Water quality evaluation of Xiaoshan water quality station in eastern Zhejiang Water Diversion Project Based on BP network

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Abstract. East Zhejiang water diversion project is a major water resources allocation project to ensure the sustainable economic and social development of xiaoshaoningzhou area in eastern Zhejiang. The project task is to introduce Qiantang River water to provide domestic, industrial and agricultural irrigation water to xiaoshaoning plain and Zhoushan City, and to improve water environment. In this paper, BP network algorithm based on error back propagation is used to evaluate the water quality station of Xiaoshan junction. The evaluation results show that most of the water quality in Xiaoshan water diversion project is class II water and class III water.

1. Introduction
East Zhejiang water diversion project [1] is a major water resources allocation project to ensure the sustainable economic and social development of xiaoshaoningzhou area in eastern Zhejiang. The project task is to introduce Qiantang River water to provide domestic, industrial and agricultural irrigation water to xiaoshaoning plain and Zhoushan City, and to improve water environment. The East Zhejiang water diversion project connects xiaoshaoningzhou area in eastern Zhejiang Province through six projects, including Xiaoshan junction, Cao’e jiang sluice, Cao’e jiang Cixi diversion, Cao’e jiang Ningbo water diversion, Zhoushan mainland water diversion, Qincun reservoir. Xiaoshan water diversion project leads Qiantang River water into the upstream channel of Cao’e River sluice through Xiaoshao plain river network, and then from Sanxing sluice and Daxing sluice on the right bank of Cao’e river and the Dashezha diversion water to Yuci and ningzhou areas respectively. Qincun reservoir stores and diverts water from Cao’e River into Tingxia reservoir in Fenghua City, and supplies water to Ningbo City through Tingxia reservoir. The East Zhejiang water diversion project involves Hangzhou, Shaoxing, Ningbo, Zhoushan four cities and 19 counties (cities, districts), spanning Qiantang River Basin, Cao’e River Basin, Yongjiang River Basin and Zhoushan Island, with a total length of 294km. The annual average water diversion volume of the project is 890 million m³, with a total investment of more than 10 billion yuan[2]. It is a major water resources strategic allocation project with the largest cross basin, the widest cross region[3], the longest water diversion route and the largest investment in the history of Zhejiang Province[4]. In order to guarantee the
benefit of water diversion function in eastern Zhejiang Province, it is necessary to obey the principle of quantity and quality control to ensure "clear water flows eastward". Artificial neural network is a kind of intelligent data processing work with self-learning and self-memory, which has been widely used in various engineering fields. BP network is an important algorithm of artificial neural network theory, and has been used in water quality evaluation for many times. Therefore, this paper selects it as the water quality evaluation method of Xiaoshan water quality station.

2. Brief introduction of water quality station of Xiaoshan junction at the head of East Zhejiang Water Diversion Project

The water intake head hub of East Zhejiang water diversion project is Xiaoshan junction, and its water quantity and quality monitoring station is Xiaoshan water quality automatic monitoring station. The water quality station is located about 50 meters on the right bank of the downstream water conveyance channel of Xiaoshan hydropower project. It is used to monitor the water quality of the water diversion source of Xiaoshan junction, so as to provide reference for the water diversion work of East Zhejiang water diversion project. The water quality was officially monitored in September 2015, once every four hours.

3. Brief introduction of BP artificial neural network

Artificial neural network [5] is a nonlinear data processing, storage and retrieval system of the model human brain neural system. It has the processing functions of self-learning, self-memory and self-calculation. It does not need accurate mathematical model. Through the learning of input and output data, it carries out parallel calculation, establishes a network system suitable for data series, carries out simulation calculation and prediction calculation. Artificial neural network has been applied in various fields of engineering, and it is proved to be a good intelligent algorithm. BP neural network is a kind of artificial neural network algorithm, which was proposed by rumalhart et al. In 1986. Since it was put forward, BP neural network has been widely used in water quality evaluation by water conservancy authors.

The specific steps of BP algorithm is:

Step 1: set the number of iterations $t = 0$, and randomly initialize each connection weight, threshold, learning rate and inertia impulse.

Step 2: $t ← t + 1$, input the first sample $P$ into the model, and calculate the activation value and output value of hidden layer and output layer according to the formula.

Step 3: calculate the total error $E(t)$ according to the formula, if $E(t) ≤ ε$ (allowable error), stop iteration; otherwise, carry out step 4.

Step 4: calculate the error of hidden layer and output layer according to the following formula, and calculate the error of each layer according to the following formula

$$d_k^{2,q} = (t_k^{q} - y_k^{q})y_k^{q}(1 - y_k^{q})$$ (1)

$$d_j^{1,q} = (\sum_{k=1}^{Q} d_k^{1,q}w_{jk}^{q}h_j^{q}(1 - h_j^{q})), k = 1, 2, ..., n; j = 1, 2, ..., l; q = 1, 2, ..., Q$$ (2)

Step 5: dynamically adjust learning rate $η$, inertia factor $α$, weight $w$ and threshold $θ$,

if $E(t) ≤ E(t-1)$$$
\begin{align*}
\eta(t) &= \eta(t) \times (1 + \lambda) \\
n(t) &= n(t) \times (1 + \lambda)
\end{align*}$$ (3)

Else

$$\begin{align*}
\eta(t) &= \eta(t) \times (1 - \lambda) \\
n(t) &= n(t) \times (1 - \lambda)
\end{align*}$$ (4)

Where: $\lambda$ is the adjustment rate, $\lambda \in (0,1)$.
The weights from hidden layer to output layer and input layer to hidden layer are adjusted to

\[ w_{jk}^t(t) = w_{jk}^t(t-1) + \eta(t) \sum_{q=1}^{Q} h_q^t d_{jk}^d q + a(t)(w_{jk}^t(t-1) - w_{jk}^t(t-2)) \]

(5)

The threshold from hidden layer to output layer and input layer to hidden layer are adjusted to

\[ \theta_k^t(t) = \theta_k^t(t-1) + \eta(t) \sum_{q=1}^{Q} (-1) d_{kj}^d, q + a(t)(\theta_k^t(t-1) - \theta_k^t(t-2)) \]

(6)

Return to step 2 and continue the iteration.

