Stress fitting and forecast model of dams based on BP neural network

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Abstract. Safety monitoring is significant in the daily management of the dams. Plenty instruments are planted in the dam to collect the health data of the dam. It is essential to evaluate and forecast the condition of the dam. This paper proposed a method to forecast the future stress condition of the dam.

1. Introduction

Recently, extreme weather across the country continue to occur. Dam safety is of great importance considering the enormous damage it may bring if dam’s damage occurs. Dam monitoring is the key to the whole dam safety system. Many instruments are planted in the dam body to monitor the safety condition. Thus, much data is collected during the years’ monitoring. In the safety management, it is vital to fully understand the meaning of the data and make reasonable forecast to deal with the potential danger. It is not enough to simply analyze the monitoring data. The connections between data from different time period and different positions should be taken into consideration as well.

Unlike the simple analyzing methods that are commonly used in the practice, senior mathematical model can help the managers understand the monitoring data better. Back propagation neural network is a method to analyze the known data and forecast the future data. It is a multilayer feedforward neural network trained by error back propagation algorithm. The BP neural network is commonly used in many areas to analyze the known data and forecast the future data.

2. Methodology

BP neural network has been used widely in many areas for its stability and precision. It has three basic layers: input layer, hidden layer and output layer. Figure 1 is a classic BP Neural network structure. Neurons in the same layer do not connect each other. Neurons of adjoining layers are connected by a weighing function. The information is transferred forwardly. And the error is transferred backward to minimize the error.
Figure 1. Topological structure of the BP neural network

BP neural network uses non-linear transforming function which is named as Sigmoid function. The Sigmoid function has two types which are unipolar function and bipolar function. The function used is shown below.

\[ S(x) = \frac{1}{1 + e^{-x}} \]

\[ S(x) = \frac{1 - e^{-x}}{1 + e^{-x}} \]

In the numerical example, unipolar function is used. Thus, the formula is shown as:

\[ y = f(net) = \frac{1}{1 + e^{-net}} \]

As talked above, neurons in the same layer does not connect to each other. It is the weighing function \( w \) which connect the neurons in the adjoining layers. Thus, the relationships between different layers is shown as below.

\[ o_k = f(net_k) \]

\[ net_k = \sum w_k y_k, k = 1, 2, ... \]

The network can be activated by the sigmoid method mentioned above. The error can be measured by the error function \( E \):

\[ E = \sum (y_k - t_k)^2 \]

By measuring the error, the model can be improved by itself. The error is weakening with several rounds’ training.

3. Numerical example
Xianlin reservoir is located in Hangzhou and it is the backup water source supplier of the city. As shown in the figure 1, the Xianlin reservoir has many sensors to monitor the stress condition of the face plate.

To monitor the stress condition of the dam, strain ometers are planted in the dam body as well as the plate.
Data has been collected since 2015. In this paper, 3 instruments and 2-year period’s data are collected to simulate. The result is illustrated below.

(a) Instrument S-1 analysis

(b) Instrument S1-2 analysis
As the result shown above, the overall fitting is quite well despite some sudden change of the monitoring data. In the numerical analysis, the more the model cluster, the better regression the model will have. The three instruments chosen have different features, but the regressions are all close to 1 which means the model fit well with the real data.

4. Conclusion
In this paper, BP neural network is used to simulate the transformation process of the stress in the dam. And the model is used to forecast the stress condition of the dam plate. As the result shows, the model shows a good fitting of the forecast and real stress data. This model can be used in the daily monitoring and safety management of the dam.

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