Geophysical Inversion Workshop 2006
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Abstracts (Alphabetical by primary author's last name.)

Explicit wavefield extrapolation directly from topography

By Saleh Al-Saleh and Gary Margrave, Department of Geology and Geophysics, University of Calgary

Downward continuation methods assume that extrapolation takes place between two planes, but most land surveys are acquired over irregular surfaces. Most approaches that allow downward continuation methods to handle such data, like the wave equation datuming and zero-velocity layer methods, require some processing prior to migration. In this paper, we show how explicit wavefield extrapolation methods in the space-frequency domain can efficiently extrapolate data directly from rugged topography. By building operators with different depth steps, these wavefield extrapolators can handle lateral velocity and topographic variations. We use a source-receiver migration technique to illustrate how this approach can be implemented, using a synthetic dataset as an example.

Kirchhoff inversion for Incident Waves Synthesized from Common-Shot Data Gathers

By Norm Bleistein, Center for Wave Phenomena, Dept. of Geophysics, Colorado School of Mines

Synthesis is a process for producing reflection responses from more general sources or from prescribed incident waves by combining common-shot data gathers. Synthesis can provide survey-wide data sets, similar in that regard to common-offset data gathers, but with the added advantage that each synthesized data set is a solution to a single wave equation. A common-offset data set does not have this last feature. Thus, synthesized data sets can be processed by true amplitude wave equation migration. The output is then known to be true amplitude, as well, in the same sense as is the output of Kirchhoff inversion. Alternatively, the Kirchhoff inversion of synthesized data has a Beylkin determinant that is expressed in terms of the *wkbj* Green's function amplitude. This is in contrast to 3D common offset inversion where the Beylkin determinant is most difficult to compute. We present here a theory of data synthesis based on application of Green's theorem to the ensemble of common-shot gathers and pre\-scribed more general sources or prescribed incident waves. Specific examples include delayed-shot line sources and incident dipping plane waves at the upper surface. We also discuss two cases in which waves are prescribed at depth, back-projected to the upper surface and then used to generate a synthesized data set.

Some comments on the Born approximation

By Chris Chapman, Schlumberger Cambridge Research

The Born approximation - the first-order term in the Lipmann Schwinger series - forms the basis for much modelling and inversion work. If the Green function is known exactly in the background, reference model, then the Born approximation models the first-order scattered signals from perturbations to the model, and gives the exact Frechet differential kernel for linearized inversion. Except when the background model is homogeneous, the Green function must be calculated by an expensive numerical scheme or approximated. Unfortunately, an approximate Green function introduces a fundamental ambiguity into the Born approximation. The errors in the Green function may be as important as the scattered signals from the Born approximation. At the extreme of a homogeneous background model, the Green function is known exactly but the Lipmann Schwinger series only converges slowly for a realistic, heterogeneous model - it is particularly ineffective at correcting the travel times; at the other extreme where the background model is the true model, then the scattered signals are errors in the Green function but the standard Born approximation contributes nothing. The solution is to reformulate the Born integral acknowledging errors in the Green function. Although the result is similar to the Born approximation - a volume integral over scatterers - the two methods are fundamentally different. In the Born approximation, the integral is over perturbations from the background model, whereas in the alternative, the integral is over error terms from the approximate Green function. For modelling, the advantage is that the background model can be chosen to model as accurately as possible observed properties, e.g. the travel times, in the approximate Green functions. For inversion, the formulation is very similar to that used for direct inversion of one-dimensional data, suggesting that it might form a useful starting point for an inverse theory.

Electromagnetic Imaging of Buried Objects

By David Colton, University of Delaware

We consider the problem of determining the shape of buried objects by using time harmonic electromagnetic waves.As data we use the total electric and magnetic fields measured on the surface of the earth due to an array of electric dipoles above the surface of the earth.The objects can be either perfect conductors or partially coated dielectrics but this information is not known a priori.The approach we use to solve this problem is based on the reciprocity gap functional and does not require a knowledge of the Green's function for the piecewise homogeneous background medium. In the case of a homogeneous background and the dipoles replaced by plane waves this approach reduces to the well known linear sampling method.Numerical examples using synthetic data will be given to show the efficaciousness of our method.

References:

1.D. Colton and H.Haddar,An application of the reciprocity gap functional to inverse scattering theory,Inverse Problems 21(2005),383-398.
2.F.Cakoni,M.Fares and H.Haddar,Analysis of two linear sampling methods applied to electromagnetic imaging of buried objects,Inverse Problems,to appear.

Advances in wave equation tomography

By M. V. de Hoop, Purdue University

We discuss a common framework for the 'wave-equation approach' to tomography with transmitted and reflected (scattered) phases, and shear-wave splitting. Here, reflection tomography is a method of migration velocity analysis. We discuss the 'mismatch' criteria, and, following a (local) linearization, address various properties of the associated sensitivity kernels and their computation. We illustrate the kernels from a multiresolution and data assimilation perspective. We touch upon applications in exploration seismology and global seismology.

Imaging below salt: where are we and how did we get there, an "industrial" perspective

By John T. Etgen, Senior Advisor, Seismic Imaging, BP

Talk description pending.

An FIO calculus for the marine seismic imaging: folds and cross caps

By Raluca Felea and Allan Greenleaf Rochester Institute of Technology

We are interested in a linearized inverse scattering problem considered by Symes and Nolan for the marine data acquisition geometry. This arises as follows: an airgun sends acoustic waves through the ocean to the subsurface. The reflected rays are received by hydrophones towed behind a vessel. The pressure field at the surface is used to reconstruct an image of the subsurface. Our goal is to invert F, the linearized operator which maps singularities in the sound speed in the subsurface to the singularities in the resulting pressure field at the surface. Standard techniques tell us to consider the operator F*F. Symes and Nolan proved that under no caustic assumption, F*F is a pseudodifferential operator. We make the assumption that only fold caustics occur and we identify the canonical relation associated to F. Fold caustics were considered before by Nolan in the single source case. He stated that the operator F*F belongs to a class of distributions associated to two cleanly intersecting lagrangians: the diagonal Δ and a two sided fold, and showed that the artifact has the same strength as the pseudodifferential part. In this article, we prove that the kernel of F*F belongs to a class of distributions similar to that in the single source geometry, but that the order of the nonpseudodifferential part of F*F is ½ lower. This means that the artifacts arising in the seismic imaging from the presence of the fold caustics are ½ derivative smoother for the marine geometry then for the single source geometry. Finally, we show the same result for general canonical relations with the same geometry.

A Hitchhiker's Guide to the Seismic Phase Space and Path Integral Universe

By Lou Fishman, MDF International

Seismic depth migration imaging attempts to produce an "image" of the earth's substructure from reflection data collected at the surface. However, seismic wave propagation modeling and imaging are complicated by the large-scale and rapidly-varying environments encountered in the earth, and, further, often by the relatively low experimental frequencies employed. Often, in these situations, Kirchhoff (ray-theory-based) methods will not be capable of producing accurate, high resolution images. This recognition led to the development of wave field extrapolation depth migration (WFEDM) methods, which incorporate the full-wave nature of the model, and are based on an (approximate) imaging condition and a wave field extrapolator (propagator). These wave field extrapolators can be modeled and computed with computational partial differential equation (pde) methods or approximate analytical wave field models. The Generalized Phase Shift Plus Interpolation (GPSPI) wave field extrapolator represents an example of the latter approach, and many other wave equation migration imaging models are actually just approximations to this model. The GPSPI approximation is nothing more than the locally homogeneous medium approximation to the exact wave field extrapolator in the frequency domain. Within the seismic community, there are several important misconceptions about the approximate nature and characterization of the GPSPI algorithm. Understanding these misconceptions sets the stage and provides the motivation for the introduction of a mathematical physics framework for WFEDM based on what is loosely referred to as "phase space and path integral methods."

