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Heuristic optimization methods for run-time intensive models (Dynamically Dimensioned Search, Particle Swarm Optimization, GA) – a comparison of performance and parallel implementation using R

Till Francke (1), Axel Bronster (1), and Christine A. Shoemaker (2)

(1) Universität Potsdam, Institut für Geoökologie, Potsdam, Germany (francke@uni-potsdam.de), (2) School of Civil and Environmental Engineering, Cornell University, Ithaca, USA

Calibrating complex hydrological models faces two major challenges: firstly, extended models, especially when spatially distributed, encompass a large number of parameters with different (and possibly a-priori unknown) sensitivity. Due to the usually rough surface of the objective function, this aggravates the risk of an algorithm to converge in a local optimum. Thus, gradient-based optimization methods are often bound to fail without a very good prior estimate.
Secondly, despite growing computational power, it is not uncommon that models of large extent in space or time take several minutes to run, which severely restricts the total number of model evaluations under given computational and time resources.
While various heuristic methods successfully address the first challenge, they tend to conflict with the second challenge due to the increased number of evaluations necessary. In that context we analyzed three methods (Dynamically Dimensioned Search / DDS, Particle Swarm Optimization / PSO, Genetic Algorithms /GA). We performed tests with common "synthetic" objective functions and a calibration of the hydrological model WASA-SED with different number of parameters. When looking at the reduction of the objective function within few (i.e.< 1000) evaluations, the methods generally perform in the order (best to worst) DDS-PSO-GA. Only at a larger number, GA can excel. To speed up optimization, we executed DDS and PSO as parallel applications, i.e. using multiple CPUs and/or computers. The parallelisation has been implemented in the ppso-package for the free computation environment R. Special focus has been laid onto the options to resume interrupted optimization runs and visualize progress.