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PREDICTION MODEL OF AMMONIA NITROGEN CONTENT BASED ON BP NEURAL NETWORK

Chuanli Liu and Tigang Xiao
School of Automation & Information Engineering, Sichuan University of Science & Engineering, Zigong 643000, China
E-mail: lcl9307@163.com

Abstract: Water is one of the most common substances on Earth, and is known as the source of human life. Though China's total water resources are extremely rich, but it's unbalance distribution, extremely serious water pollution, has already jeopardized people's daily life. The concentration of ammonia nitrogen in water is an important index to reflect the water's pollution situation. In order to improve the detection accuracy of ammonia nitrogen concentration in water, reduce the influence of other factors such as temperature, PH, probe laser, and standing time etc. at the same time. In this paper, a real-time ammonia nitrogen detection system is designed. The BP neural network based method is used to establish an analysis and prediction model. The experimental results show that the average absolute error of the method is 0.0861 and the average relative error is 4.117%. The simulation results show that the algorithm reduces the error, enhances the generalization ability, improves the accuracy of prediction, and the effect of analysis and prediction is better.
Keywords: Water; Ammonia nitrogen; BP neural network.

Introduction

Today, China's economy is in a good period of relatively stable, sustained growth, and economic efficiency's significant improvement in, since the founding of the People's Republic of China. During this period, the ecological environment, national economic strength, and social productive forces are constantly improving, the industrialization process is also constantly developing. However, industrial waste water discharge and domestic waste water discharge are also increasing at the same time[1]. Only by timely monitoring the water quality essentially can we ensure the normal proceed of society, and the quality of people's daily life. In the national "Twelfth Five-Year Plan", ammonia nitrogen has been formally incorporated into water quality monitoring indicators[2]. The ammonia nitrogen in water can be converted into nitrite, which combined with protein can form nitrosamine. Nitrosamine is a strong

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carcinogen, which is bad for human body. Ammonia nitrogen, especially free ammonia (also known as molecular ammonia, NH_3), affects various kinds aquatic creature in water. When the ammonia nitrogen content in water reaches a certain concentration, it will directly lead to fish death[3]. The detection of ammonia nitrogen in water helps to evaluate and analyze water body's pollution and "self-cleaning" condition[4]. It is an important significance to monitor the ammonia nitrogen content in water timely[5].

Ammonia nitrogen in water mainly derives from original pollution of the daily life's waste water, if there's organic matter containing nitrogen, also coking and fertilizer plant waste water. The most original method of the water quality's detection is collecting the water sample first, and then analyzing it after preprocess. This method has a limited range measurement and large amount of work. The automatic ammonia nitrogen online detection system has many advantages[6], such as high degree of automation, small measurement error and large measuring range, etc. which greatly improve the efficiency of water quality monitoring. Methods for detecting ammonia nitrogen content in the laboratory include Nessler's reagent spectrophotometry, electrode method, salicylic acid spectrophotometry, gas phase molecular absorption method, phenol-hypochlorite colorimetric method, ion chromatography, and so on[7].

Li Ying etc[8] analyzed uncertainty temperature, mass and volume etc., which influence the test results, and pointed out that the equipment should be verified and corrected regularly, in order to make the test results within the controllable range. Xie Tingting[9] analyzed the experiment effects by display time, cuvette, and placement time, and concluded that the instrument should be clean and pay attention to the experimental environmental conditions during the test. In this paper, an ammonia nitrogen on-line detection system is designed, which can automatically extract water samples, automatically detect and upload the test results through the network. For the detection of ammonia nitrogen concentration, the most commonly Nessler's reagent spectrophotometry is used, which is based on the principle that mercury iodide and potassium iodide solution react with ammonia to generate a light reddish brown compound. This color has strong absorption in a wide wavelength range. The reaction process is shown in formula (1):

$$NH_4^+ + OH^- \rightarrow NH_3 + H_2O$$
$$NH_3 + OH^- \rightarrow NH_2^- + H_2O \quad (1)$$
$$2K_2HgI_4 + NH_2^- + 2OH^- \rightarrow NH_2Hg_2OI + 4K^+ + 7I^- + H_2O$$

Before the start of the experiment, configure the Nessler reagent and draw a calibration curve. The Nessler reagent is thoroughly mixed with the appropriate amount of water sample to be tested, and the Nessler reagent chemically reacts with the ammonia nitrogen in the water sample to form a light reddish brown colloidal compound, and then irradiates the compound with a broad wavelength ultraviolet light source because The absorbance is proportional to the ammonia nitrogen content, as shown in equation (2).

$$\text{Absorbance} = \lg \frac{\text{Reference light}}{\text{Measuring light intensity}} \quad (2)$$

Therefore, the absorbance is measured, the absorbance at the blank is subtracted, and the ammonia nitrogen concentration in the sample water sample can be obtained according to the calibration curve. The advantages of using Nessler's reagent spectrophotometry are simple operation, sensitivity, short processing time and high accuracy, which are suitable for the online detection system of ammonia nitrogen.

