Geophysical Research Abstracts
Vol. 18, EGU2016-8649-1, 2016
EGU General Assembly 2016

SISYPHUS: A high performance seismic inversion factory

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In the recent years the massively parallel high performance computers became the standard instruments for solving the forward and inverse problems in seismology. The respective software packages dedicated to forward and inverse waveform modelling specially designed for such computers (SPECFEM3D, SES3D) became mature and widely available. These packages achieve significant computational performance and provide researchers with an opportunity to solve problems of bigger size at higher resolution within a shorter time. However, a typical seismic inversion process contains various activities that are beyond the common solver functionality. They include management of information on seismic events and stations, 3D models, observed and synthetic seismograms, pre-processing of the observed signals, computation of misfits and adjoint sources, minimization of misfits, and process workflow management. These activities are time consuming, seldom sufficiently automated, and therefore represent a bottleneck that can substantially offset performance benefits provided by even the most powerful modern supercomputers. Furthermore, a typical system architecture of modern supercomputing platforms is oriented towards the maximum computational performance and provides limited standard facilities for automation of the supporting activities.

We present a prototype solution that automates all aspects of the seismic inversion process and is tuned for the modern massively parallel high performance computing systems. We address several major aspects of the solution architecture, which include (1) design of an inversion state database for tracing all relevant aspects of the entire solution process, (2) design of an extensible workflow management framework, (3) integration with wave propagation solvers, (4) integration with optimization packages, (5) computation of misfits and adjoint sources, and (6) process monitoring. The inversion state database represents a hierarchical structure with branches for the static process setup, inversion iterations, and solver runs, each branch specifying information at the event, station and channel levels. The workflow management framework is based on an embedded scripting engine that allows definition of various workflow scenarios using a high-level scripting language and provides access to all available inversion components represented as standard library functions. At present the SES3D wave propagation solver is integrated in the solution; the work is in progress for interfacing with SPECFEM3D. A separate framework is designed for interoperability with an optimization module; the workflow manager and optimization process run in parallel and cooperate by exchanging messages according to a specially designed protocol. A library of high-performance modules implementing signal pre-processing, misfit and adjoint computations according to established good practices is included. Monitoring is based on information stored in the inversion state database and at present implements a command line interface; design of a graphical user interface is in progress. The software design fits well into the common massively parallel system architecture featuring a large number of computational nodes running distributed applications under control of batch-oriented resource managers. The solution prototype has been implemented on the “Piz Daint” supercomputer provided by the Swiss Supercomputing Centre (CSCS).