2SC7691 – Optimization of a seismic exploration campaign for infrastructure protection

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Language of instruction: ANGLAIS
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 80
On-site hours (HPE): 48,00

Description

Project topic in partnership with CEA-DAM.

After the accident in Fukushima (Japan), the use of high-performance computing has become increasingly common in estimating the seismic risk associated with nuclear power plants. These tools are of strategic importance not only in the context of the design of new installations, but also in order to study the performance of existing power plants in the face of extreme vents, not anticipated during their design. In this context, the SEISM Institute (of which CentraleSupélec and CEA are founders) was founded in 2012. It is a French scientific grouping, comprising academic and industrial partners (including CEA and EDF), with the 'objective of bringing together the various know-how in seismology and earthquake engineering to improve the prediction of the seismic response of critical sites and structures in France, as well as the assessment of the associated risk.
In this context, this project concerns the optimization of a geophysical exploration campaign on an experimental site, using its digital twin, built using a wave propagation code (SEM3D) in development between CentraleSupélec, CEA and the Institute of Globe Physics. SEM3D simulates the propagation of seismic waves over large 3D domains, with domain decomposition on a Cartesian (or spherical) mesh. It also integrates the site topography and complex geological structures. The project therefore consists of solving an inverse problem in order to optimize - using SEM3D - the geological configuration of the site of interest. This optimization is based on the *Reverse Time Migration* method (i.e. resolution by adjoint problem). The optimization strategy provides for many realistic simulations, from source to sensors (forward) and back-propagation of the misfit (backward) in order to be able to update iteratively the mechanical properties of the subsoil. Indeed, given the size of the site of interest (~10 km wide) and the spatial resolution sought (~100m), although SEM3D is parallelized and distributed on supercomputers, each wave propagation simulation can last

several hours on many shared computing cores. For this, at each iteration, the *Forward* and *Backward* steps must be properly chained with an appropriate job scheduling strategy (launch of batch calculations). Finally, the number of sensors for in situ recordings must be reduced, given the associated costs, in terms of sensors, acquisition campaigns and storage of the data obtained.

The objective of this study is therefore threefold:

1. propose a geology model minimizing the difference between simulation and records,

2. minimize the number of sensors required to arrive at a model at a reasonable financial cost (considering their spatial layout),

3. manage to design this solution over the duration of the project with high-performance computers and with a limited quota of computing hours.

For this purpose, an optimization loop will be developed using the wave propagation simulation code as efficiently as possible: by sparingly exploring the space of possible configurations, to economically find a good solution.

Technical details of the system:
The studied system consists of a sedimentary basin surrounded by outcropping bedrock, possible candidate for the construction of a new nuclear power plant. To evaluate the seismic response of the site and to propose possible earthquake scenarios, one needs to know:

- the 3D geometry of the geological layers,
- the mechanical properties of these layers.

This information is fundamental for the definition of site effects on seismic energy radiated by an active fault.

Quarter number
ST7

Prerequisites (in terms of CS courses)
First year courses:

- SG1 common course "Systèmes d'Information et Programmation" (1CC1000)
- ST2 common course "Algorithmique et complexité" (1CC2000)

Courses of the ST: