MS67 Advances and new directions in seismic imaging and inversion

Organizers:
Mauricio Sacchi (*University of Alberta*)
Sergey Fomel (*University of Texas, Austin*)
Laurent Demanet (*MIT*)

MS67-1 - **Friday, 08 at 09:30** Room G (Palazzina A - Building A, floor 0)

Comet interior imaging using radar tomography.
The Rosetta mission to comet 67P/C-G revolutionized comet science, but left major questions on the table. Are cometary nuclei primordial or are they collisionally-evolved as predicted by modern theories of planet formation? The CONSERT radar experiment sounded the interior of the nucleus showing it to be transparent to a depth of kilometers at 90 MHz, thus demonstrating the feasibility of a 3D global reflection tomography. The Comet Radar Explorer mission will acquire a dense network of in-phase radar echoes from orbit to obtain a high resolution 3D image. Full wavefield tomography facilitate high quality imaging of the comet interiors, particularly if the comet nucleus is characterized by complex structure and large contrasts of physical properties. Knowledge of the comet shape and all-around orbital radar acquisition enable accurate and computationally-efficient 3D wavefield tomography.

Paul Sava (*Colorado School of Mines*)

Seismic image matching
Numerous applications in seismic image analysis require matching two or more images. Examples include time-lapse and multicomponent image registration, migration deconvolution, full waveform inversion, adaptive subtraction of multiples, etc. Some applications benefit from separating the matching procedure into components, such as scaling, shifting, and smoothing. I review different techniques for seismic image matching and compare them using synthetic and field data examples.

Sergey Fomel (*University of Texas, Austin*)
Sarah Greer (*University of Texas at Austin*)

Data-to-Born transform for inversion and imaging with seismic waves
We consider an inverse problem for the acoustic wave equation, where an array of sensors probes an unknown medium with pulses and measures the scattered waves. The goal is to determine from these measurements the structure of the scattering medium, modeled by a spatially varying acoustic impedance function. Many conventional inversion algorithms assume that the dependency of the scattered waves on the unknown impedance is approximately linear. The linearization, known as the Born approximation, is not accurate in strongly scattering media, where the waves undergo multiple reflections before reaching the sensors. This results in artifacts in the impedance reconstructions. We show that it is possible to remove the multiple scattering effects from the data, using a reduced order model (ROM). The ROM is an orthogonal projection of the wave equation propagator on the subspace spanned by the time domain snapshots of the wavefields. While the snapshots are only known at sensor locations, this information is enough to construct the ROM. Once the ROM in constructed, we use its perturbations to generate a new data set that the same impedance would generate if the waves in the medium propagated according to Born approximation. We refer to such procedure as the Data-to-Born transform. Once the multiple scattering effects are removed from the data by the transform, it can be fed to conventional linearized inversion workflows.

Alexander Mamonov (*University of Houston*)

Direct waveform inversion (DWI) by explicit time-space causality
The full waveform inversion (FWI) is widely used to obtain images using recorded waveforms and it can be cast into a global nonlinear optimization problem. There are many known challenges in FWI. Using time-space causality of the wavefield, we propose to convert the global nonlinear optimization into many local linear inversions that can be directly solved (DWI). The conversion has no information loss. DWI naturally uses all data types and is unconditionally convergent and efficient.

Yingcai Zheng (*University of Houston*)

MS67-2 - **Friday, 08 at 14:00** Room G (Palazzina A - Building A, floor 0)

Efficient estimates of uncertainty in time-lapse seismic imaging
Multiple seismic data sets are often recorded to monitor changes in Earth properties. Results from studies using Full Waveform Inversion (FWI) to recover 4D changes have been encouraging thus far. Since 4D monitoring involves looking for small changes in localized regions, understanding the uncertainty in the measurement of those changes is key. We present an efficient way of creating big samples of data in a fast and computationally inexpensive way. We then use them in a statistical inversion technique to evaluate the performance of current 4D FWI techniques.

Maria Kotsi (*Memorial University of Newfoundland*)
Alison Malcolm (*Memorial University of Newfoundland*)

Experiments in bandwidth extension
This talk considers the basic question of frequency extrapolation of bandlimited recordings of scattered waves. I will discuss two methods that were shown to give meaningful results for seismic imaging: (i) a model reduction approach, where the phases of atomic seismic events are estimated by tracking, and (ii) a model extension approach, based on TV-regularized least-squares inversion of the extended Born modeling operator. Both methods are meaningful in the sense that they can help bootstrap the frequency sweeps for full waveform inversion. Joint work with Yunyue Elita Li.

