### Title

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# Closure to "Application of a Hybrid Optimization Method in Muskingum Parameter Estimation" by Omid Bozorg Haddad, Farzan Hamedi, Elahe Fallah-Mehdipour, Hosein Orouji, and Miguel A. Mariño

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These writers thank the discusser for the insightful comments about the original paper. However, the following explanations and responses are necessary.

## Responses to Simulation Procedure Issues

- As mentioned in the "Abstract" section of the original paper, the main objective of the original study was the evaluation of 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. In other words, the original paper focuses on the calibration of hydrologic parameters of two new nonlinear Muskingum models with (1) experimental, (2) real, and (3) multimodal examples. Therefore, the same numerical solution method (Tung 1985; Yoon and Padmanabhan 1993; Mohan 1997; Kim et al. 2001; Geem 2006; Chu and Chang 2009; Barati 2012; Xu et al. 2012; Orouji et al. 2013a; Karahan et al. 2013; Easa 2013; Vatankhah 2014) was used to compare the results with other parameter estimation algorithms. Based on the results of the original paper, the SFLA-NMS method was found to be a promising approach for parameter calibration of the nonlinear Muskingum routing procedure.
- The discusser claimed that an improved version of Tung's (1985) method can be considered by changing the inflow input of the traditional numerical solution procedure. The traditional Tung's method had satisfactory results for the field conditions in the calibration and verification steps (Barati 2012). However, the alternative procedure for estimating the weighted average ($W_j$) of $I_{j-1}$ and $I_j$ as proposed by the discusser was only evaluated in the calibration procedure. Therefore, the alternative procedure for estimating $W_j$ must be established under field conditions by considering the calibration and verification steps.

## Responses to Optimization Procedure Issues

- In the discussion, the nonlinear programming solver (NLP) available in the language for interactive general optimization, *LINGO* was used as an alternative way to optimize the hydrologic parameters of the original and modified Tung (1985) methods. The NLP is a mathematical solver technique available for parameter estimation of nonlinear Muskingum models. The NLP relies on local search algorithms, which may converge in a few iterations but lack global optimality, in general. In addition, they achieve global optimal solutions contingent on the specification of suitable initial parameter estimates, a nontrivial task (Geem 2011). This is one of the reasons for developing the evolutionary and metaheuristic algorithms (Ahmadi et al. 2014; Ashofteh et al. 2013a, b, 2015a, c, b; Beygi et al. 2014; Bolouri-Yazdeli et al. 2014; Bozorg-Haddad et al. 2013, 2014, 2015a, b; Fallah-Mehdipour 2013b, a; Orouji et al. 2013b, 2014; Shokri et al. 2013, 2014; Seifollahi-Aghmiuni et al. 2013; Soltanjalili et al. 2013). On the other hand, the SFLA-NMS method is a hybrid algorithm of phenomenon-mimicking algorithms (SFLA) and mathematical techniques (NMS). The hybrid optimization algorithm overcomes the disadvantages of mathematical techniques (requirements for a good initial vector, convergence to local optima, and nonconvergence limitations) and the phenomenon-mimicking algorithms (difficulty in locating global optima, poor in terms of convergence performance). Also, in practical problems, the use of SFLA-generalized reduced gradient (GRG) (*MATLAB 9.0*) over the NLP (*LINGO*) has a wider range of applicability.
- The discusser claimed that NLP is more effective than the SFLA-NMS method for estimating the parameters of nonlinear Muskingum flood routing models because NLP reaches a lower value of the sum of the squared deviations between observed and routed outflows (SSD) with the Nonlinear5 (NL5) model in the second case study of the original paper. However, this issue is not due to the performance of SFLA-GRG. This is due to the low number of frogs that were imposed in the SFLA-NMS procedure. If the number of frogs is increased, SFLA-NMS can reach the SSD = 30,841.6 for the parameter vector ($K = 0.674$, $X = 0.651$, $\alpha_1 = 1.056$, $\alpha_2 = 1.163$, and $\beta = 1.398$) of NL5 model. This shows that the accuracies of the NLP and SFLA-NMS are alike. However, as cited previously, the SFLA-NMS (*MATLAB*) is a more practical tool.

## Concluding Remarks

The proposed modification of Tung's (1985) method by the discusser must be evaluated with the calibration and verification steps to convincingly make the conclusion of the discussion that "employing the modified Tung (1985) method will always produce better results than those of Tung (1985) method." Moreover, although the NLP procedure of *LINGO* and the SFLA-NMS procedure of *MATLAB* have the same accuracy, the latter procedure is a more practical tool. Also, the NLP is a mathematical search technique, whereas the SFLA-NMS is a hybrid algorithm of phenomenon-mimicking algorithms (SFLA) and mathematical techniques (NMS). The hybrid optimization algorithms overcome the disadvantages of mathematical techniques and the phenomenon-mimicking algorithms. Therefore, it is fair to state that SFLA-NMS is a more effective approach than the NLP for the parameter estimation. Moreover, the SFLA-NMS has a wider-range of applicability in engineering optimization problems than NLP.

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