

WAVE ACOUSTIC PROPAGATION FOR GEOPHYSICS IMAGING, FINITE DIFFERENCE vs FINITE ELEMENT METHODS COMPARISON AND BOUNDARY CONDITION TREATMENT

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ABSTRACT

Imaging techniques for geophysical prospection of sea bottom are extremely demanding in terms of mathematical methods and computational resources [8]. This is because the measurements are going deeper than before, thus making the structures identification a hard task, and the datasets to be computed huge. Besides, the current trend is to analyze the images in three dimensions (3D) [4], adding an extra difficulty to the process. Currently, the prospection process is highly automatized by computer programs, where these programs not only implement and solve the mathematical model, but also carry the burden of the datasets manipulation, particularly in pre and post processing. All of these demands (complex mathematical models to be solved and huge datasets to be manipulated) lead us to high performance computing (HPC) environments, which are mainly available by supercomputers composed by thousands of computational nodes, thus efficient parallelization of those computer programs is required.

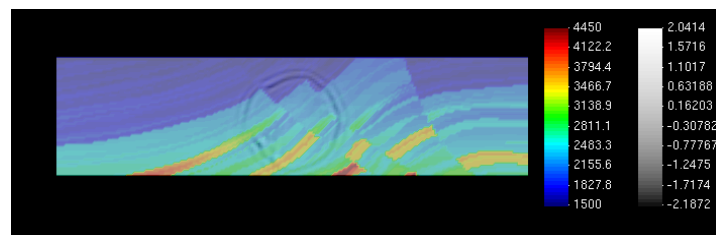


Figure 1: Marmousi test case. Impulse response test at $t = 0.36s$ on a 2D cut

Geophysical prospection of the sea bottom widely and recently use isotropic acoustic wave propagation [4]. From the mathematical modeling point of view two crucial points have to be considered. The first point is the numerical method used to solve the particular PDE of acoustic. In this paper, we compare two methods: Finite Difference (FD) [3] and Finite Element (FE) [6]. Their drawbacks and advantages are exposed, specifically under the light of HPC implementation. FD is a classic method,

highly appreciated by geophysicist. A basic FD computational implementation is straightforward, but high order implementations are very limited in terms of parallel performance and close to unsuitable for complex meshes. FE method is harder to be implemented (including mesh generation), but has almost no limits in terms of parallel performance, and it applies naturally to unstructured meshes, which is very important to handle hard to get features of the physical problem. The second crucial point to be considered is the unbounded domain technique (UDT) [1] to be used. UDT is needed to model the wave non-reflections at the computation domain boundary, those reflections does not exists in the physical domain. We compare three UDT methods: the Engquist first order absorbing boundary condition (ABC) [2], a damping layer and the convolutional perfectly matched layer (CPML) [7].

In order to compare the quality of the above methods, we first describe the mathematical and implementation features of them, all implementations are in-house software, where the FE solver is part of ALYA multi-physics framework [5]. Secondly, we compare impulse responses test results for the mentioned methods on two test cases: homogeneous and heterogeneous Marmousi (as can be observed in Figure 1). Results show that FD is the direct method to get high order scheme to control numerical dispersion. CPML is the best UDT method, unfortunately it is computational expensive, thus open an interesting trade-off.

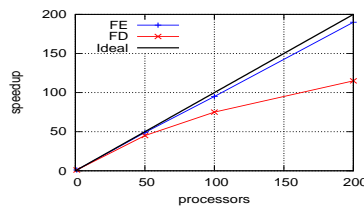


Figure 2: Speedup FE vs FD, MareNostrum supercomputer

From the computational point of view, we carry out experiments (including industrial size datasets) that allow us to compare the performance of the mentioned methods. FD is quicker on sequential computations than FE. However, in terms of parallel speedup FE performs better (Figure 2), in fact for large number of computational nodes the speedup is almost ideal.

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