

Prediction of Dissolved Oxygen Using Artificial Neural Network

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Abstract. The paper is concerned with the use of a neural network model for the prediction of dissolved oxygen in canals. The neural network model is developed using experimental data which are obtained from the Department of Drainage and Sewerage, Bangkok Metropolitan Administration, during 2006-2008. The input parameters of the neural network are pH value (pH), biochemical oxygen demand (BOD), chemical oxygen demand (COD), substance solid (SS), total kjeldahl nitrogen (TKN), ammonia nitrogen (NH₃N), nitrite nitrogen (NO₂N), nitrate nitrogen (NO₃N), total phosphorous (T-P) and total coliform. The Levenberg–Marquardt algorithm is used to train the artificial neural network (ANN). The optimal ANN architecture was determined by trial and error method. The ANN architecture having 16 hidden neurons gives the best choice. Results of ANN models have been compared with the measured data on the basis of correlation coefficient (R), mean absolute error (MAE) and mean square error (MSE). Comparing the modeled values by ANN with the experimental data indicates that neural network model provides accurate results.

Keywords: Artificial Neural Network, Dissolved Oxygen, Canal

1. Introduction

Dissolved oxygen (DO) is one of the best indicators of the health of a water ecosystem. Dissolved oxygen can range from 0-18 parts per million, but most natural water systems require 5-6 parts per million to support a diverse population. Oxygen enters the water by direct absorption from the atmosphere or by plant photosynthesis. The oxygen is used by plants and animals for respiration and by the aerobic bacteria which consume oxygen during the process of decomposition. When organic matter such as animal waste or improperly treated wastewater enters a body of water, algae growth increases and the dissolved oxygen levels decrease as the plant material dies off and is decomposed through the action of the aerobic bacteria [1].

In recent years, Artificial Neural Network (ANN) methods have become increasingly popular for prediction and forecasting in a number of disciplines, including water resources and environmental science. ANNs are able to find and identify complex patterns in datasets that may not be well described by a set of known processes or simple mathematical formula [2]. Many modeling studies have been carried out to compute dissolved oxygen concentration in streams [3], river [4], lake [5], and canals. The main purpose of this study is to analyze the performances of neural network (NN) models in predicting of dissolved oxygen of Dusit district canals in Bangkok.

2. Data and Site Description

Dusit district is one district of Bangkok which comprised of 11 sites of canals. This network of canals is important for the daily life of the people in Bangkok. Bangkok is the capital city, as well as, the economic center of Thailand. Its activities, which include commercial, industrial and service have caused the expansion of the city and its population to accumulate environmental pollution to the point that nature cannot cope with the pollution loading; especially for water quality [11]. Dissolved oxygen is an important parameter for the condition of surface waters. The prediction of dissolved oxygen results can be utilized in water management and treatment systems.

In this study, water quality data are provided by the Department of Drainage and Sewerage, Bangkok Metropolitan Administration, during 2006-2008. There are 384 records of data. Each record consists of 11

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parameters, namely: pH value (pH), biochemical oxygen demand (BOD), chemical oxygen demand (COD), substance solid (SS), total kjeldahl nitrogen (TKN), ammonia nitrogen (NH₃N), nitrite nitrogen (NO₂N), nitrate nitrogen (NO₃N), total phosphorous (T-P), total coliform and dissolved oxygen (DO).

Hence, these eleven parameters are included in model development. The statistics of the variables is listed in Tab. 1, where SD means standard deviation.

Tab.1 Water quality characteristics of Dusit district canals (2006-2008)

Parameters	Unit	Minimum	Maximum	Mean	SD
pH	Standard Units	6.3	7.9	6.95	0.19
BOD	mg/l	1.4	69	10.2	7.65
COD	mg/l	5	565	37.32	35.59
SS	mg/l	2	336	34.19	42.06
TKN	mg/l	0.6	30.8	5.91	3.86
NH ₃ N	mg/l	0	9.5	1.54	1.85
NO ₂ N	mg/l	0	0.74	0.12	0.14
NO ₃ N	mg/l	0.3	4.6	1.67	0.69
T-P	mg/l	0	2.1	0.70	0.50
total coliform	MPN/100ml	300	24000000	2304734.63	6296173.15
DO	mg/l	0	10.8	1.73	1.37

3. Methodology

Artificial neural network and measure of performance are described in this section.

