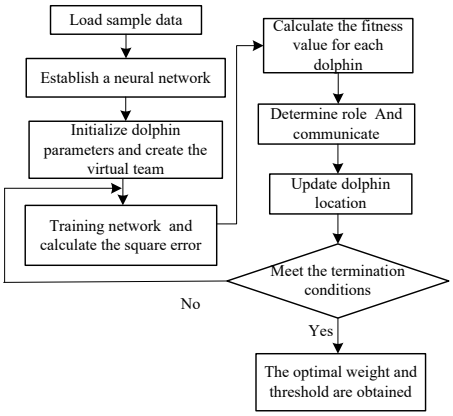

Fig.2 Working flow chart

3. SIMULATION RESULT AND DISCUSSION

3.1 Research data

The data comes from the Data Center of the Environmental Protection Department of China. 150 groups water data of Huai river was used as the train sample and the four factors (Ph, DO, CODMn, and $NH_3 - N$) were as the factors of water evaluation[3,5]. In this paper, the water data of 18 monitoring sites of Huai river was evaluated by DSA-ELM model and ELM model. The data of 18 monitoring sites of Huai river is shown as Table1.

Table1 water data of 18 monitoring sites of Huai river

Factors	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8	No.9
Ph	6.89	8.43	7.35	7.48	7.8	7.2	6.69	7.76	7.52
DO (mg/l)	6.24	3.73	2.94	6.15	4.65	6.36	6.08	2.68	6.3
CODMn (mg/l)	3.3	6.9	5.7	1	4	8.3	3	3.5	4.8
NH3-N (mg/l)	0.33	0.06	0.1	0.05	0.08	1.03	0.34	0.19	0.65

Continue to Table 1

Factors	No.10	No.11	No.12	No.13	No.14	No.15	No.16	No.17	No.18
Ph	7.42	8.63	8.58	8.59	7.85	8.91	8.82	7.06	7.15
DO (mg/l)	7.37	8.61	9.25	10.4	4.78	6.4	7.73	3.05	3.85
CODMn (mg/l)	4.6	8.4	6.7	6.7	4.7	10.7	1.7	2.9	4
NH3-N (mg/l)	0.25	0.11	0.15	0.44	1.36	0.2	0.07	1.57	1.89

3.2 Results analysis and comparison

The evaluation results of water quality using the DSA-ELM model and the ELM model are shown as Fig.3 and Fig.4. It's shown in Fig.3 that the accuracy of water classification evaluated by ELM model is 83.33% (15/18: The water classifications of 15 monitoring sites are right) and in Fig.4 the accuracy of water classification evaluated by DSA-ELM model is 100%. Compared the ELM model, the DSA-ELM model has the high accuracy and good stability.

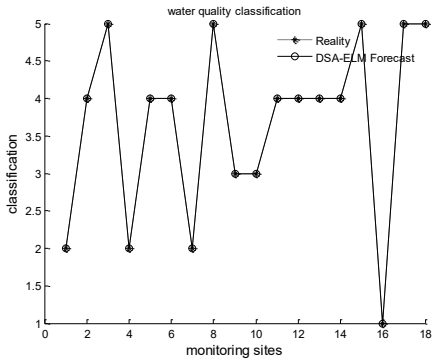

Fig.3 Comparison of ELM forecast and reality

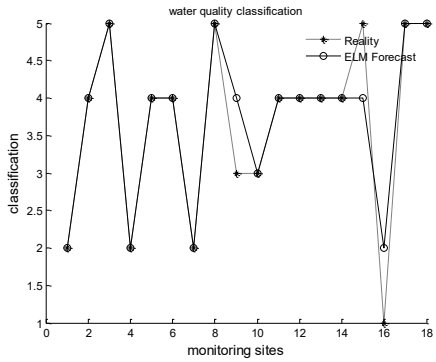

Fig.4 Comparison of DSA-ELM forecast and reality

4. CONCLUSIONS

In this paper, the Dolphin Swarm Algorithm was used to optimize the Extreme Learning Machine algorithm. Optimal weight and threshold of Extreme Learning Machine algorithm was searched by the process of creating a virtual team and seeking the best position of Dolphin Swarm. The water quality of 18 monitoring sites of Huai river is evaluated by DSA-ELM model and ELM model and the result shows that the DSA-ELM model has the high accuracy and good stability.

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