A MULTI-STEP-AHEAD PREDICTION MODEL FOR DAILY RESERVOIR INFLOWS

Dep. of Civil and Env. Eng., Ehime University Member of JSCE ○Camilo Allyson Simões de Farias (Ph.D. Student)
Dep. of Civil and Env. Eng., Ehime University Fellow of JSCE Koichi Suzuki (Dr. of Eng., Professor)
Dep. of Civil and Env. Eng., Ehime University Member of JSCE Akihiro Kadota (Dr. of Eng., Associate Professor)

1. INTRODUCTION

The management of water resources systems has become one of the best options for cities suffering from water shortage-related problems (Murase *et al*, 2004; Frederiksen, 2007). In order to develop optimal policies for reservoir operation, it is usually necessary to predict variables such as reservoir inflows. This study investigates a procedure based on Artificial Neural Networks (ANNs) that predicts daily reservoir inflows up to three days ahead. The procedure is applied to Ishitegawa Dam, which is the reservoir that supplies water to the city of Matsuyama, Japan.

2. ANN MODEL

An ANN model trained by the back-propagation algorithm is employed for predicting daily reservoir inflows. The architecture of the network is formed by the input layer, one hidden layer and the output layer. The input layer is composed of the previous inflow $I(t\text{-}1)$, current inflow $I(t)$, and forecasted precipitation $P(t+1)$. The number of neurons in the hidden layer was determined based on a trial-error procedure. The one-day-ahead inflow $I(t+1)$ is the single neuron of the output layer. The tan-sigmoid and linear functions are chosen as the activation functions of the hidden neurons and output neuron, respectively. The network architecture is illustrated in Figure 1.

In this approach, the Levenberg-Marquardt algorithm is used for the back-propagation training. A detailed explanation of LM algorithm is provided by Hagan & Menhaj (1994). The training process stops by means of the *Early Stopping Method* (Demuth & Beale, 2005).

3. ANN-BASED MULTI-STEP-AHEAD PREDICTION MODEL

The predictions of inflows up to three days ahead are done by means of the calibrated ANN model, which provides the prediction for one step ahead. The procedure consists of applying the ANN model successive times in order to obtain predictions for one day ahead $Ip(t+1)$, two days ahead $Ip(t+2)$, and three days ahead $Ip(t+3)$. In view of the fact that meteorological short-range forecasts are normally accessible, the daily precipitation values up to three days ahead are assumed to be reliable. The basic steps for the multi-step-ahead prediction of inflows are shown in Figure 2.

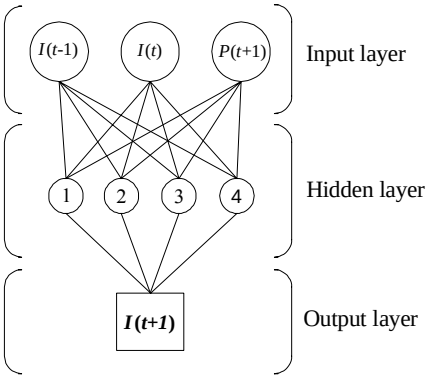

Figure 1 Architecture of the ANN model.

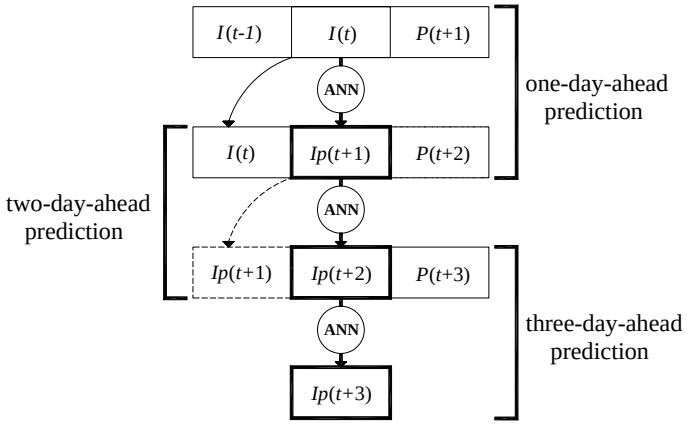

Figure 2 Steps for predicting inflows up to three days ahead.