3.1. Artificial Neural Network

Neural network models are generally comprised of three independent layers: input, hidden, and output. Each layer consists of several processing neurons. Each neuron in a layer operates in logical similarity. Information is transmitted from one layer to others in serial operations. The neurons in the input layer include the input values. Each neuron in the hidden layer processes the inputs into the neuron outputs. The pattern of hidden layers to be applied in the modeling can be either multiple layers or a single layer. The most widely used training algorithm for neural networks is the backpropagation algorithm [7].

Fig.1 shows the architecture of a multilayer perceptron network. The multilayer perceptron (MLP) is an example of an artificial neural network that is used extensively to solve a number of different problems, including pattern recognition and interpolation [8][9]. Each layer is composed of neurons, which are interconnected with each other by weights. In each neuron, a specific mathematical function called the activation function accepts input from previous layers and generates output for the next layer. In the experiment, the activation function used is the hyperbolic tangent sigmoid transfer function [10] which is defined as in equation (1):

$$f(s) = \frac{1 - e^{-2s}}{1 + e^{-2s}} \quad (1)$$

where $s = \sum_{i=1}^n w_i x_i + b$, in which w_i are weights, x_i are inputs of neuron, b is bias and n is the number of variables.

The MLP is trained using the Levenberg–Marquardt technique as this technique is more powerful than the conventional gradient descent techniques [8].

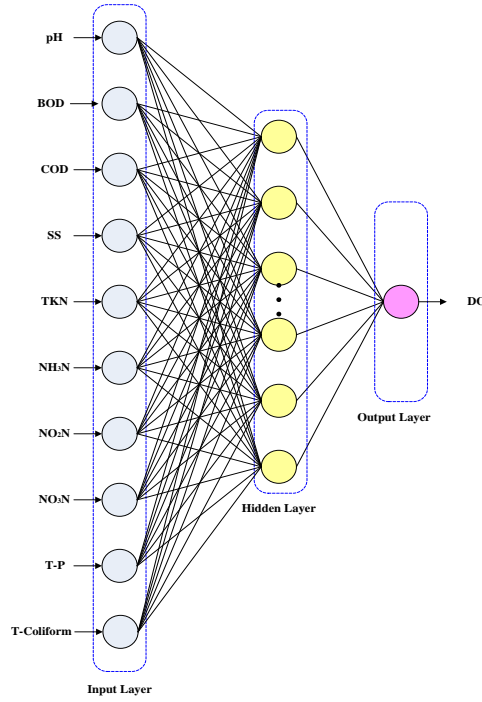


Fig. 1: The architecture of a multilayer perceptron

3.2. Measurement of performance

The performance of model was evaluated by calculating the following statistical parameters: correlation coefficient (R), mean absolute error (MAE) and mean square error (MSE) defined by equations (2) – (4), respectively.

$$R = \frac{\sum (Q_o - M_o)(Q_p - M_p)}{\sqrt{\sum (Q_o - M_o)^2 \sum (Q_p - M_p)^2}} \quad (2)$$

$$MAE = \frac{1}{N} \sum |Q_o - Q_p| \quad (3)$$

$$MSE = \frac{1}{N} \sum (Q_o - Q_p)^2 \quad (4)$$

where Q_o and Q_p are the observed and estimated concentrations at the time step, M_o and M_p are the mean of the observed and estimated concentrations respectively, and N is the total number of observations of the data set.

4. Experiment and Results

This section discusses data preprocessing, experimental data and neural network model.

