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Flash flood prediction in large dams using neural networks

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A flow forecasting methodology is presented as a support tool for flood management in large dams. The practical and efficient use of hydrological real-time measurements is necessary to operate early warning systems for flood disasters prevention, either in natural catchments or in those regulated with reservoirs. In this latter case, the optimal dam operation during flood scenarios should reduce the downstream risks, and at the same time achieve a compromise between different goals: structural security, minimize predictions uncertainty and water resources system management objectives. Downstream constraints depend basically on the geomorphology of the valley, the critical flow thresholds for flooding, the land use and vulnerability associated with human settlements and their economic activities.

A dam operation during a flood event thus requires appropriate strategies depending on the flood magnitude and the initial freeboard at the reservoir. The most important difficulty arises from the inherently stochastic character of peak rainfall intensities, their strong spatial and temporal variability, and the highly nonlinear response of semiarid catchments resulting from initial soil moisture condition and the dominant flow mechanisms. The practical integration of a flow prediction model in a real-time system should include combined techniques of pre-processing, data verification and completion, assimilation of information and implementation of real time filters depending on the system characteristics.

This work explores the behaviour of real-time flood forecast algorithms based on artificial neural networks (ANN) techniques, in the River Meca catchment (Huelva, Spain), regulated by El Sancho dam. The dam is equipped with three Taintor gates of 12x6 meters. The hydrological data network includes five high-resolution automatic pluviometers (dt=10 min) and three high precision water level sensors in the reservoir. A cross correlation analysis between precipitation data and inflows was previously performed for several historical events. Optimal time lags were found to be in the range of 2 to 6 hours, depending on the event. On the other hand, the flow autocorrelation analysis shows an average correlation of 0.50 for a lag=5 hours, and 0.40 for a lag= 6 hours, suggesting a reasonable prediction horizon.

The proposed forecasting methodology includes the on line time series historical reconstruction of the average rainfall in the catchment by the Thiessen polygons method, and the inflow estimation through the mass balance in the reservoir, while output flows derive from the hydraulics of the gates. The future values of inflows are predicted with an ANN model. This technique was chosen because of the general good ability shown by ANN in a number of publications, and due to its very high computational efficiency. Several ANN models architectures have been evaluated and compared. In all cases, input variables are average hourly flows and rainfalls in the catchments with different time delays, according to the forecasting horizon. Also the immediate future precipitation from an outside weather model is processed. The prediction horizon has been set to 3 hours, although results show that it could be extended a few extra hours if the external precipitation forecasts were reliable enough.

All the ANN models analyzed have a very simple architecture based on the conventional Three Layer Feed Forward Perceptron, with a variable number of hidden nodes and one single node in the output layer producing the next hour flow value. For the following time steps, a serial-propagated neural networks structure scheme is used, following the strategy suggested by F. Chang J. et al (2007). The ANN models have been compared using the root mean square error (RMSE) and the Nash-Sutcliffe efficiency (NSE) statistical indices.

The best model among all was chosen and implemented. Quality of predictions has been found to be strongly affected by reliability of rainfall predictions, in particular when it is overestimated, and not so much when it is underestimated. To reduce such sensitivity, a new model was proposed eliminating completely predicted rainfalls in the input set. Although results are slightly poorer, NSE index reveals a satisfactory performance in the validation set (0.80). The robustness and simplicity of ANN schemes makes them particularly appropriate in real-time systems, as they can easily be integrated and programmed, handling well the presence of possible errors and uncertainties in data. On the other hand, they are computationally very efficient, and over all, they are easily updated without changing the general conception and operation of the real-time decision making support tool.