Open position for an internship at *POEMS*

UMR 7231 CNRS/INRIA/ENSTA

2012/2013 Academic year

Coupling between the Fast Multipole Accelerated Boundary Element Method and the Finite Element Method for 3D visco-elastodynamics

- **Scientific Context.** The modeling of seismic wave propagation to understand complex phenomena such as site-effects or soil-structure interaction is an active area of research. The difficulties are related to the complexity of the system to model and the large spatial scale of the problems. Currently, 3D simulations are still limited to simplified configurations. This internship is part of an effort towards the development of tools to simulate real-life problems related to seismic wave propagation.

  Various numerical methods can be used to simulate seismic wave propagation. The main advantages of the Boundary Element Method (BEM) are to reduce the discretization to the domain boundary and to exactly take into account radiation conditions at infinite. As a result, BEMs are well suited to deal with problems in (semi-)infinite domains. However standard BEMs lead to a fully-populated influence matrix, and are thus severally limited regarding problems with complex geometries or in a large frequency range [4]. To address these limitations, recent works, in our group, have concerned the Fast Multipole accelerated BEM for 3D visco-elastodynamics [2, 5]. The Fast Multipole Method (FMM) permits to reduce drastically the solution time and the memory requirements of the BEM and to considerably enlarge the BEM model size.

  However the FM-BEM is limited to piecewise homogeneous domains and linear mechanical properties. For real-life problems it is thus necessary to deal with non-linear or heterogeneous materials. Since non-linearities in the soil can usually be treated as spatially bounded, the idea is to couple the FM-BEM with the Finite Element Method (FEM).

- **Objectives.** A first attempt towards this goal has been done in the PhD of E. Grasso [6]. E. Grasso has proposed two approaches for coupling FM-BEM and FEM. She has implemented the proposed approaches with a simple "in-house" FEM program. The first objective is to extend the FM-BEM/FEM coupling approaches proposed by E. Grasso [6] with an open source FEM program (for example FEAPpv developed by R.L. Taylor).

  This kind of coupling can also be seen as a competitive approach to standard Absorbing Boundary Conditions (ABCs) used to artificially truncate infinite domains. ABCs for elastic wave problems are known to raise difficult issues [1]. The two main approaches are the Perfectly matched layers (PMLs) and the high-order ABCs. The main drawback of those methods is their reliance on, and sensitivity to, algorithmic parameters such as the thickness of the layer for PMLs. On the other hand the FM-BEM/FEM is expected not to critically rely on specific parameters. The second task of the internship will be the comparison of the efficiency of the FM-BEM/FEM coupling with other absorbing boundary conditions (PMLs and high-order ABCs).

▷ **Knowledge.** Solid backgrounds in applied mathematics or computational mechanics and scientific programming skills are expected. Prior knowledge on the boundary element methods will be appreciated. Scientific interest in Earth problems is an asset.

▷ **Contact and location.** The internship (expected duration 5-6 months) will take place in the POems team (Propagation d'ondes: études mathématiques et simulation) of the applied mathematics department at ENSTA (Palaiseau). It will be supervised by Stéphanie Chaillat (CNRS junior scientist) and Marc Bonnet (CNRS senor scientist). Applications including a CV and a cover letter have to be sent to stephanie.chaillat@ensta.fr.

▷ **Prospect.** Depending on progress and results, this internship work may result in a published peer-reviewed article. Moreover a PhD continuation on this topic is a possibility.

The position is open to an international student.

References

[1] D. Baffet, J. Bielak, D. Givoli, T. Hagstrom, D. Rabinovich, Long-time stable high-order absorbing boundary conditions for elastodynamics. *Computer Methods in Applied Mechanics and Engineering*, 241-244: 20-37, 2012.

[2] S. Chaillat, M. Bonnet, J.F. Semblat, A multi-level Fast Multipole BEM for 3-D elastodynamics in the frequency domain. *Computer Methods in Applied Mechanics and Engineering*, 197: 4233-4249, 2008.

[3] S. Chaillat, J.F. Semblat, M. Bonnet, A preconditioned 3-D multi-region fast multipole solver for seismic wave propagation in complex geometries. *Communications in Computational Physics (special issue WAVES 2009)*, Vol. 11, 594-609, 2012.

[4] N. Delepine, J.F. Semblat, Site effects in an alpine valley with strong velocity gradient: Interest and limitations of the 'classical' BEM. *Soil Dynamics and Earthquake Engineering*, Vol. 38, 15-24, 2012.

[5] E. Grasso, S.Chaillat, M.Bonnet, J.-F. Semblat, Application of the multi-level time-harmonic fast multipole BEM to 3-D visco-elastodynamics. *Engineering Analysis with Boundary Elements*, Vol. 36, 744-758, 2012.

[6] E. Grasso, Modelling visco-elastic seismic wave propagation: a fast multipole boundary element method and its coupling with finite elements. PhD dissertation, 2012.