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Using an Artificial Neural Network Model for Early Warning of Water Quality

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Abstract: Water quality early warning model is a key technology for building intelligent decision-making and environmental management systems in the era of big data. In recent years, the improvement of automatic water quality monitoring capabilities and the high demand for ecological models in measurement and management coordination have prompted researchers to explore new modeling methods and strive to improve model predictions. Among them, the artificial neural network (ANN) model has developed rapidly. This paper summarizes the development history and structural characteristics of three types of ANN models, and also integrates the ANN model with water quality data and soft measurement data. It summarizes the anomaly detection, time series forecasting and other research processes, and introduces the general modeling process, technical proposals, and commonly used indicators of model performance. Research shows that the use of ANN models depends on the quality of monitoring data, the interpretability of the model is poor, and the hardware resources required to run the model are required. It is necessary to accelerate the coordinated development and business application of water environment monitoring technology and early warning model, carry out technical iteration through testing various application scenarios, and form an online water quality system, intelligent early warning and emergency management system based on big data, which will help modernize China's environmental management capabilities.

Keywords: artificial intelligence, artificial neural network, big data, water quality, early warning.

Introduction. Water pollution is one of the major environmental problems facing humanity, and its damage is largely due to the lack of forecasting and early warning capabilities, as well as the lack of emergency response. Therefore, it is urgent to build an effective monitoring and early warning system to realize intelligent water quality management and decision-making. This is one of the major scientific and technological problems that need to be solved. Water quality forecasting is the initial stage of water quality early warning. Traditional statistical forecasting models mainly include methods such as multivariate linear regression (MLR) and differential autoregressive integrated moving average model (ARIMA). However, due to the nonlinear and non-stationary characteristics of water quality indicators, traditional statistical models often have difficulty in providing accurate forecasts[1].

Mechanism models based on hydrological physical processes and biogeochemical cycle processes, such as the Water Quality Analysis Modeling Program (WASP) (Ambrose, 1988), the Environmental Hydrodynamics Computer Code (EFDC) (Hamrick et al., 2000), and others, require a large number of input parameters, which requires a large amount of labor and material resources in the modeling and application process. In addition, the monitoring data used to verify the model are insufficient and temporarily unsatisfactory. Such models have few practical applications and are difficult to support effective early warning of water quality[2].

Currently, a new technological revolution is underway in the world, and artificial intelligence has become the main direction of industrial transformation. Artificial intelligence is being used as a driving force for development in various fields, creating new opportunities in the research process. In this context, intelligent algorithms such as support vector machine (SVM), fuzzy logic, evolutionary computation (EC), and artificial neural network (ANN) based on data are becoming increasingly popular and are also being applied to the problem of early warning of water quality. This opens up new possibilities [3]. Among them, ANN has become a research focus in academia and industry due to its high learning ability and generalization capabilities. Based on the “black box” approach as a mathematical method to establish an optimal mathematical relationship between input and output data, this method is suitable for studying systems with fuzzy rules and has good application potential in the field of early warning of water quality. However, we currently do not understand this type of model well enough.

This paper analyzes the development history and model structure characteristics of ANN, the soft measurement of water quality data, the research progress of data anomaly detection and time series forecasting, summarizes the overall modeling process, puts forward relevant technical proposals, summarizes the existing problems in the application of the model, and proposes future research ideas and key directions. It is only aimed at attracting new ideas, and hopes to communicate with many colleagues and promote interdisciplinary research and application of environmental modeling. An artificial neural network (ANN) is a large-scale information processing system that takes neurons as the basic structural unit, and usually consists of an input layer, a hidden layer, and an output layer. In the training process of an ANN, the data is input into the activation function after the weighted sum, the output value is calculated, and then the loss function value is calculated and the weights are updated. The development history of ANN covers more than 60 years since it was proposed in 1957. The years 1957-1969 constituted the first wave of ANN development, during which ANN emerged and developed rapidly. After 1986, the second wave of ANN development began, and great progress was made in model research. After 2006, ANN began to grow at an explosive rate, the pace of innovation and research accelerated significantly, and the technology was further developed in practical terms.

Classification and technical characteristics of artificial neural network models. There are many classifications of ANNs, of which the three main types used in the field of water quality early warning are: feed-forward neural network (FFNN), recurrent neural network (RNN), and convolutional neural network (CNN)[4,5].

FFNN is a neural network in which neural connections exist only between the input layer, hidden layer, and output layer, and has many networks with different structures and functions. The backpropagation neural network (BPNN) trained with the BP algorithm is one of the most common feed-forward neural networks. BPNN can calculate the input values and activation values of each layer, calculate the error term of each layer by backpropagating the error term, and finally calculate the derivative to update the change of the parameters of each layer. Radial basis function neural network (RBFNN) is an FFNN that uses a radial basis function as the activation function. RBFNN is a neural network with local approximation, and only the best approximation point can effectively solve the local optimum problem of BPNN. General regression neural network (GRNN) is an improved form of RBFNN. GRNN removes the hidden layer and extracts the connection between layers, and adds a template layer and a pooling layer, achieving good results in the small sample problem. Extreme learning machine (ELM) is an FFNN with extremely fast learning. ELM replaces the BP algorithm in traditional FFNN with the matrix inverse operation method with fast learning speed and strong generalization capabilities. It has higher learning and processing speed than traditional FFNN under the condition of ensuring a certain accuracy, and is suitable for various scenarios requiring real-time computing. Time-delay neural network (TDNN) is a type of FFNN used to process time series data. TDNN processes the dynamic characteristics of time series data using time-delay units, which has a strong effect on the sequence data. Compared with FFNN, the biggest difference of RNN is that the processing unit has a cyclic information flow. This special structure allows RNN to remember the previous state and affect the current output. However, when the time series data is too long, RNN often has the problem of gradient decay or gradient explosion, and it has no memory function for the original sequence data, which in turn affects the complexity of training the RNN model and its prediction performance. To solve this problem, LSTM creatively proposes the structure of forget gates, input and output gates, which can selectively filter out a part of the original sequence data.

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