Application of the SVR-NSGAII to Hydrograph Routing in Open Channels

Mahyar Aboutalebi, A.M.ASCE[1]; Omid Bozorg Haddad[2]; and Hugo A. Loáiciga, F.ASCE[3]

Abstract: Flow routing is used to simulate or predict downstream hydrographs on the basis of the features of upstream flow hydrographs. This paper combines support vector regression (SVR) and the nondominated sorting genetic algorithm II (NSGAII) into a hybrid hydrologic routing model called SVR-NSGAII in this paper for the prediction of a downstream flow hydrograph in simple and compound channels. The SVR-NSGAII hydrologic routing predictions are compared with those from hydraulic models in simple and compound channels. This paper's results indicate that the SVR-NSGAII predicts the downstream hydrograph flow in a simple and compound channel, with approximately 94 and 98% accuracy, respectively. **DOI: 10.1061/(ASCE)IR.1943-4774.0000969.** *© 2015 American Society of Civil Engineers.*

Author keywords: Flow routing; Open channels; Support vector machine; Nondominated sorting genetic algorithm.

Introduction

Recent publications dealing with newly developed models for the optimization and simulation of water resources systems have addressed topics, such as reservoir operation (Ashofteh et al. 2013b, 2015a, c), design operation of pumped-storage and hydropower systems (Bozorg Haddad et al. 2014b), levee layouts and design (Bozorg Haddad et al. 2015b), hydrology (Ashofteh et al. 2013a), qualitative management of water resources systems, (Bozorg Haddad et al. 2015a), and algorithmic developments (Ashofteh et al. 2015b). However, few of these models have focused on the application of support vector regression (SVR) and the nondominated sorting genetic algorithm II (NSGAII) (SVR-NSGAII) or hydrograph routing in open channels.

Flow routing procedures used to simulate or predict a downstream hydrograph can be accomplished into hydrologic or hydraulic methods. Hydrologic routing methods simulate the flow hydrograph downstream on the basis of the continuity equation and functions relating to storage, outflow, and possibly inflow. In contrast, hydraulic routing methods model the flow hydrograph on the basis of the continuity and momentum equations, but they have many parameters that must be calibrated and channel characteristics to be incorporated in the analysis. Recently, artificial intelligence (AI) algorithms, such as the artificial neural network (ANN) (Peters et al. 2006), support vector machine (SVM) (Han et al. 2007), and genetic programming (GP) (Fallah-Mehidpour et al. 2013) were used to simulate downstream hydrographs on the basis of the features of upstream hydrographs. These AI algorithms are classifiable as hydrologic routing methods.

Concerning hydraulic routing methods, Saint-Venant (1871) introduced the dynamic wave equations. These equations have been widely used for flood forecasting in routing and software packages, such as *MIKE11* and *HEC-RAS* (Néelz and Pender 2009). However, these hydraulic equations are nonlinear and require numerical solutions. Mahmood and Yevjevich (1975) and Montes (1998) presented a comprehensive investigation on historical developments in numerical modeling of unsteady open channel flows. Proust et al. (2009) developed a new one-dimensional (1D) model called the independent subsections method (ISM) that computes the water profiles in each subsection of compound channels for uniform flow. Moreover, Proust et al. (2010) reported on the energy losses under nonuniform conditions in compound channels. Moghaddam and Firouzi (2011) developed the dynamic flood wave routing in natural rivers through the implicit numerical method. They presented a solution for the full Saint-Venant equations with the Preissmann implicit finite-difference scheme for hypothetical flood routing problems in a wide rectangular river and compared the solution of the developed model with *HEC-RAS*. Costabile and Macchione (2012), Tsakiris and Bellos (2014), and Costabile and Macchione (2015) provide more comprehensive views of hydraulic routing methods.

Concerning hydrologic routing methods, McCarthy (1938) developed a flood routing procedure for the Muskingum River in Ohio, now called the Muskingum method. Software packages, such as *HEC-1* (USACE 1998), apply the Muskingum method, whereby the outflow hydrograph is calculated for a given inflow hydrograph. Similar to hydraulic routing models, the parameters of the Muskingum method must be calibrated by using a set of observed inflow and outflow hydrograph data. The calibration of Muskingum-type methods plays a key role in its predictive accuracy. Many researchers, therefore, have addressed the estimation of Muskingum parameters with various techniques. The genetic algorithm (GA) (Mohan 2009), particle swarm optimization (PSO) (Chu and Chang 2009), immune clonal selection algorithm (ICSA) (Luo and Xie 2010), Nelder-Mead simplex algorithm (NMSA) (Barati 2011), harmony search (HA) (Geem 2011), differential evolution (DE) (Xu et al. 2012), Microsoft *Excel* solver (Barati 2013), hybrid harmony search algorithm (HHSA) (Karahan et al. 2013), metaheuristic algorithms (Orouji et al. 2013), GP (Orouji et al. 2014), and

[1]Dept. of Irrigation and Reclamation Engineering, Faculty of Agricultural Engineering and Technology, College of Agriculture and Natural Resources, Univ. of Tehran, Karaj, 14378-35693 Tehran, Iran. E-mail: Aboutalebi@ut.ac.ir

[2]Associate Professor, Dept. of Irrigation and Reclamation Engineering, Faculty of Agricultural Engineering and Technology, College of Agriculture and Natural Resources, Univ. of Tehran, Karaj, 31587-77871 Tehran, Iran (corresponding author). E-mail: OBHaddad@ut.ac.ir

[3]Professor, Dept. of Geography, Univ. of California, Santa Barbara, Santa Barbara, CA 93106-4060. E-mail: Hugo.Loaiciga@ucsb.edu

Note. This manuscript was submitted on June 2, 2015; approved on August 11, 2015; published online on December 16, 2015. Discussion period open until May 16, 2016; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Irrigation and Drainage Engineering***, © ASCE, ISSN 0733-9437.