Large-scale 3D Controlled source EM modeling with a Block Low-Rank MUMPS solver

Sébastien de la Kethulle de Ryhove[1] , Piyoosh Jaysaval[2,3] and Daniil V. Shantsev[1,2]
[1] *EMGS, I&I Technology Center, P.O. Box 2087 Vika, 0125 Oslo, Norway*
[2] *University of Oslo, Department of Physics, P.O. Box 1048 Blindern, 0316 Oslo, Norway*
[3] *University of Texas at Austin, Institute for Geophysics, Austin, TX, USA*

Marine controlled-source electromagnetic (CSEM) method is commonly used to detect hydrocarbon accumulations on the continental shelf. In order to invert data acquired in a typical 3D CSEM survey we need to solve linear systems with dimensions of $\sim 10^7$ that arise from a finite-difference discretization of the frequency-domain Maxwell equations. The present study (see [1]) proposes to factorize the corresponding sparse matrices using a MUMPS solver with Block Low-Rank (BLR) functionality. A numerical threshold, the so called BLR threshold, controlling the accuracy of low-rank representations was optimized by balancing errors in the computed EM fields against savings in floating point operations (flops). The flop count, size of factor matrices and elapsed run time for matrix factorization are reduced dramatically by using BLR representations and can go down to, respectively, 10%, 30% and 40% of their full rank values for our largest system with $N=20.6$ million unknowns. The reductions are almost independent of the number of MPI tasks and threads at least up to $90\times10= 900$ cores. The BLR savings increase for larger systems, which reduces the factorization flop complexity from $O(N^2)$ for the full-rank solver to $O(N^m)$ with $m=1.4-1.6$. The BLR savings are significantly larger for deep-water environments that exclude the highly resistive air layer from the computational domain. A study in a scenario where simulations are required at multiple source locations shows that the BLR solver can become competitive in comparison to iterative solvers as an engine for 3D CSEM Gauss-Newton inversion that requires forward modelling for a few thousand right-hand sides.

[1] D. Shantsev, P. Jaysaval, S. de la Kethulle de Ryhove, P. R. Amestoy, A. Buttari, J.-Y. L'Excellent and T. Mary, *Large-scale 3D EM modeling with a Block Low-Rank multifrontal direct solver, Geophysical Journal International,* Accepted 2017 March 10. Received 2017 February 08; in original form 2016 October 26, *(2017)*