1 Online ammonia nitrogen detection system

The structural block diagram of the designed ammonia nitrogen online detection system is shown in Figure 1.

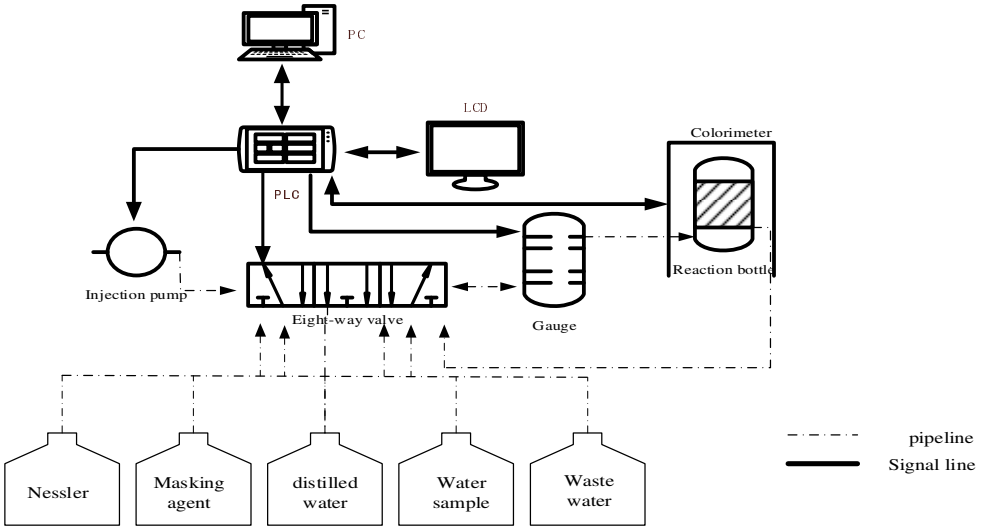

Fig.1 System block diagram

As can be seen from Figure 1, the components of the ammonia nitrogen on-line detection system are LCD, IPC, PLC, syringe pump, liquid meter, eight-way valve, reaction bottle, colorimetric reagent, Nessler reagent, masking agent, water to be measured. Sample, distilled water, waste liquid. The heater can keep the temperature of the reactor constant at the required temperature, and the eight-way valve realizes free switching of the pipe. The operation flow of the ammonia nitrogen online detection system is shown in Figure 3.

