Flood prediction in a compound channel using machine learning techniques

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ABSTRACT

Flood prediction in a synthetic trapezoidal, compound channel is made, using an emulator of the computationally demanding 2D hydrodynamic model FLOW-R2D.

1 INTRODUCTION

Accurate flood prediction in reasonable computational time is of great importance for operational purposes, such as flood warning schemes. Accuracy in results requires fine scale modelling in the (usually 2D) hydrodynamic modelling.

However, even if 2D hydrodynamic studies are feasible in practice, the required computational time is still prohibitive for real-time prediction. Therefore in real world applications, flood warning schemes are usually based on ad hoc, empirical approaches, although the results derived are characterised by significant uncertainties.

One way for achieving results of higher accuracy with low computational cost, is the use of machine learning techniques (Carbajal et al., 2017; Bellos et al. 2017). In this study, we present an example of using an emulator for a detailed 2D hydrodynamic simulator, named FLOW-R2D (Tsakiris and Bellos, 2014), in a hypothetical case study.

2 METHODS AND MATERIALS

2.1 *Case study*

The hypothetical case study consists of a synthetic trapezoidal compound channel with a length of 1 km and a constant slope of 1‰ along the channel. A 3D view and the geometrical characteristics of the synthetic channel are shown in Figure 1. This hypothetical study can be generalised to real world scenaria. Herein we capture the most relevant aspects, i.e. the main river and the floodplains.

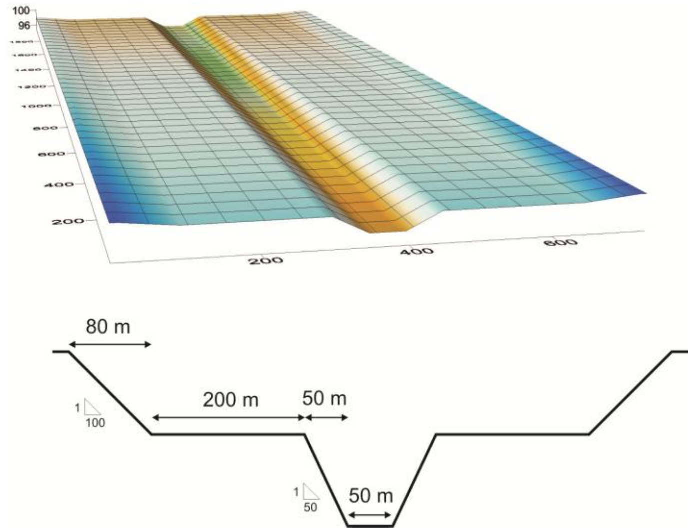

Figure 1. 3D view and geometrical characteristics of the synthetic channel

2.2 *Hydrodynamic modelling*

The simulator used for this study is the in-house FLOW-R2D model, based on the 2D Shallow Water Equations (2D-SWE), solved using the Finite Difference Method and a modified version of McCormack numerical scheme. The simulator has been used in several real world case studies (Bellos and Tsakiris, 2016).

The channel geometry is represented with a 10x10 m grid resolution. For the friction modelling, Manning equation is selected, assuming that n=0.04 s/m$^{1/3}$ in the main river and n=0.08 s/m$^{1/3}$ in the floodplains. Diffusion factor is selected as ω=0.90 and the time step is determined by Courant number equal to 0.1. The threshold which distinguishes wet and dry cells is set as 1 cm.

Dry bed is selected as initial condition, whereas for the downstream boundaries, open boundaries are set. For the upstream boundaries, a 4-hour hydrograph is used, determined by four parameters (Todini, 2007):

$$Q(t) = Q_0 + \left(Q_p - Q_0\right)\left[\frac{t}{t_p} exp\left(1 - \frac{t}{t_p}\right)\right]^{\beta} \qquad (1)$$

where Q is an inflow function of time t, Q_0 is the initial flow, Q_p is the flood peak, t_p is the time which the flood peak occurs and β is a shape factor.

2.3 *Emulator*

The input data for the emulator is a vector of the three of the four parameters describing the inflow hydrograph (initial flow is assumed to be constant and equal to 10 m^3/s). The output is the dynamic evolution of the water depth in three critical points located in the floodplains.

The training data for the emulator consists of 200 water depth time series derived by the simulator, in which the three input parameters are sampled using Latin Hypercube technique in a pre-specified range: Q_p[400,600] m^3/s, t_p[0.5,1.0] h, β[2.5,3.5].

3 CONCLUSION

Herein, an emulator is developed for flood prediction in critical points located in a synthetic compound trapezoidal channel, based on data produced by a computationally expensive physically-based simulator. The computational time was reduced from the magnitude of hours to the magnitude of seconds, whereas the error due to emulation is small. This demonstrates how machine learning techniques (in particular Kernel methods) can be leveraged to permit the use of accurate simulators in real-time application, such as flood warning schemes etc.

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5 AUTHOR CONTRIBUTIONS

VB developed the idea and performed the hydrodynamic modelling, JPC developed the idea and performed the emulation, JPL developed the idea and supervised the work.

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