Welcome to my world! These methods were originally developed in the quantum physics and theoretical pde communities, and include the phase space path integral constructions for general, one-way Schrödinger equations, and the theories of pseudodifferential (ψDO) and Fourier integral (FIO) operators, for example. For fixed-frequency modeling, the primary aims of this approach are (1) to incorporate well-posed, one-way methods into the inherently two-way global formulations, (2) to exploit the correspondences between the classical wave propagation problem, quantum physics, and modern mathematical asymptotics (microlocal analysis), and (3) to effectively extend Fourier-analysis-based constructions to inhomogeneous environments.

This talk will briefly illustrate how the explicit, exact, well-posed, one-way reformulation of "elliptic wave propagation" problems (e.g., the scalar Helmholtz equation) in phase space provides a detailed mathematical framework for WFEDM, both unifying the diverse approximations (e.g., wide-angle parabolic modeling, generalized phase screens, GPSPI), and systematically extending the physically based GPSPI algorithm. The extensions of GPSPI are at the levels of both decoupled and coupled wave field extrapolation in the background medium, with the basic GPSPI marching algorithm preserved in each case. Moreover, the one-way reformulation in phase space provides exact imaging conditions relating (1) the up- and down-going wave field components and (2) the total wave field and its normal derivative at an arbitrary level in the subsurface. This, subsequently, results in a direct (non-optimization-based), non-perturbative, one-way marching, inversion algorithm for the complete velocity field, accounting, in principle, for all of the multiple scattering.

Industrial-strength depth imaging methods: One-way, two-way, or two-pass one-way?

By Samuel H. Gray, James Sun, and Yu Zhang, Veritas DGC

Seismic imaging is not just about the most accurate possible imaging algorithms. It is also about data preconditioning (removal of multiple energy and other forms of noise), velocity estimation, workflow efficiency, and other issues. For this reason a number of imaging algorithms remain popular, ranging from Kirchhoff and beam migration through migration by wavefield extrapolation to migration using the two- way wave equation. In this talk, we describe some of the relative advantages of these methods: speed, accuracy, steep-dip preservation, ability to handle anisotropy, amplitude preservation, suitability for velocity analysis, etc.

Stabilizing wavefield extrapolation with locally WKBJ operator symbols

By Chad Hogan and Gary Margrave, Department of Geology and Geophysics, University of Calgary

We develop a new operator for explicit wavefield extrapolation. We modify the commonly used locally homogeneous wavefield extrapolation operator to include a local vertical gradient, whose purpose is simply to enhance stability when spatially localized. The locally homogeneous operator assumes that wavefield extrapolation across a single depth step can be done with straight raypaths using the assumed constant velocity at the output point. Such operators can produce excellent seismic images but the straight ray assumption means that their spatial aperture is infinite, which leads to instability when the operator is localized by spatial windowing (truncation). Adjusting the operator to accommodate a suitably chosen positive vertical velocity gradient causes raypath curvature which naturally limits the operator within a finite aperture. This new operator is developed as the composition of many operators by applying elliptic pseudodifferential operator theory, leading to a WKBJ-style integrated phase within the operator symbol. The resulting operator has a finite aperture and is sufficiently stable when localized to be used in an explicit depth migration scheme. We demonstrate fidelity with excellent images of the Marmousi model.

From basic analysis of information content and resolvability to pre-stack inversion of multicomponent seismic data

By Charlie Jing and Tommie D. Rape, ExxonMobil Upstream Research Company

With the advancements in seismic acquisition hardware systems, multicomponent seismic surveys have been made more easily available for both marine and land environments. Multicomponent seismic data provide us more complete information compared to single-component data (either vertical geophone data or hydrophone data) about the vector wave field on the acquisition surface. What is the information content for different components of multicomponent seismic data? How much more information about the subsurface elastic properties is contained in multicomponent data compared to traditional single-component data? Under what conditions and how can we derive reliable subsurface rock elastic properties from multicomponent seismic data? In this talk, we are trying to answer some of these questions through the analysis of information content and the resolvability of rock property inversions of multicomponent seismic data. Pre-stack inversions using Monte Carlo simulated annealing will be illustrated on synthetic and field multicomponent seismic data.

