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A sediment concentration forecasting model integrating multiple artificial neural networks and the switched prediction method

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Abstract

Reservoir sedimentation reduces the reservoir capacity and consequently the water resource availability. The main source of reservoir sedimentation is the large amount of sediment inflow. The accuracy of sediment concentration forecasts is crucial for reservoir management. To avoid the risk of selecting artificial neural networks (ANNs), the switched prediction method is adopted. In this study, the switched prediction method is developed to determine the appropriate ANNs, including the back propagation networks (BPN), improved self-organizing linear output map (ISOLO) and four types of kernel function of support vector machines (SVM). An application to Shihmen reservoir is presented to demonstrate the ability of the proposed model. The results confirm that the performance of the ANN with the switched prediction method is significantly better than that of the optimal individual ANN and the ensemble mean forecasts of ANNs. In conclusion, the uncertainty of the forecasts could be reduced by using the switched prediction method. The accurate sediment concentration forecasting could be a reference for reservoir sediment management.

Keywords: Reservoir sedimentation; Sediment concentration forecasting; Artificial neural networks; Switched prediction method

1 Introduction

During typhoons and extreme rainfall events, the heavy rainfall brings the large amount of sediment inflow into reservoirs. It results in serious reservoir sedimentation and reduces the reservoir capacity (Pandey et al. 2016). Therefore, the sediment concentration forecast is crucial for reservoir management. A physically based mathematical model is difficult to construct for real-time forecasting due to the computational time and data requirement. The alternative to numerical based models is the artificial neural networks (ANNs), with superior ability in nonlinear processes. ANNs, such as back propagation networks (BPN), improved self-organizing linear output map (ISOLO) and four types of kernel function of support vector machines (SVM), have been applied in hydrology and sediment transport (Yadav et al., 2018, Kokpinar et al., 2018, Chang et al., 2018, Sun and Trevor, 2018). However, different ANNs could lead to different forecasting performance, and it is hard to determine which ANN should be adopted. To avoid the risk of selecting ANN, Lian et al. (2015) proposed a switched prediction method, which significantly

improves the model generalization. Hence, in this study, the proposed model using multiple ANNs and the switched prediction method is conducted for reservoir inflow sediment concentration forecasting. To demonstrate the capability of the proposed model, an application to Shihmen reservoir, northern Taiwan, and one of typhoon events from 2008 to 2015 is selected to establish the proposed model herein. To highlight the effect of the switched prediction method, the high inflow sediment concentration event, Typhoon Soulik, are analyzed.

2 Methodology construction

To reduce the risk of selecting ANN, the multiple ANNs using the switched prediction method is developed. Firstly, the BPN, SOLO and four types of kernel function of SVMs, including linear (SVM-LN), polynomial (SVM-PL), radial basis function (SVM-RBF) and sigmoid (SVM-SIG), are conducted to yield the sediment concentration forecasts. Secondly, the switched prediction method is adopted to combine the candidate ANNs. The flowchart of the model development is shown in Fig. 1. To demonstrate the ability of the switched prediction method, the ensemble mean (EM) and optimal forecasts (OPT), which extracting forecasts with minimum errors from aforementioned ANNs, are used for comparison.

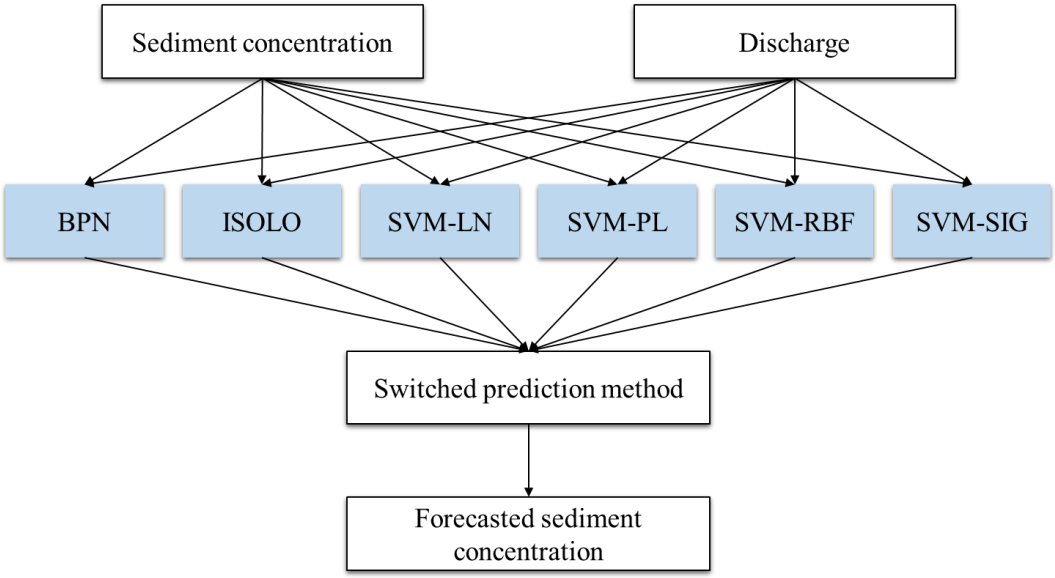

Fig. 1: Flowchart of the model development

3 Result and discussion

3.1 The performance of the multiple ANNs

This study first evaluates the performance of the different types of ANNs (Fig. 2). Due to the poor performance of BPN and SVM-PL, the ensemble mean forecasts at the peaks are under forecasted.