Key words: Multi-step-ahead Prediction, Artificial Neural Networks, Reservoir Inflows

Contact Address: 3 Bunkyo-cho, Matsuyama, Ehime 790-8577, Japan TEL +81 (089) 927-9831

4. APPLICATION AND RESULTS

The historical data utilized in the procedure contain 13 years of daily data (1991-2003). The ANN model was calibrated using the data from 1991 until 2001 and tests were carried out over the years 2002 and 2003. The model calibration used the *Early Stopping Method* and, therefore, the calibration data set was divided in two subsets: the first was used for the ANN model training (1993-1999), and the second for validation (2000-2001), which specifies when to stop the network training. After the calibration of the ANN model, the sequence of inflows was predicted as described in Section 3.

The correlation (r) and bias (B) statistical indexes were used as criteria for evaluating the performance of the ANN-based model. A perfect prediction, which is unlikely to happen, would have $r = 1$ and $B = 0$.

The test results between observed and predicted inflows up to three days ahead are displayed in Figure 3. The respective correlations and biases were calculated and are also presented in Figure 3. The results were shown to be very reliable and presented slight decreases of accuracy for longer daily steps. As a consequence, this procedure may be an important support for a better management of Ishitegawa Dam.

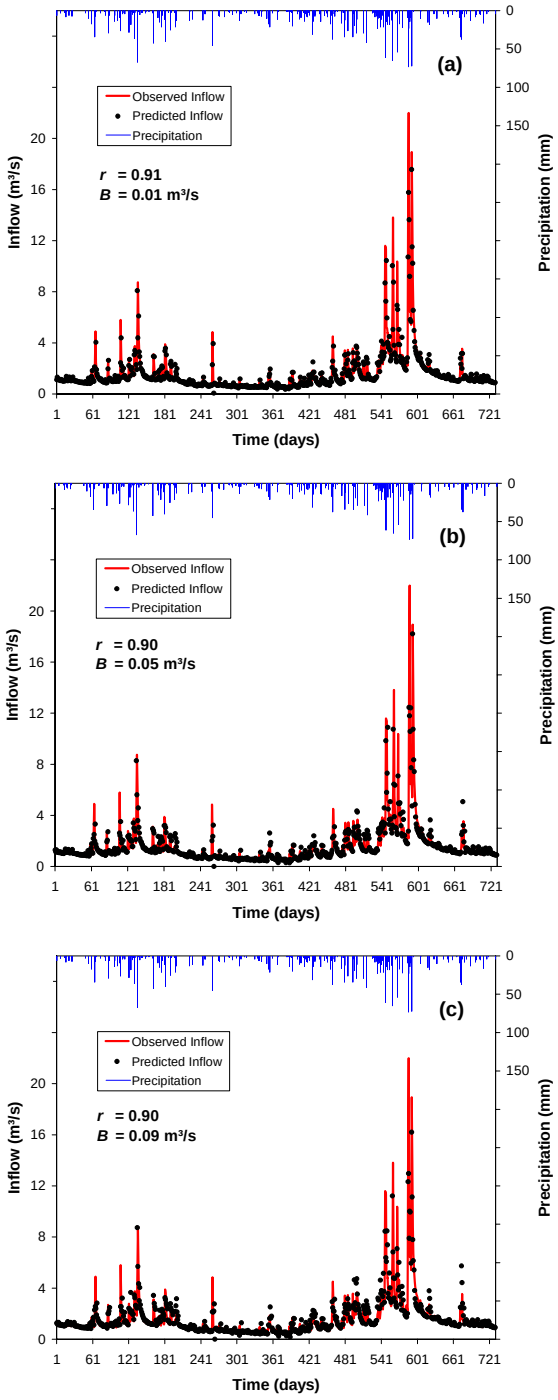

Figure 3 Comparison between observed and predicted inflows for (a) one day ahead, (b) two days ahead and (c) three days ahead.

5. CONCLUSION

The ANN-based multi-step-ahead prediction model was shown to be trustworthy and, therefore, very appropriate for short-term prediction of reservoir inflows as long as accurate short-range forecasts of precipitations are available. Thus, this model may produce reliable data for the application of techniques to the sustainable management of Matsuyama City's water supply system.

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