Application of a Hybrid Optimization Method in Muskingum Parameter Estimation

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Abstract: Two new mathematical forms of the nonlinear Muskingum model called NL4 and NL5, involving four and five parameters, respectively, can be used in river flood routing. The accuracy of the estimation of the Muskingum model parameters is essential for flood routing. This paper proposes a novel hybrid algorithm, based on the shuffled frog leaping algorithm (SFLA) and Nelder-Mead simplex (NMS), for the estimation of parameters of two new nonlinear Muskingum models. The proposed methodology is applied by considering minimization of the sum of the square deviation (SSD) between observed and routed outflows in (1) experimental, (2) real, and (3) multimodal examples. Results show that the SSD is 0.91, 3.97, and 4.44% smaller (better) than pertinent values obtained by the genetic algorithm-generalized reduced gradient (GA-GRG) method in experimental, real, and multimodal examples, respectively. **DOI: 10.1061/(ASCE)IR.1943-4774.0000929.** *© 2015 American Society of Civil Engineers.*

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Introduction

Many classic and evolutionary optimization techniques have been developed and applied in various aspects of water resource systems such as reservoir operation (Fallah-Mehdipour et al. 2011, 2012; Yang et al. 2012; Gandomi and Alavi 2012; Gandomi 2014), hydrology (Orouji et al. 2013), cultivation rules (Noory et al. 2012; Fallah-Mehdipour et al. 2013), water distribution networks (Seifollahi-Aghmiuni et al. 2011, 2013), site selection of infrastructures (Karimi-Hosseini et al. 2011), and algorithmic developments (Shokri et al. 2013). Only a few of these works dealt with the application of hybrid optimization methods, especially in the estimation of Muskingum parameters.

Flood routing in open channels is a process for calculating the shape of a flood wave along a river channel. In general, two sets of methods can be used for flood routing calculation in open channels (Samani and Jebelifard 2003). These methods are classified as hydraulic and hydrologic routing methods. Hydraulic methods, which employ mathematical equations, involve time-consuming processes to route floods in open channels. However, those methods cannot be used in places that lack topographical data. For this situation, another approach, named hydrologic methods, can be used in flood routing. The Muskingum model is a popular hydrologic flood routing method based on the continuity and storage equations. In practical applications, accuracy in the estimation of Muskingum parameters is the most important task for applying the Muskingum model (Chow et al. 1988).

The nonlinear Muskingum model has been employed in several investigations. Various methods have been used to estimate the parameters of the nonlinear Muskingum model. Geem (2011) classified available methods for parameter estimation of the nonlinear Muskingum model in two groups: (1) mathematical techniques, such as the segmented least-squares method (S-LSM) (Gill 1978), nonlinear least-squares method (N-LSM) (Yoon and Padmanabhan 1993), Lagrange Multiplier (LM) method (Das 2004), Broyden-Fletcher-Goldfarb-Shanno (BFGS) technique (Geem 2006), Nelder-Mead simplex (NMS) algorithm (Barati 2011), and generalized reduced gradient (GRG) method (Barati 2013a; Hamedi et al. 2014b); and (2) phenomenon-mimicking algorithms, such as the genetic algorithm (GA) (Mohan 1997), harmony search (HS) (Kim et al. 2001), particle swarm optimization (PSO) (Chu and Chang 2009), immune clonal selection algorithm (ICSA) (Luo and Xie 2010), differential evolution (DE) (Xu et al. 2012), parameter setting free harmony search (PSF-HS) algorithm (Geem 2011), and a combination of the simulated annealing (SA) algorithm and shuffled frog leaping algorithm (SFLA) (Orouji et al. 2013).

Comparisons of different aspects of the two aforementioned procedures (mathematical techniques and phenomenon-mimicking methods) show that various methods of the former group rely on local search algorithms, which may converge in a few iterations but lack global optimality. However, those techniques necessitate a proposed initial solution for the parameter estimation to achieve global optimal solutions. On the other hand, procedures in the latter group randomly search for a near-global optimal solution, and

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