Laurent Demanet (*MIT*)

Imaging complex near surface using noisy and narrow band surface wave data

Surface wave data are processed to retrieve dispersion curves that are inverted to estimate velocity models of the subsurface. Recent approaches avoids the inversion step using data transforms that estimate directly the velocity. Dispersion curves are discontinuous and noisy data that requires interpolation and smoothing.

Valentina Socco (*Politecnico di Torino*)

Multi-domain target-oriented imaging using extreme-scale matrix factorization

In this work, we present an alternative approach to re-datum both sources and receivers at depth, under the framework of reflectivity-based extended images with two-way wave propagation in the background medium. In our work, we will consider a linear algebra approach to deal with the low-rank representation of extended image volumes with full offsets. We will never build entirely the resulting matrix but get only actions of it on well-chosen probing vectors, based on Low-Rank decomposition or randomized SVD. The proposed scheme allows us to have access to all the energy of the extended image volume matrix and still overcome the computational cost and memory usage associated with the number of wave-equation solutions and explicit storage employed by conventional migration methods. Experimental results on complex geological models demonstrate the efficacy of proposed methodology in performing multi-domain target imaging.

Marie Graff-Kray (*Dr.*)
Felix J. Herrmann (*Georgia Institute of Technology*)
Rajiv Kumar (*Georgia Institute of Technology*)
Ivan Vasconcelos (*Dept. of Earth Sciences, Utrecht University*)

MS67-3 - **Friday, 08 at 16:30** Room G (Palazzina A - Building A, floor 0)

Multi-parameter full-waveform inversion: the influence of the parameterization

In multi-parameter full-waveform inversion (FWI) the choice of parameterization is fundamental to correctly separate the different parameter classes. We investigate the influence of the parameterization on the parameter separation for an elastic isotropic FWI problem from a mathematical standpoint. We also study this influence numerically using a simple model containing multiple anomalies in each parameter class positioned at different locations.

Ettore Biondi (*Stanford University*)

Retrieving full-wavefields within the medium from incomplete, one-sided data

Retrieving detailed and accurate images of targets that lie beneath or behind unknown complex overburdens or obstacles is a highly challenging problem in waveform-based imaging, such as in seismic, acoustic or radar applications. This problem is particularly difficult when experimental limitations are such that the medium in question cannot be fully surrounded by both by sources and receivers, thus only limited aperture, one-sided scattered-wave data are available. Overcoming some of the issues arising from having one-sided data, we will present an imaging framework based on wavefield redatuming, i.e., on retrieving scattered fields within the medium where observations are otherwise not available, that decouples the influence of the overburden from that of the target in imaging and inversion: thus separately allowing for better target images and/or overburden/obstacle characterization. The key enabler for this is solving an intermediate inverse scattering problem for the medium's focusing functions, in the context of 3D Marchenko field equations: these fields encode the effects of different portions of the medium without the need to first characterize medium properties. In this talk, we will review the 3D Marchenko system, discuss the theoretical and numerical inverse-problem aspects of retrieving focusing functions, and show examples of imaging options from one-sided data that are enabled by this framework.

Joeri Brackenhoff (*TU Delft*)
Matteo Ravasi (*Statoil*)
Christian Reinicke (*TU Delft*)
Tristan van Leeuwen (*Utrecht University*)
Ivan Vasconcelos (*Dept. of Earth Sciences, Utrecht University*)

Salt Geometry Reconstruction in Seismic Imaging

Full-Waveform Inversion attempts to estimate a high-resolution model of the Earth by inverting all the seismic data. This procedure fails if the Earth model contains high-contrast bodies such as salt. These bodies are important for hydrocarbon exploration.We propose a parametric level-set method to estimate these geometries by incorporating prior information about their properties. Tests ona suite of idealized salt geometries show that the proposed method is stable against a modest amount of noise.

Ajinkya Kadu (*Utrecht University*)
Wim Mulder (*Shell Global Solutions*)
Tristan van Leeuwen (*Utrecht University*)

Edge preserving filter for full waveform inversion

Full waveform inversion (FWI) provides accurate subsurface images. In spite of its success, the application of FWI in areas with high-velocity contrast remains a challenging problem. Quadratic regularization methods are often adopted to stabilize inverse problems. Unfortunately, edges and sharp discontinuities are not adequately preserved by quadratic regularization. During the iterative FWI method, an edge-preserving filter, on the other hand, can gradually incorporate sharpness into seismic images. We use an edge-preserving filter to stabilize FWI.

Amsalu Anagaw (*University of Alberta*)
Mauricio Sacchi (*University of Alberta*)