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On the use of Hessian information for solving full waveform inverse problems with Salvus

Christian Boehm, Lion Krischer, Korbinian Sager, Michael Afanasiev, Martin van Driel, and Andreas Fichtner
ETH Zurich, Institute of Geophysics, Zurich, Switzerland (christian.boehm@erdw.ethz.ch)

The ever-increasing power of high-performance computing clusters makes full waveform inversion applicable to a growing range of data sets to provide high-resolution images of subsurface structure. This presentation focusses on recent methodological and algorithmic advances in Salvus, which is a comprehensive collection of software packages covering the complete toolchain of time-domain waveform inversion with modules for numerical wave propagation, meshing, inversion, and workflow management.

Specifically, we discuss Newton-type trust-region methods and the use of Hessian information for multi-parameter waveform inversion. Due to the fast decaying spectrum of the Hessian operator, dominant curvature information can be extracted with only a few Hessian-vector products that can be efficiently computed using adjoint methods. The resulting low-rank approximation of the Hessian has plenty of useful applications, such as preconditioning the Newton system to speed up the solution of the inverse problem. In addition, it provides crucial information on uncertainties and parameter tradeoffs, which is particularly important for multi-parameter or joint source-structure inversions.

Furthermore, we introduce an automated, interactive, and graph-based workflow framework to steer the inversion procedure. It subdivides full waveform inversion into a sequence of tasks that are orchestrated by the workflow manager, thereby separating the numerical simulation from data processing and model handling. This enables us to automatically adjust the computational resources to the current needs, to distribute and execute tasks on remote clusters, and to foster data provenance and reproducibility.

Several numerical examples ranging from regional to planetary scale illustrate the wide range of applications that can be tackled with Salvus.