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Nonlinear Muskingum Flood Routing Model with Variable Parameters

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Abstract
The Muskingum method is the most widely used method of hydrologic routing with numerous applications throughout the world in which its popularity is because of its simple conceptual and ease of use. Since the relation between the weighted-flow and the storage seems to be nonlinear, a constant exponent parameter is used to account for this nonlinearity. On the other hand, the three constant-parameter model cannot address the variations of nonlinearity during routing period. In this paper, the nonlinear Muskingum model with variable parameters was recommended and the Modified Honey Bee Optimization Algorithm was successfully utilized to minimize the sum of squared (SSQ) deviations between the observed and routed outflows. The proposed variable-parameter model reduced the SSQ value more than 89 % comparing with the best constant-parameter Muskingum model in the literature and more than 83 % related to the exponent variable parameter model.
Keywords: Flood routing; Variable-parameter Muskingum Model; Optimization; MHBMO algorithm.

1. INTRODUCTION

In general, flood routing approaches can be categorized as the hydrological and hydraulic routing methods. The Muskingum model is the most common hydrological routing procedure in the world because of its simplicity and ease of use. The continuity and storage equations are the basic concept of this model. The only challenge in the Muskingum model is calibration of its parameters. This parameter is conventionally calibrated using the history of the floods in the river. The calibrated parameters are utilized to predict future floods only in the corresponding river. Linear Muskingum model has two constant parameters in which both have conceptual background. In most rivers, the relation between the weighted-flow and the storage seems to be nonlinear. Hence, one constant exponent was utilized to account for this nonlinearity in which this made the parameters in the nonlinear Muskingum model lose their physical meanings. Among different nonlinear relationships, the following one (Eq. 1) has an exponent parameter, m, in which it is practically provides more degrees of freedom for a better fit to nonlinear relationships but simultaneously make parameter estimation process more complicated.

$$S_t = K[xI_t + (1-x)Q_t]^m \quad (1)$$

Where S_t, I_t and Q_t are the total storage, the inflow magnitude and the outflow magnitude at time t, respectively, K is a storage-time constant which sometimes may be as an approximation of travel time of the peak flow through the reach, x is a weighting factor ranges between 0 to 0.3 for natural streams and m is an exponent parameter. In hydrological routing approach, the values of K and x are estimated from analysis of historical inflow and outflow records and also considered to be constant throughout the range of flow which is used for synthesizing flood hydrographs for the same stream reach. The additional parameter is supposed to account for the nonlinearity of the relation between the weighted-flow and storage volume. Unlike the linear model, the K parameter in the nonlinear Muskingum models is not an approximation of the travel time of the peak flow [1]. Since the additional parameters cannot be directly estimated from historical hydrograph records, alternative nonlinear parameter estimation techniques are utilized [2-9]. All of these studies consider constant parameters for the whole routing period. Although the accuracy in estimating Muskingum parameters has been improved, there is a quite considerable difference between the hydraulic routing approaches and Muskingum model.

In order to provide more accurate results using Muskingum method, some researchers recommended variable parameters for linear Muskingum model mostly physically-based relying on Saint-Venant equations [10-17]. Not physically-based methods were also proposed in which the linear Muskingum parameters are varying at every routing time interval using the averaging techniques [18]. More recently, an improved