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Bayesian wavelet neural network models for forecasting reservoir inflow

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Accurate forecast of reservoir inflows is necessary for the effective operation and management of water resources. For example, accurate reservoir inflow forecasts are important for arriving at appropriate releases for flood control, hydro power generation and irrigation. Various models ranging from physically based to data driven approaches have been developed for the purpose of inflow forecasting. While majority of the models perform well in short lead forecasts, attaining similar level of good performance for long lead times remains a daunting challenge, mainly due to weak dependence between output and input variables for such long lead times.

In this study, we have employed artificial neural network modelling to provide long lead-time inflow forecasts for reservoir operation. To improve the output-input dependence structure for the long-lead times, we have employed wavelet transfer function to decompose the original model inputs into detailed discrete signals, which capture the useful information for analysing the local variation in a time series. Finally, the uncertainty intervals for the forecasts have been constructed using a Bayesian framework in which the model parameters (i.e. weights and biases of neural network links) are defined as probability distribution functions.

The proposed hybrid Bayesian-wavelet ANN (BWANN) method was applied to the Beas River inflow to the Pong Reservoir in the Indian State of Himachal Pradesh. Of the available 10 years monthly data, 7 years were used for model calibration and the remaining for validation. Model inputs comprise antecedent inflow values, rainfall and evaporation following extensive statistical analyses involving examination of correlation, auto-correlation and partial-autocorrelation functions. The Daubechies-10 mother wavelet transfer function was used and the number of details required in the signal decomposition of input variables was decided using a commonly applied empirical method. The training of the ANN employed the usual trial-and-error approach to arrive at the appropriate number of neurons in the lone hidden layer.

The results showed that the BWANN provided reliable estimates of long lead inflow forecast values (with Nash-Sutcliff Efficiency, NSE, index of 86% and 67% respectively for the 3-month lead and 12-month lead forecasts), complete with quantification of uncertainty intervals, which can be used for effective reservoir operation. In order to further demonstrate the superiority of BWANN, especially the effect of the modelling enhancement offered by the wavelet decomposition, its results were compared to those of a Bayesian artificial neural network (BANN) which used original inputs without any wavelet pre-processing. The results showed that the performance of the BANN models was consistently poorer, with corresponding NSE indices of 78% and 46% for the 3-month and 12-month lead forecasts respectively.