World Academy of Science, Engineering and Technology
International Journal of Aerospace and Mechanical Engineering
Vol:14, No:04, 2020

An Optimal Control Method for Reconstruction of Topography in Dam-Break Flows

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Abstract : Modeling dam-break flows over non-flat beds requires an accurate representation of the topography which is the main source of uncertainty in the model. Therefore, developing robust and accurate techniques for reconstructing topography in this class of problems would reduce the uncertainty in the flow system. In many hydraulic applications, experimental techniques have been widely used to measure the bed topography. In practice, experimental work in hydraulics may be very demanding in both time and cost. Meanwhile, computational hydraulics have served as an alternative for laboratory and field experiments. Unlike the forward problem, the inverse problem is used to identify the bed parameters from the given experimental data. In this case, the shallow water equations used for modeling the hydraulics need to be rearranged in a way that the model parameters can be evaluated from measured data. However, this approach is not always possible and it suffers from stability restrictions. In the present work, we propose an adaptive optimal control technique to numerically identify the underlying bed topography from a given set of free-surface observation data. In this approach, a minimization function is defined to iteratively determine the model parameters. The proposed technique can be interpreted as a fractional-stage scheme. In the first stage, the forward problem is solved to determine the measurable parameters from known data. In the second stage, the adaptive control Ensemble Kalman Filter is implemented to combine the optimality of observation data in order to obtain the accurate estimation of the topography. The main features of this method are on one hand, the ability to solve for different complex geometries with no need for any rearrangements in the original model to rewrite it in an explicit form. On the other hand, its achievement of strong stability for simulations of flows in different regimes containing shocks or discontinuities over any geometry. Numerical results are presented for a dam-break flow problem over non-flat bed using different solvers for the shallow water equations. The robustness of the proposed method is investigated using different numbers of loops, sensitivity parameters, initial samples and location of observations. The obtained results demonstrate high reliability and accuracy of the proposed techniques.

Keywords : erodible beds, finite element method, finite volume method, nonlinear elasticity, shallow water equations, stresses in soil
Conference Title : ICMEAM 2020 : International Conference on Mechanical Engineering and Applied Mechanics
Conference Location : London, United Kingdom
Conference Dates : April 23-24, 2020