Postdoctoral position

Advanced modeling of wave equations in conducting porous media for Full Waveform Inversion

The sustainable exploration and exploitation of the natural resources of the Earth's are fundamental for the socio-economic development. Hence, obtaining accurate images of water, mineral and energy sources deep below the surface is a key step for their management and exploitation. Seismic imaging allows obtaining detailed maps of the Earth's interior, thanks to the analysis of the deformations and electromagnetic fields measured at the surface, similar to tomography imaging of the human body. This analysis is carried out by applying complex algorithms running on high-performance computers and depends strongly on the efficiency of the numerical direct solver and of the underlying model. The goal of this project is to improve the accuracy of the images by developing new models and numerical methods for the simulation of elastic and electromagnetic wave propagation in porous media. The numerical model will be confronted to laboratory experiments carried out in saturated sand where propagating mechanical and electromagnetic waves will be precisely monitored. The expected outcome of the post-doctoral project is the development of an inverse problem solver able to characterize conducting porous media from the knowledge of the diffracted seismic or electromagnetic fields. The targeted applications are geothermal exploitation, CO2 storage and oil exploration.

We will consider the Biot's equations but it would be interesting to figure out if they are the more relevant model to use. They are indeed obtained through a homogenization process which tends to average the problem. As a consequence, the postdoctoral work will start with working on the modeling of the forward problem by assessing different ways of representing the porosity. Still related to modeling is the need of suitable boundary conditions which are used to limit the computational domain. This problem deserves a particular interest as because it has been only partially solved for elastic media. It is clear that there are challenges ahead to which our approach needs to adapt. On the one hand, perfectly matched layers are widely used for truncating wave propagation domains. They are very efficient in the harmonic regime while they show some instability when used for time-dependent simulations. On the other hand, absorbing boundary conditions may be an option but to be trully effective, they have to be of high order. Thus their construction is tricky and high order absorbing boundary conditions for waves in porous media have never been constructed. One of the post-doc tasks will be then to construct effective boundary conditions to truncate the computational domain and the post-doc will benefit from the experience of Magique-3D team which has formerly proposed ways for truncating the computational domain (cf. Boillot et al., 2014). In particular, it would be interesting to provide an in-depth review of the propagation of waves near the interface between two different porous media. This study could help us to understand the characteristics of the propagation phenomenon to end up with the construction of a non-reflecting operator representing how waves can propagate outwardly to a given interface. Once boundary conditions have been constructed, which should put us on halfway, we consider that the postdoctoral work should focus on the solution of inverse problems. As discussed in Boxberg et al. (2014), there is a need in working on the parametrization of the medium. This question is currently addressed in Magique-3D team for elastic wave inversion and the same study should be done for porous media. We have observed that the accuracy of the solution to the inverse problem depends strongly on the parameter that is reconstructed. This is true even in the simplest case of acoustic Full Waveform Inversion where for instance it is more effective to retrieve $1/c_2$ than the velocity c itself. In the case of conducting porous media, the resistivity is a good candidate but it is unclear if its reconstruction has to be straightforward or through an intermediate step dealing with a function of the resistivity. Since the solution of the inverse problem is very expensive even once optimized, the post-doc will use first the 3D-stratified solver developed by Stéphane Garambois in Grenoble (Garambois and Dietrich, 2001) to perform a series of numerical experiments aiming at defining which parameter should be selected for inversion. The post-doc will take advantage of solvers that have been developed by Magique-3D for elastic (Beretta et al., 2016) and magneto-telluric (Alvarez-Aramberri et al., 2015) Full Waveform Inversion.

Funding: E2S scientific challenges project of the University of Pau and Pays de l'Adour (UPPA)
Hosting Laboratory: Team-project Inria-UPPA Magique-3D, Pau
Starting Date: from 2019/03/01
Duration: 1 year renewable twice
Gross salary: 34 k€ / year (which includes extra gratification for teaching duties 64h)
Key words: wave equations, inverse problems, numerical analysis, numerical schemes based on finite element methods.

Applicant's skills: PhD in Mathematics; Previous experience in inverse problems regarding both theory and computing; Previous experience in mathematical modeling; Advanced knowledge of English is required and knowledge of French would be a plus; Experience in trans-disciplinary research.

Application will include (in a single pdf file): A motivation letter; a curriculum vitae; a short summary of your past research (2 pages maximum)

Selection of candidate will be ensured by a scientific comity composed of local and exterior members of UPPA.

Application must be send to the following email address with the title "Post-doctoral application": helene.barucq@inria.fr

For more details on the hosting laboratory, see https://team.inria.fr/magique3d/fr/

References

Alvarez-Aramberri J.; Pardo D.; Barucq H., *A Secondary Field Based hp-Finite Element Method for the Simulation of Magnetotelluric Measurements* , Journal of Computational Science, 12-31, 2015.
Beretta E., De Hoop M. V., Faucher F. and Scherzer O., *Inverse Boundary Value Problem For The Helmholtz Equation: Quantitative Conditional Lipschitz Stability Estimates* , *SIAM Journal on Mathematical Analysis* , Society for Industrial and Applied Mathematics, 48 (6), pp.3962 – 3983, 2016.
Boillot, L., Barucq, H., Calandra, H., and Diaz, J., A *bsorbing Boundary Conditions for 2D Tilted Transverse Isotropic Media* , ESAIM: Proceedings, EDP Sciences, 45, pp.400-409, 2014.
Boxberg, M. S., Prévost, J. H., and Tromp, J., *Wave propagation in Porous Media Saturated with Two Fluids: Is it Feasible to Detect Leakage of a CO 2 Storage Site Using Seismic Waves?* Transp. Porous Med., 2014.
Garambois, S., & Dietrich, M., *Seismoelectric wave conversions in porous media: Field measurements and transfer function analysis* . Geophysics , 66 (5), 1417-1430, 2001.