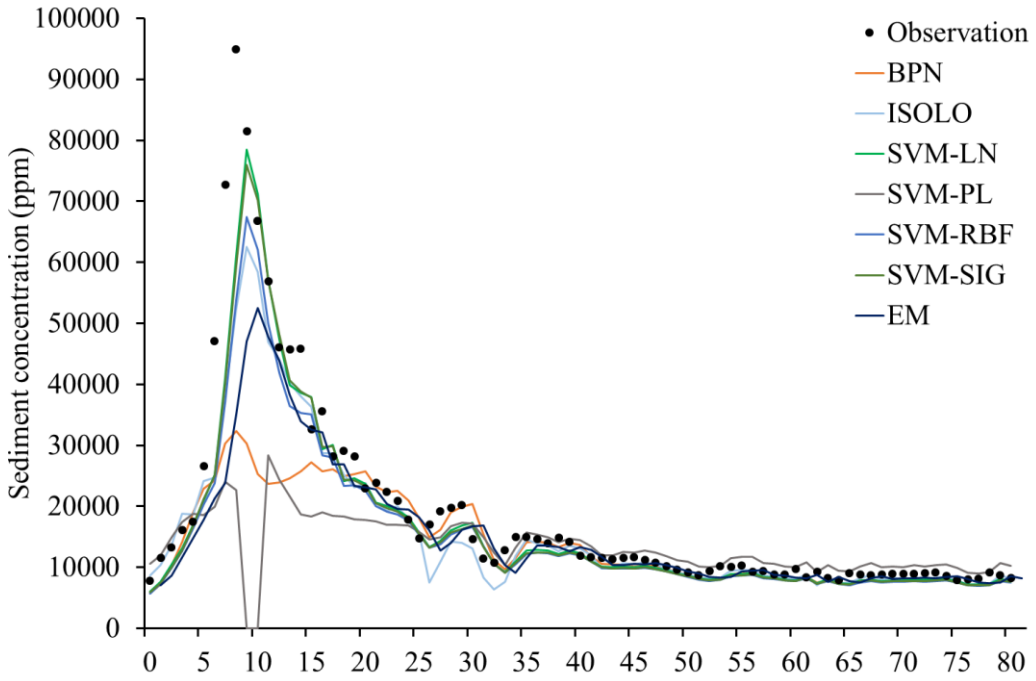

Fig. 2: Performance of the different types of ANNs and ensemble mean

3.2 The improvement due to the use of the switched prediction method

The comparison of forecasts from using the switched prediction method (SP), ensemble mean and optimal forecasts is shown in Fig. 3. It clearly illustrates that the SP has extrapolated ability for selecting the forecasting model. The performance of SP at peaks is better than EM and forecasts from SP have a good agreement with those from OPT.

4 Conclusions

The SP can significantly reduce the risk of selecting ANN. The results indicate that the extracted forecasts with SP are similar to the optimal forecasts (i.e. OPT). Based on the aforementioned results, using the SP could effectively select high performance models and filter out the noise. The accurate sediment concentration forecasts could help the sediment management in reservoirs.

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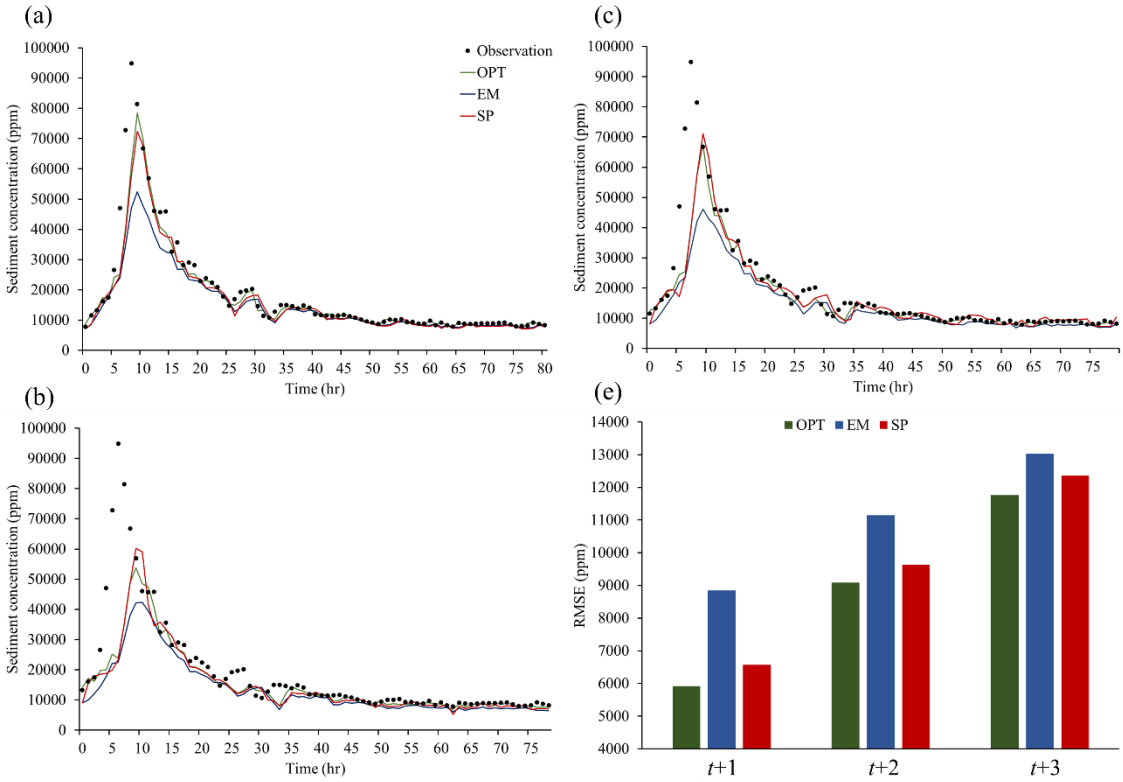

Fig. 3: Comparison of the observed sediment concentration with the forecasts of OPT, EM and SP

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