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High performance GPU processing for inversion using uniform grid searches

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Many geophysical problems are described by systems of redundant, highly non-linear systems of ordinary equations with constant terms deriving from measurements and hence representing stochastic variables. Solution (inversion) of such problems is based on numerical, optimization methods, based on Monte Carlo sampling or on exhaustive searches in cases of two or even three “free” unknown variables.
Recently the TOPological INVersion (TOPINV) algorithm, a grid search-based technique in the Rn space, has been proposed. TOPINV is not based on the minimization of a certain cost function and involves only forward computations, hence avoiding computational errors. The basic concept is to transform observation equations into inequalities on the basis of an optimization parameter k and of their standard errors, and through repeated “scans” of n-dimensional search grids for decreasing values of k to identify the optimal clusters of gridpoints which satisfy observation inequalities and by definition contain the “true” solution. Stochastic optimal solutions and their variance-covariance matrices are then computed as first and second statistical moments.
Such exhaustive uniform searches produce an excessive computational load and are extremely time consuming for common computers based on a CPU. An alternative is to use a computing platform based on a GPU, which nowadays is affordable to the research community, which provides a much higher computing performance. Using the CUDA programming language to implement TOPINV allows the investigation of the attained speedup in execution time on such a high performance platform.
Based on synthetic data we compared the execution time required for two typical geophysical problems, modeling magma sources and seismic faults, described with up to 18 unknown variables, on both CPU/FORTRAN and GPU/CUDA platforms. The same problems for several different sizes of search grids (up to 1012 gridpoints) and numbers of unknown variables were solved on both platforms, and execution time as a function of the grid dimension for each problem was recorded. Results indicate an average speedup in calculations by a factor of 100 on the GPU platform; for example problems with 1012 grid-points require less than two hours instead of several days on conventional desktop computers. Such a speedup encourages the application of TOPINV on high performance platforms, as a GPU, in cases where nearly real time decisions are necessary, for example finite fault modeling to identify possible tsunami sources.