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Parameter Estimation of Nonlinear Muskingum Models Using the Modified Honey Bee Mating Optimization

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Abstract

Since the relationship between weighted-flow and storage volume exists in most rivers tends to be a nonlinear one, the need for precise calibration of the nonlinear Muskingum model parameters provides an active area of research in hydrologic engineering. Although various techniques have been proposed to estimate the three parameters in nonlinear Muskingum model, a more accurate method with the fast convergence rate is still required to improve the computational precision. In the present paper, the Modified Honey Bee Mating Optimization (MHBMO) with the modified routing procedure is utilized for estimating the mentioned parameters. The proposed algorithm is applied for two case studies from previous literature and the results are compared with the other proposed methods. The results demonstrate that not only the MHBMO algorithm converges so quickly but also it captures the best optimal parameters values.
Keywords: Nonlinear Muskingum model, Optimization, MHBMO algorithm, Flood routing.

1. INTRODUCTION

Flood routing is the process of determining flow hydrograph at a point on a watershed from known hydrographs at upstream. In general, there are two basic approaches in order to route floods called the "hydrological routing approach" and the "hydraulic routing approach." In the former approach, the flow is calculated just as a function of time based on the storage-continuity equation at a specific location whereas in the latter one, the flow is calculated as a function of both time and space based on the Saint-Venant equations or its simplified forms at any desirable location. The more complicated the approaches become, the more amounts of time, effort and also data are required to calibrate and solve the model consequently.

One of the most widely used method of the hydrological routing techniques is Muskingum method in which models river channel storage either by a linear or nonlinear combination of wedge and prism storage. Linear Muskingum model utilizes continuity and linear storage equations:

$$\frac{dS_t}{dt} = I_t - Q_t \tag{1}$$

$$S_t = K[xI_t + (1-x)Q_t] \tag{2}$$

Where S_t, I_t and Q_t are total storage, inflow and outflow magnitudes at time t respectively, K is storage-time constant and x is a weighting factor ranges between 0 for reservoir-type storage to 0.5 for a full wedge. The value of x depends on the shape of the modeled wedge storage and in natural streams it is between 0 and 0.3, with a mean value near 0.2 [1]. In this model, the values of K and x are determined by using historical inflow and outflow records for a specific length of a reach. These two parameters are expected to capture the flood propagating characteristics of the reach in its entirety and no additional information of the topography of the channel is required for flood routing [2].

The linear Muskingum model may be inappropriate for representing some reaches [2]. In such situations, when the storage versus weighted flow relationship is not linear, use of a nonlinear model may be more appropriate [3]. For nonlinear relationships, three nonlinear forms of Muskingum model have been recommended [3-8] which practically provide more degrees of freedom for a better fit to nonlinear relationships but simultaneously make parameter estimation process more complicated.

$$S_t = K[xI_t + (1-x)Q_t]^m \tag{3}$$

$$S_t = K[xI_t^m + (1-x)Q_t^m] \tag{4}$$