

Downstream flow top width prediction in a river system

Parthasarathi Choudhury¹ and Nazrin Ullah^{1*}

¹Department of Civil Engineering, NIT Silchar, Assam, India, PIN: 788010

ABSTRACT

ANFIS, ARIMA and Hybrid Multiple Inflows Muskingum models (HMIM) were applied to simulate and forecast downstream discharge and flow top widths in a river system. The ANFIS model works on a set of linguistic rules while the ARIMA model uses a set of past values to predict the next value in a time series. The HMIM model assumes a power-law relationship between water discharge and flow top width at a section. The models were used to simulate and forecast discharge and flow top width at a downstream section in the Barak River system in India. Flow top widths corresponding to different flow depths at the downstream section were estimated using a digital elevation model (DEM). The parameters in the hybrid model were estimated by applying Non-dominated Sorting Genetic Algorithm II (NSGA-II). The study shows that the power-law relationship involving section characteristics can describe the top width versus discharge relationship for a section. The models allow direct estimation of the downstream flow top width on the basis of upstream flow variables. Results obtained in the study show that performances of the HMIM, ANFIS and ARIMA models are satisfactory, having average prediction errors of less than 7% of the average value of the observed series. Application of the ANFIS, ARIMA and the HMIM models to the studied river system demonstrate the suitability of the models in simulating and forecasting downstream flow top width in river systems.

Keywords: River system, flow top width, genetic algorithm, flood flow, hybrid model

INTRODUCTION

River flood forecasting and warning is one of the most important components of flood management. Reliable forecasts of future river flow conditions and early warning is necessary to take preventive measures and to mitigate flood damage. In addition to depth of flow and discharge, flow top width, which represents the extent of inundation, is an important factor for assessing the impact of flooding. Estimation of the flow top width at a channel section is important to get an idea of the impact and probability of flooding. Until recently, different types of models have been used for simulating fluvial flows in general and flood inundation in particular. These can range in complexity from using high resolution digital elevation models (DEM) capable of giving the flooded area (Zheng et al., 2008) to the use of full three-dimensional solutions of the Navier-Stokes equations (Yu and Lane, 2006; Gilles, 2010). Pappenberger et al. (2006) used the St. Venant equations for flood inundation prediction and applied Generalised Likelihood Uncertainty Estimation (GLUE) methodology to account for the uncertainty in forecasting inundation. Hashmi et al. (2012) used Mike 11 software to develop a rainfall-runoff model for Lai Stream Basin, Pakistan, and simultaneously generated flood maps for the area. Two-dimensional finite difference and finite element models (Anderson and Bates, 2000) have also been used to analyse flood movement in river reaches. Though the two-dimensional models give better representation of flood flow and flood inundation, these require extensive physical data and computational efforts for model calibration. Acquiring the required physical data for river reaches is often difficult; the

non-availability of a pertinent dataset is a drawback that usually restricts model development and its applications.

Apart from the abovementioned models, extensive use of data-driven models, time-series models and lumped empirical Muskingum models in flood flow modelling can be found in the literature. Data-driven models such as the adaptive neuro-fuzzy inference system (ANFIS), artificial neural network (ANN) and fuzzy logic (FL) have been found to be potentially useful in modelling time-series problems. The main advantage of these models is that they do not require specifying a functional relationship a priori; instead they self-organise the structure; adapt to it in an interactive manner, and can learn the underlying relationship(s) from the input-output data sets. In the hydrological forecasting context, application of data-driven models can be found in the works of Liong et al. (2000), Bazartseren et al. (2003), Chen et al. (2006), Jacquin and Shamseldin (2006), and Dastorani et al. (2009), among others. Fernandez et al. (2010) applied a neuro-fuzzy model for level prediction in Magdalena River, Columbia, and reported better performance by the ANFIS model compared to the deterministic models. The ANFIS model works on a set of linguistic rules and can handle imprecision and uncertainty inherent in the model and the data structure. Studies which have reported on the applications of ANFIS reveal that the model is useful in simulating and forecasting hydrologic time series.

As hydrologic events are essentially time-dependent, a number of time-series models have been used in modelling the problems. Time-series models such as Autoregressive Integrated Moving Average (ARIMA), and Autoregressive Moving Average (ARMA) models have been proposed and have been widely used for modelling hydrological time series (Box and Jenkins, 1976; Wang et al., 2006; Martins et al., 2011). An ARIMA model is a generalisation of an ARMA model; it makes time-series stationary in both calibration and forecasting phases. Khashei and Bijari (2010) applied hybrid ANN-ARIMA

* To whom all correspondence should be addressed.

☎ +9085228262; e-mail: nazrinullah@gmail.com

Received 29 January 2013; accepted in revised form 10 June 2014.