References:
Charlie Jing and Tommie Rape, "Resolvability analysis for rock property inversions of multicomponent seismic data", 74th Ann. Internat. Mtg., Soc. Expl. Geophys., Expanded Abstracts, MC2.7, 2004.

Gary F. Margrave, Robert R. Stewart, and Jeffrey A. Larsen, "Joint P-P and P-S seismic inversion", Vol. 20, No. 9, pp 1048-1052, 2001.

Cooperative Inversion in Reservoir Characterization

By Larry Lines, Department of Geology and Geophysics, University of Calgary

Cooperative inversion computes an Earth model whose response fits all available data sets to within an acceptable error level. In geophysics, this approach often involves fitting seismic, potential field, and well log data. Reservoir characterization generally involves the creation of a dynamic Earth model of a petroleum reservoir that can adequately describe production history. As in the case of geophysical inversion, reservoir modeling to fit production data can be ambiguous. In essence, the application of cooperative inversion to reservoir characterization seeks to reduce ambiguity in models by honoring geological, geophysical and reservoir engineering data. Such an approach is very challenging and will often benefit from the use of 3-D time-lapse seismic surveys to aid in reservoir description. This talk outlines a methodology for this inversion and provides a few examples in enhanced oil recovery (EOR). Although the issue of inexpensive Jacobian calculations in this inversion still requires further research, this talk discusses the mathematical coupling between the inversion of different data sets. Given the increasing importance of reservoir characterization for EOR, it is anticipated that cooperative inversion will receive considerable attention in the decades to come.

3D wave-equation prediction of multiples

By Dmitri Lokshtanov, Norsk Hydro Research Centre, Bergen, Norway

We present two approaches for 3D wave-equation prediction. One is for generally irregular 3D sea-floor and arbitrary 3D structure below it. The second is a much faster scheme for locally 1D sea-floor with an arbitrary 3D structure below it. The latter is suitable for the majority of data from the North Sea. In both approaches the prediction and adaptive subtraction of multiples are performed in the same domain, therefore no additional sorting or additional transformations are required. All source-side and receiver-side multiples of all orders are suppressed simultaneously in one consistent step.

Seismic Depth Imaging with the Gabor Transform

By Yongwang Ma and Gary F. Margrave, Department of Geology and Geophysics, University of Calgary

Wavefield extrapolation by spatially variable phase shift is currently a migration tool of importance. We present a new prestack seismic migration algorithm using the Gabor transform with application to the Marmousi acoustic dataset. The imaging results show a very promising depth imaging algorithm, which is competitive with the best depth imaging algorithms. The Gabor depth imaging algorithm approximates generalized phase-shift-plus-interpolation (GPSPI) wavefield extrapolation using a Gabor, or windowed Fourier, transform to localize the wavefield. The key to an efficient algorithm is to develop an adaptive windowing scheme that only localizes the wavefield as required by the lateral velocity variation. If there is no lateral velocity variation then no localization (windowing) is required. When velocity varies rapidly, then many, relatively narrow, windows are required for accurate wavefield extrapolation. We present the details of an adaptive windowing method that is controlled by position errors. Programs have been coded with the adaptive windowing algorithm, which substantially reduces the computational burden in wavefield extrapolation when compared to the full GPSPI integral. We will illustrate the performance of this algorithm with images from prestack depth migration of the Marmousi dataset.

