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Solid Earth Physics on EGEE

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This abstract describes the “Solid Earth Physics” applications of the ESR(Earth Science Research) VO. These applications, developed or ported by the “Institut de Physique du Globe de Paris” (IPGP) address mainly seismology, data processing as well as simulation.
Solid Earth Physics deployed successfully two applications on EGEE.
The first one allows the rapid determination of earthquake mechanisms, and the second one, SPECFEM3D, allows numerical simulation of earthquakes in complex three-dimensional geological models.
A third application, currently being ported, will allow gravity gradiometry studies from GOCE satellite data.

1) Rapid determination of Earthquake centroid moment tensor (E. Clévédé, IPGP)

The goal of this application is to provide first order informations on seismic source for large Earthquakes occurring worldwide.
These informations are: the centroid, which corresponds to the location of the space-time barycenter of the rupture; the first moments of the rupture in the point-source approximation, which are the scalar moment giving the seismic energy released (from which the moment magnitude is deduced), the source duration, and the moment tensor that describes the global mechanism of the source (from which is deduced the orientation of the rupture plane and the kind of displacement on this plane).
The data used are three-components long-period seismic signals (from 1 to 10 MHz) recorded worldwide. In the case of a ‘rapid’ determination we use data from the GEOSCOPE network that allows us to obtain records from a dozen of stations within a few hours after the occurrence of the event.
In order to deal with the trade-off between centroid and moment tensor determinations, the centroid and the source duration are estimated by an exploration over a space-time grid (longitude, latitude, depth and source duration).
When the centroid is supposed to be known and fixed, the relation between the moment tensor and the data is linear.
Then, for each point of the centroid parameter space, we compute Green functions (one for each of the 6 elements of the moment tensor) for each receiver, and proceed to linear inversions in the spectral domain, for each different source durations.
The best solution is determined by the data fit.

This application is well adapted to the EGEE grid, as each point of the centroid parameter space can be treated independently, the main part of the time computation being the Green functions computation.
For a single point, a run is performed in a few minutes.
In a typical case, an exploration grid (longitude, latitude, depth and source duration) of 10x10x10x10

requires about 100h of time computation, which is reduced to about 1 hour over a hundred different jobs submitted to the EGEE grid.

The new features for workflow provided by gLite should allow the simplification of the management of the different steps of a run.

2) SPECFEM3D: Numerical simulation of earthquakes in complex three-dimensional geological models (D. Komatitsch MIGP; G. Moguilny, IPGP)

The spectral-element method (SEM) for regional scale seismic wave propagation problems is used to model wave propagation at high frequencies and for complex geological structures.
Simulations based upon a detailed sedimentary basin model and this accurate numerical technique produce generally nice waveform fits between the data and 3-D synthetic seismograms. Moreover, remaining discrepancies between the data and synthetic seismograms could ultimately be utilized to improve the velocity model based upon a structural inversion, or the source parameters based upon a centroid moment-tensor (CMT) inversion.

This application, written in Fortran 90 and using MPI, is very scalable and already ran outside EGEE on 1994 processors in the Japanese Earth Simulator, and inside EGEE on 64 processors at Nikhef (NL).

The amount of disk space and memory depend on the input parameters but are never very large. However, this application has some technical constraints : the I/O have to be done in local files (on each node) and on shared files (seen by all nodes), and the script must be able to submit 2 executable files sequentially, which use the same nodes in the same order. This is because the SPECFEM3D software package consists of two different codes, a mesher and a solver, which work on the same data.

Some successful tests have been done with gLite but the problem of differentiate a node (with several CPUs) and a CPU when requiring the resources, doesn't seem to be solved.

It also will be interesting to have access to "fast clusters" (with high throughput and low latency networks, as Myrinet, SCI...), and, to access larger configurations, by having the possibility to access various sites during a given run.

3) Gravity gradiometry (G. Pajot, IPGP)

The GOCE satellite (see [1]) is to be launched by the European Space Agency by the end of this year. Onboard is an instrument, called a gradiometer, which measures the spatial derivatives of the gravity field in three independent directions of space. Although gravity gradiometry was born more than a century ago and successfully used for geophysical prospecting, GOCE satellite will provide the first set of gravity gradiometry data on the whole Earth with unprecedented spatial resolution and accuracy and specific methods have to be developed. Thanks to these data, we will be able to derive information about the Earth inner mass distribution patterns at various scales (from the sedimentary basin to the Earth's Mantle).

To this aim, we develop a pseudo Monte Carlo inversion method (see [2]) to interpret GOCE data. One step of it is the model generation, which is the limiting factor of it. A model is a possible density distribution, to which correspond calculated gravity gradients as they would be measured by the instrument. These calculated gradients are compared to those actually measured; the nearer they are from measured ones, the closer the model is from real Earth. One rough pseudo random model takes about 5 minutes to be generated on a 2.8 GHz CPU, finest ones generation reaches 20 minutes and a set of 1000 models is a good basis to start the model space exploration, each one being independent from the others. Thus, EGEE is the perfect frame to develop such an application. We test and validate our algorithm using a set of marine gradiometry measurements provided by the Bell Geospace Company. These data need a frequent restricted access. First results of the application and solutions to the confidentiality problem are exposed here.

References:
[1] http://ganymede.ipgp.jussieu.fr/frog/
[2] Geophysical Inversion with a Neighbourhood Algorithm -I.
Searching a parameter space,*Sambridge, M.,*Geophys. J. Int., **138*,
479-494, 1999.

In conclusion, the main goal of these three applications is to create a Grid-based infrastructure to process, validate and exchange large sets of data within the worldwide Solid Earth physics community as well as to provide facilities for distributed computing. The stability of the infrastructure and the easiness to use the Grid are prerequisites to reach these objectives and bring the community to use the Grid facilities.

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