Downscaling shallow water simulations using neural networks

Katia AIT-AMEUR, Inria, team LEMON / IMAG, Univ. Montpellier, CNRS - Montpellier
Luis MARTI, Inria Chile Research Center - Santiago, Chile
Antoine ROUSSEAU, Inria, team LEMON / IMAG, Univ. Montpellier, CNRS - Montpellier
Nayat SANCHEZ-PI, Inria Chile Research Center - Santiago, Chile
Gwladys TOULEMONDE, Inria, team LEMON / IMAG, Univ. Montpellier, CNRS - Montpellier

Urban flood simulations require the assessment of numerous indicators of different natures. Shallow water models provide flow data from which hydraulic variables may be derived with a satisfactory trade-off between model complexity and accuracy. However, such models remain too computationally demanding according to the level of detail required by an accurate meshing of the geometry. For this reason, substantial research effort has been devoted to developing multiscale modelling approaches. Multiscale modelling involves two steps :

- upscaling [3], whereby the flow problem of interest is solved over a coarse, or Low Resolution (LR) space-time grid,
- downscaling, whereby the results of the LR model are used as a basis to reconstruct High Resolution (HR) variables and risk indicators.

The interest of the approach lies in its computational efficiency : LR models are several orders of magnitudes as fast as HR models, and the downscaling process is usually computationally affordable. In an urban flooding context, the relationship between the Low Resolution and High Resolution fields can be inferred via neural networks.

In this work, we design a downscaling framework relying on statistical models to estimate HR hazard indicators from LR ones derived from upscaled flow simulations. The first analyses carried out in [1, 2] showed that this may yield fast and accurate estimates of the HR hazard indicators (water depth or norm of the unit discharge). A special effort is made to design physically relevant neural networks to fit realistic flow scenarios and evaluate the potential of these techniques when it is used in conjunction with upscaled flood models such as porosity models.

[1] K. Bakong, V. Guinot, A. Rousseau, G. Toulemonde. *Downscaling shallow water simulations using artificial neural networks and boosted trees.* Discrete and Continuous Dynamical Systems - S, 16(2) :220–239, 2023.

[2] J. Carreau, V. Guinot. *A pca spatial pattern based artificial neural network downscaling model for urban flood hazard assessment.* Advances in Water Resources, 147 :103821, 2021.

[3] V. Guinot. *Multiple porosity shallow water models for macroscopic modelling of urban floods.* Advances in Water Resources, 37 :40–72, 2012.

Contact : katia.ait-ameur@inria.fr