Amplitude Corrections for Estimating Imaging Artifacts from Multiples

By Alison Malcolm (Institute for Mathematics and its Applications, University of Minnesota) and Maarten de Hoop (Center for Computational and Applied Mathematics, Purdue University)

Multiples cause artifacts in images because they do not obey the single-scattering assumption fundamental to most seismic imaging methods. Standard processing techniques attenuate multiples in the data with the goal of estimating data which satisfy the single-scattering assumption. If the multiples are perfectly attenuated, this results in an image without multiple-scattering artifacts. If the attenuation is not perfect, however, residual multiply scattered energy remains in the data, creating artifacts in the image. Discriminating between true image features and these artifacts can be difficult. To alleviate this problem, we have proposed an approach, in the framework of wavefield extrapolation migration, by which the artifacts caused by multiples are estimated directly in the image. This allows the locations of incompletely subtracted multiples to be identified in the image domain. The attenuation of these artifacts, however, still depends on the accuracy of the estimate. A good match between the estimated artifacts and those in the image requires that both have accurately computed amplitudes. This requires a method to correctly account for the amplitudes within wavefield extrapolation migration. Wavefield extrapolation methods of migration are based on a parabolic approximation to the wave equation. The so-called double square-root equation, typically used in seismic imaging, accounts only for the kinematics of this approximation. This is readily seen by deriving this equation through the diagonalization of the wave operator, written as a first-order system. Amplitude correction terms arise naturally from this diagonalization procedure. These amplitude correction terms are pseudodifferential operators and can, thus, be applied approximately using, for example, a split-step methodology. It is these correction factors that are necessary to match the amplitudes of estimated artifacts with those of the artifacts that internal multiples cause in the image.

Nonlinear migration and full waveform tomography

By W.A. Mulder, Shell International Exploration and Production, Rijswijk, The Netherlands

The least-squares functional measures the difference between observed and modelled seismic data. Because it has a high computational cost and suffers from local minima, its use for the inversion of model parameters is limited. A good initial velocity model is required. Given such a model, the minimisation of the least-squares functional resembles nonlinear migration more than inversion. Several authors, however, use diving waves to update the velocity model without the risk of ending up in a local minimum. The approach is called full waveform tomography and can be used to a limited depth.

In 2D, frequency-domain acoustic modelling codes are more efficient than time-domain codes. The dichotomy between waveform tomography and migration has consequences for the choice of frequencies. Problems may arise when applying an acoustic approximation to long-offset data that have seen an anisotropic elastic earth.

Numerical issues involve the extension of frequency-domain modelling to 3D and minimization methods for the least-squares functional.

Least Squares Inversion Revisited

By Frank Natterer, Munich

Starting with works of Tarantola in the 1980-ties, least squares inversion has been tried and studied by many authors, without ever leading to a recognized inversion method for seismic reflection data. This is in contrast to the stunning success of least squares based algorithms in medical imaging, where most algorithms that deal with the fully nonlinear problem belong to this class. In the talk we describe our favorite least squares method, the Kaczmarz method, its implementation for seismic and medical data. We describe efficient implementations by plane wave stacking in time domain and by marching schemes in frequency domain. We study its failure for seismic reflection data in the light of Fourier analysis and suggest a way out.

Reconstruction of medium from boundary measurements. New prospections

By Victor Palamodov, Tel Aviv

The inverse scattering, the inverse kinematic problem (reconstruction of velocity from travel-time), and the electric impedance are common modalities in geophysics. In spite of formal similarity: only boundary measurements are used, the outcomes are quite different. The reconstruction problems of one kind (of these three) can not be reliably solved in the sense that no stable algorithm is possible (and no sophisticated mathematics can help). Problems of another type can be only solved in a limited sense and for the third type of problems stable numerical solutions are hopefully possible.

In the talk, I will focus on new mathematical arguments that could help.

Interferometric array imaging in clutter and optimal illumination.