4. Water quality evaluation of Xiaoshan water quality station in East Zhejiang Water Diversion Project Based on BP network

The diversion of water from eastern Zhejiang Province must comply with the regulation of Qiantang River mouth resource allocation project (Trial Implementation). The regulation method defines the water allocation principle of Qiantang River Estuary, such as the water allocation of living, production and environment. According to the method, more water should be diverted in the wet season and less in the dry season. The daily water intake of the water intake unit should be determined according to the average discharge of Fuchunjiang power station in the first three days and the chlorine content of the river water in the high tide on the day before the gate station. According to this standard, in accordance with the operation and scheduling scheme of eastern Zhejiang water diversion project, combined with the rainfall along the line, and as far as possible to ensure that "one river flows eastward in spring", the water diversion project in eastern Zhejiang will carry out water diversion dispatching. In 2017, the total water diversion period in eastern Zhejiang was 215 days. This water quality assessment is based on the Zhejiang provincial government assessment index of water quantity and quality issued by zhzbf [2013] No. 134.

Taking the standard value of water quality data as input and water quality category as output, the BP neural network system is established. In order to eliminate the influence of dimension, the standard value of water quality data is standardized. The standardized index is the input item and the water quality category is the output item. According to the steps of BP algorithm, the BP network between the evaluation index and the grade is established. The min max method was used for the standardization. The method of min max standardization is linear transformation of original data. Let Min a and Max a be the minimum and maximum values of attribute a, and map an original value x of a into the value x ’ in the interval [0,1] by min max normalization. The formula is: new data = (original data minimum) / (maximum minimum value).

In the establishment of BP network, the most important thing is to select the number of hidden layers, to determine the function of input layer and output layer, and to finish training conditions. If the number of hidden layers is too much, it will be over trained, and too few will be insufficient. According to the research of domestic scholars [6], at present, the method of N / 2 + 1 is generally used to determine, where n is the number of input layers, this time the input layer is 4, so the number of hidden layers is set to 3. There are many kinds of functions for input layer and output layer. After consulting the relevant literature, the functions that have been tested and tried out and water quality evaluation are selected. Among them, the input layer is set as Tansig function, and the output layer is set as purelin function. The end condition of training determines the quality of the network. Because there are few input items this time, referring to the relevant literature, 500 training times are set, and the error is 0.001. After training, the calculation ends with the maximum number of training. The error reduction diagram is shown in the following figure:
It can be seen from the figure above that the error is large at the beginning of training, and the error is basically stable after 200 times of training. It is considered that the BP network meets the evaluation requirements. The water quality of 215 day average water diversion period is input into the trained network, and the water quality evaluation results of Xiaoshan project in diversion period are shown in the table.

Table 1. Statistics of water quality days in water diversion period of Xiaoshan hydroproject in 2017

| Water quality category | II  | III | IV  |
|------------------------|-----|-----|-----|
| Days                   | 79  | 110 | 26  |

5. Conclusion

The task of water diversion project in eastern Zhejiang is to supply water from Qiantang River to xiaoshaoning plain and Zhoushan City for domestic, industrial and agricultural irrigation, and to improve water environment. Its head project is Xiaoshan hub project. In order to ensure the safety of water quality along the water diversion line, it is very important to strengthen the monitoring and evaluation of water quality at the source of eastern Zhejiang. In this paper, BP network algorithm based on error back propagation is used to evaluate the water quality station of Xiaoshan junction. Through the error decline curve, it can be seen that the BP network has become stable and can be used for evaluation. The trained network was used to evaluate the water quality data of water diversion period in 2017. The evaluation results show that most of the water quality during the diversion period of Xiaoshan project is class II water and class III water.

References
[1] Research on operation scheme of water diversion dispatching of East Zhejiang water diversion project, Zhejiang water resources and Hydropower Survey and Design Institute.
[2] "Qiantang River mouth resources allocation planning", Zhejiang water conservancy and Hydropower Survey and Design Institute and Zhejiang water conservancy and estuary Research Institute.
[3] Regulation measures for water resources allocation project of Qiantang River Estuary (Trial), Zhejiang water resources department.
[4] Overall planning of water resources protection, development and utilization in Zhejiang Province, Zhejiang water resources and Hydropower Survey and Design Institute.
[5] Cai Yudong, Yao Linsheng. Artificial neural network method for long-term runoff forecasting [J]. Progress in water science, 1995, 6 (1): 61-65

[6] Lou Shen, Gan Xiaorong. Water quality evaluation based on BP neural network [J], JOURNAL OF YUNNAN UNIVERSITY FOR NATIONALITIES (NATURAL SCIENCE EDITION), 2007, 16 (2), 165-167