4.1. Data Preprocessing

At the initial stage of the experiment, data were scaled or normalized to within the range 0.1-0.9 using following equation (5):

$$x_{new} = 0.8 \frac{x - x_{min}}{x_{max} - x_{min}} + 0.1 \quad (5)$$

where x_{new} is the normalized value of a original parameter, x is the original data point, x_{min} and x_{max} are the minimum and maximum values in the data set, respectively. This normalized form [6] is chosen because it tends to provide a better outcome on the water quality application.

4.2. Neural Network Model

The ratio of training to test data records employed in the experiment is 70:30. This means that with 384 data records, there are 269 records for the training set and 115 records for the test set. The Levenberg-Marquardt algorithm uses input vectors and corresponding target vectors to train the neural networks. The number of hidden units directly affects the performance of the network. Therefore, many experimental investigations are conducted. The number of hidden nodes determined to provide the optimal result is 16.

Finally, the architecture of the network is 10-16-1. The number of input nodes is 10, representing the parameters of water quality that affect dissolved oxygen. The number of the hidden nodes is set to 16. The number of output nodes is 1, representing dissolved oxygen (DO).

The stopping criteria for the training are: MSE below 0.01 or a number of epochs greater than 10000. Fig.2 shows the plot comparing the observed (actual) values of DO with the predicted DO from the network. The correlation coefficient, which measures the strength and direction of the linear relation between two variables (actual and predicted values) is $R=0.84$. The mean square error (MSE) of the model is equal to 0.78 and mean absolute error (MAE) is value to 0.7.

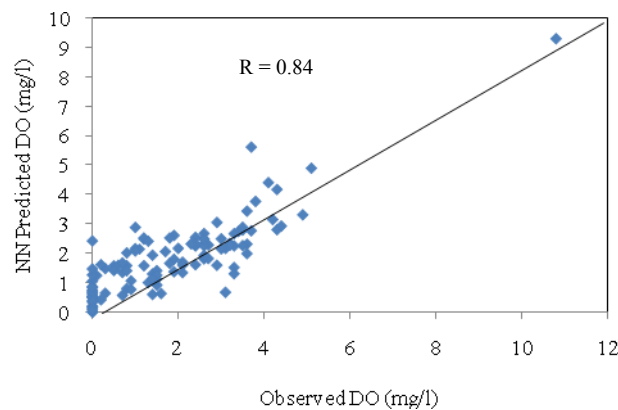


Fig. 2 Scatter plot between DO observed values and predict values using neural network model

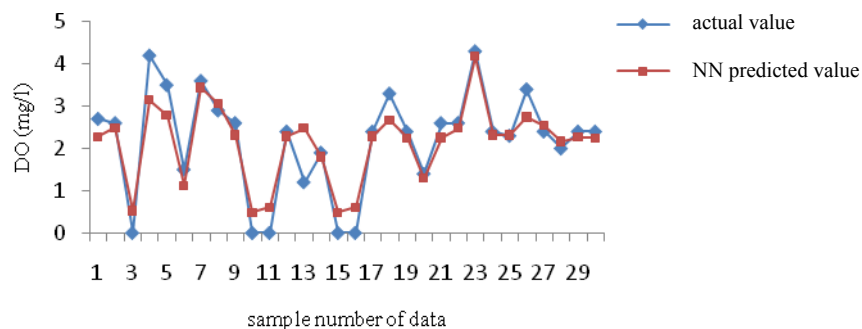


Fig. 3 Comparison of actual DO value and predicted DO value from the network on select sample points

Figure 3 demonstrated sample points of actual DO values compared with the predicted value from the neural network model. The graph illustrates that predicted values from the network is close to the DO actual value.

5. Conclusion

In this paper, the MLP neural network using the Levenberg-Marquardt algorithm is applied to predict the dissolved oxygen in Dusit district canals of Bangkok, Thailand. The results showed that the neural network model provided high correlation coefficients ($R=0.84$), mean square error ($MSE=0.78$) and mean absolute error (MAE) is equal to 0.7. Dissolved oxygen is an important parameter for usage conditions of surface waters. This result may be applied to automate DO estimations which utilized in water management and treatment systems corresponding to the government's policy in water management.

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7. References

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