By George Papanicolaou, Department of Mathematics, Stanford University

I will present an overview of some recently developed methods for imaging with array and distributed sensors when the environment between the objects to be imaged and the sensors is complex and only partially known to the imager. This brings in modeling and analysis in random media, and the need for statistical algorithms that increase the computational complexity of imaging, which is done by backpropagating local correlations rather than traces (interferometry). I will illustrate the theory with applications from non-destructive testing and from other areas. I will also discuss the mathematical problem of optimally illuminating an object for imaging by an array.

Velocity Models from Seismic Waveform Tomography: Making the theory work with data, and making the data work with the theory

By Gerhard Pratt, Queens University

Waveform inversion can be treated in theory with a variety of non-linear inverse methods. One feasible approach that has achieved some recent success is the frequency-domain implementation of the theory to seismic refraction data examples. A key common factor in these examples is the emphasis on the optimization of models that correctly predict the early (transmitted) arrival waveforms from large offset data. Due to the similarity to other tomographic schemes, we refer to this approach as "Waveform Tomography".

Wide angle, refracted arrivals observed at large offsets are generally ignored in the conventional reflection processing scheme used in seismic exploration. However, large offset data are very sensitive to velocities, and waveform tomography provides a way to unravel the complexities of the refracted arrivals in order to yield well constrained velocity models. In contrast, the CMP reflection survey is less sensitive to the macro variations in seismic velocity.

Ultimately surveys should be specifically designed for waveform tomography. Such designs will need to recognize the importance of the refracted wavefield and the equal importance of low frequencies.

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Fresnel theory in radar wave propagation problems- A better alternative to rays

By Partha S. Routh and Timothy C. Johnson, Boise State University

Traditional tomography employs the ray approximation where waves are assumed to propagate at infinite frequency. Ray approximation can cause significant model error that generates artifacts and loss of resolution in the tomographic images. The usefulness of the finite frequency nature of waves in tomographic reconstruction of seismic velocity has been a subject of recent debate. The question is: For practical problems does first order scattering (finite frequency approach) provides better information than ray theory? Several authors have proposed that the information content provided by the first order scattering approximation lies in the null-space, as a result there is insignificant contribution to the model reconstruction process. In this work, we derive and show that for Maxwell’s equation in the regime there is significant information in the finite frequency (Fresnel) kernels both for amplitude and travel time. We also demonstrate an efficient method of computing Fresnel volume sensitivities using scattering theory. These sensitivities account for finite frequency propagation and represent the physics of electromagnetic propagation more accurately than ray theory. Thus, Fresnel volume sensitivities provide better data prediction than ray-based sensitivities.

Radar attenuation-difference tomography can be used to image spatial and temporal changes in bulk electrical conductivity. Bulk conductivity changes are induced by the movement of a conductively anomalous fluid such as a tracer or contaminant. Such transport information is typically sensitive to important hydrogeologic properties such as porosity and hydraulic conductivity and can provide valuable information concerning the distribution of those properties. A number of radar attenuation-difference surveys have been conducted in near-surface environments to image fractures and time-lapse monitoring of tracer. In both of these applications ray theory was used to represent the wave propagation underlying the inverse reconstruction. The majority of tomographic inversions for velocity or attenuation structure (in both seismic and radar applications) are based on ray theory primarily because ray theory is well understood and computationally efficient allowing inversions of large data sets.

Several techniques have been developed to estimate the spatial distribution of the sensitivity of seismic arrival time to seismic velocity distributions, that are often referred to as wavepath methods. Generally, the full acoustic-wave equation is used to derive the wavepath sensitivity distribution associated with a particular source-receiver pair and velocity structure. Because they are based on a finite frequency wave equation, the wavepath sensitivities are physically more accurate than rays and include the effects of finite frequency propagation. We derive similar equations beginning from Maxwell’s equation for both amplitude and travel times. The benefits of accounting for finitefrequency effects are numerous, including the ability to image smaller scale features and reduce tomographic artifacts. We apply this methodology to synthetic and real time-lapse radar attenuation data acquired in a mesoscale hydrogeophysical research site in Boise, Idaho. Both synthetic and field results show that Fresnel theory produces more reliableimages of subsurface conductivity changes in comparison to ray theory.