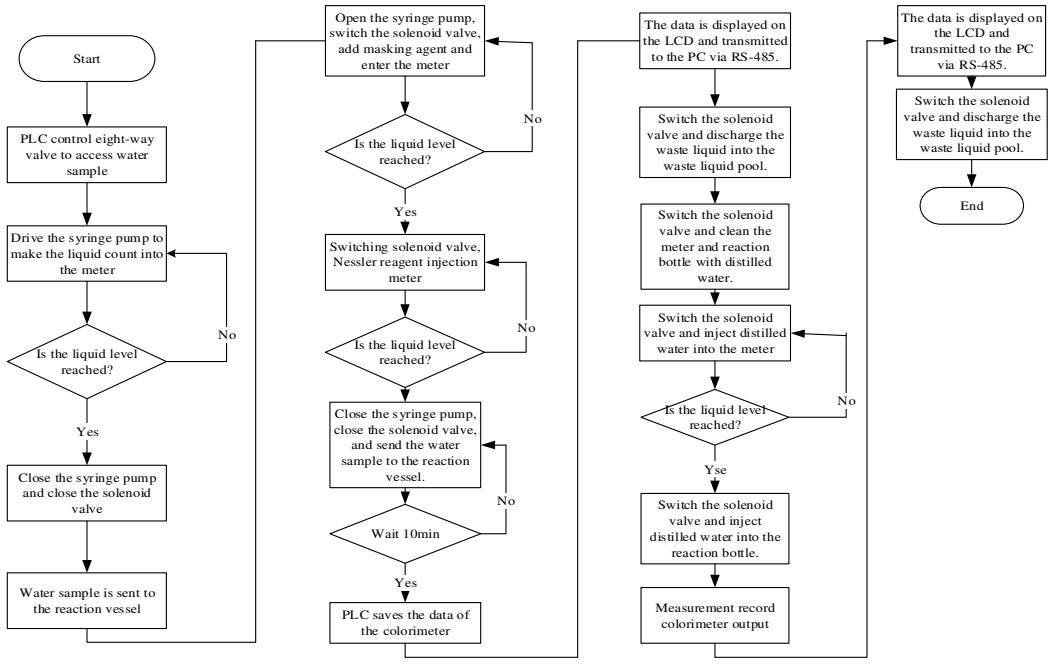

Fig. 2 flow chart

It can be seen from Fig.2 that the entire operational flow of the ammonia nitrogen on-line detection system is:

(1) The eight-way valve is controlled by the PLC to allow the water sample to enter the liquid meter; when the specified liquid level is reached, the water sample enters the reactor from the liquid meter;

(2) switching the eight-way valve to allow the masking agent to pass through the liquid meter and then enter the reactor;

(3) switching the eight-way valve, allowing the Nessler reagent to enter the reactor after being calculated by the liquid meter;

(4) The Nessler reagent is in contact with the water sample and is fully reacted. After waiting for 10 minutes, the data of the colorimeter is read, and the data at this time represents

the measured light intensity;

(5) switching the eight-way valve to discharge the reacted liquid into the waste liquid pool;

(6) Switching the eight-way valve to allow distilled water to enter the reactor, and reading the colorimeter data at this time, representing the reference light intensity;

(7) Switch the eight-way valve, clean the entire reactor, and discharge the waste water into the waste liquid pool.

2 BP Neural Network

BP neural network is a concept proposed by scientists led by Rumelhart and McClelland in 1986. It is a multi-layer feed forward neural network trained according to the reverse propagation algorithm. It is the most widely used neural network. Its advantage is that it has arbitrarily complex pattern classification ability and excellent multi-dimensional function mapping ability, and solves the problem of XOR that cannot be solved by simple perceptron. The BP neural network has an input layer, an implicit layer and an output layer. The essence of the BP algorithm is to calculate the minimum value of the objective function by using the network error squared objective function and the gradient descent method. The BP algorithm includes two processes of forward propagation of signals and back propagation of errors. The main formula is shown in (3)(4).

$$E = \frac{1}{2}\sum_{j=1}^{l}\left(\hat{y}_j - y_j\right)^2 \tag{3}$$

$$f(x) = sigmoid(x) = \frac{1}{1+e^{-x}} \tag{4}$$

Where $\hat{y}_j$ represents the output of the jth output layer neuron. Python is currently a more convenient and widely used computer programming language. This article also uses Python as the base language. The main program is as follows:

```
def main():
    data_train = dataload.load_data_train( ) #Loading training data
    modeltrain.Train_Model(data_train)   #Training models using training data
    data_pre = dataload.load_data_pre( )   #Load forecasted data
```

pre_result = dataprediction.Predict_Data(data_pre) #Return prediction results

3 Experimental results and analysis

According to the calculation rules of Nessler's reagent spectrophotometry, it is necessary to use reference light intensity and measuring light intensity to calculate the ammonia nitrogen content. In this experiment, 24 groups of data were selected. The ammonia nitrogen content started from 0, and the difference value of ammonia nitrogen content in each group was 0.3mg/L, until the ammonia nitrogen content reached 6.9mg/L. The measurement results are shown in table 1

