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Massively parallel inverse modelling on GPUs using the adjoint method

Ivan Utkin[1,2] and Ludovic Räss[1,2]
[1]Laboratory of Hydraulics, Hydrology and Glaciology (VAW), ETH Zurich, Zurich, Switzerland
[2]Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Birmensdorf, Switzerland

Continuum-based numerical modelling is a useful tool for interpreting field observations and geological or geotechical data. In order to match the available data and the results of numerical simulations, it is necessary to estimate the sensitivity of a particular model to changes in its parameters. Recent advances in hardware design, such as the development of massively parallel graphical processing units (GPUs), make it possible to run simulations at unprecedented resolution close to that of the original data. Thus, automated methods of calculating the sensitivity in a high-dimensional space of parameters are in demand.

The adjoint method of computing sensitivities, i.e., gradients of the forward model solution with respect to the parameters of interest, gains more attention in the scientific and engineering communities. This method allows for computing the sensitivities for every point of computational domain using the results of only one forward solve, in contrast to the direct method that would require runninng the forward simulation for each point of the domain. This property of adjoint method significantly reduces the amount of computational resources required for sensitivity analysis and inverse modelling.

In this work, we demonstrate the applications of the adjoint method to inverse modelling in geosciences. We developed massively parallel 3D forward and inverse solvers with full GPU support using Julia language. We present the results of performance and scalability tests on Piz Daint supercomputer at CSCS.