Table 1: Table of ammonia nitrogen content measurement results

Label	Ammonia nitrogen content (mg/L)	Measuring light intensity (lx)	Reference light (lx)	BP neural network prediction value (mg/L)	Absolute error	Relative error (%)
1	0	2055.433	1521.61	0	0	0
2	0.3	1914.12	1520.87	0.36	0.06	20
3	0.6	1783.588	1521.04	0.55	-0.05	-8.333
4	0.9	1660.866	1520.21	0.98	0.08	8.888
5	1.2	1525.303	1498.47	1.1	-0.1	-8.333
6	1.5	1409.072	1485.69	1.42	-0.08	-5.333
7	1.8	1311.501	1484.18	1.75	-0.05	-2.777
8	2.1	1210.731	1470.58	2.24	0.14	6.666
9	2.4	1136.48	1481.65	2.5	0.1	4.166
10	2.7	1054.272	1475.23	2.82	0.12	4.444
11	3	977.9461	1468.74	2.95	-0.05	-1.666
12	3.3	912.302	1470.59	3.2	-0.1	-3.0303
13	3.6	847.2654	1465.87	3.52	-0.08	-2.222
14	3.9	793.2534	1472.96	4.05	0.15	3.84615
15	4.2	742.3171	1479.42	4.13	-0.07	-1.666
16	4.2	693.0769	1482.54	4.56	0.06	1.3333
17	4.8	650.1844	1492.81	4.91	0.11	2.29166
18	5.1	597.4754	1472.35	5.03	-0.07	-1.725
19	5.4	555.644	1469.64	5.36	-0.04	-7.4074
20	5.7	519.6676	1475.21	5.56	-0.14	-2.456
21	6	487.8611	1486.47	5.93	-0.07	-1.166
22	6.3	452.6722	1480.29	6.39	0.09	1.4285
23	6.6	421.5818	1476.68	6.72	0.12	1.1818
24	6.9	391.8567	1476.17	6.85	-0.05	-0.7246

As can be seen from Table 1, the average absolute error of the BP neural network prediction model is 0.0861, and the average relative error is 4.117%. It can be seen that the accuracy of using this predictive model is very high.

The BP neural network is used to predict the prediction model, and the results of the comparison with the actual ammonia nitrogen content are shown in Fig. 3.

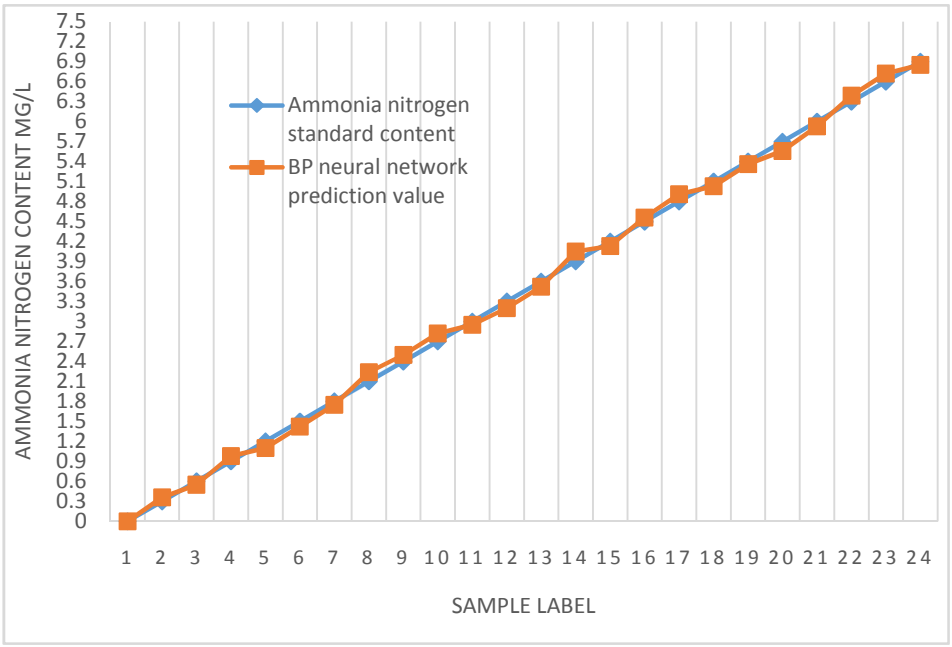

Fig. 3 Comparison of BP neural network and real value

It can be seen from Fig. 3 that the difference between the true value and the predicted value is not large, which proves that the BP neural network prediction model can detect the ammonia nitrogen content well and has high accuracy.

4 Summary

In this paper, an ammonia nitrogen on-line detection system is designed. The BP neural network algorithm is introduced into the prediction model of the system to improve the prediction accuracy. The experimental results show that the average absolute error of BP neural network prediction model in this system is 0.0861, and the average relative error is 4.117%. It has the characteristics of high prediction accuracy and small prediction error. The efficiency of the method for monitoring ammonia nitrogen in water was verified. The BP neural network-based analytical prediction model designed in this paper can also be widely used in other similar systems that require predictive analysis.

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