Some Observations on Multipath Asymptotic Imaging

By Robert Stolt, ConocoPhillips

Typically, a multipath asymptotic integral-equation imaging algorithm constructs one-way Green's functions from ray theory, ignoring any diffractive component in the Green's function. However, where multipathing exists, diffractions exist also. Is ignoring the diffractive component in the one-way Green's function the right thing to do?

A Software Framework for Inversion

By William Symes, Department of Computational and Applied Mathematics, Rice Universtiy

This talk describes an experimental framework for algorithm organization and software development in support of research on geophysical inversion. The central assumptions of this project are that software components can be designed to closely mimic the mathematical concepts they implement, and that such mimicry eases algorithm construction and hypothesis-testing. I will report some applications of these ideas to modeling and inversion of reflection seismograms via finite difference modeling.

On wavelike rays, robust norms, and independence from initial conditions

By John Washbourne, ChevronTexaco, and Kenneth Bube, University of Washington

A well known limitation of ray tracing in seismic modeling is the asymptotic high frequency nature of ray theory, which leads to ray paths inconsistent with the propagation of finite frequency energy. We present a technique for modeling rays more compatible with energy propagating in the seismic bandwidth, introduced in 2001 as "wavetracing". We employ a modified bending method that incorporates a penalty for distance along rays, and by invoking the time-domain representation of Fresnel Zones, we can compute families of rays "straighter" than asymptotic paths yet still within the first Fresnel Zone. The travel times of these rays demonstrate a systematically improved match with finite difference synthetics computed in the seismic band, relative travel times of Snell's Law rays.

We believe wavetraced rays can be an important part of nonlinear optimization for full waveform seismic inversion. Two other ideas we believe to be critically important to the solution of ill posed nonlinear optimization problems are the use of robust norms and the use of an inversion/regularization methodology that is independent of the starting model.

Independence of initial conditions is simple to show for low frequency data (travel times), but is essentially a discussion topic for the case of band limited data (seismic waveforms). We hope to stimulate discussion around this topic.

Responding to pressing seismic challenges: Removing multiples and depth imaging and inverting primaries without knowing or determining the velocity model

By Arthur B. Weglein, Physics Department, University of Houston

Isolated task subseries of the inverse scattering series provide a unique and practical capability to achieve all processing objectives associated with multiples and primaries without the typical requirement for subsurface information. Hence, this represents a direct response to the current pressing seismic challenge in complex and ill-defined media, e.g., in subsalt plays.

We will exemplify these new concepts and algorithms with synthetic and field data, and discuss open issues and plans.

High-resolution Wave Equation AVP Imaging with Sparseness Constraints

By Juefu Wang (Divestco) and Mauricio D. Sacchi (University of Alberta)

This paper presents a new scheme for high-resolution AVP (Amplitude Variation with ray Parameter) imaging that uses non-quadratic regularization. We pose migration as an inverse problem and propose a cost function that makes use of a priori information about the AVP common image gather. In particular, we introduce two regularization constraints: smoothness along the offset ray parameter axis and sparseness in depth. The two-step regularization yields high-resolution AVP gathers with robust estimates of amplitude variations with ray parameter. An iterative re-weighted least-squares (IRLS) conjugate gradients (CG) algorithm is used to minimize the cost function of the problem. We test the algorithm with synthetic data (a wedge model and the Marmousi data set) and a real data set (Erskine area, Alberta). Our tests show that the method helps to enhance the vertical resolution of common image gathers and improve the amplitude accuracy along the ray parameter direction.

True-amplitude, true-reflection imaging and scattering tomography

By Ru-Shan Wu, University of California, Santa Cruz

True-amplitude, true-reflection imaging tries to relate the image amplitude faithfully to the local reflection (scattering) property. Our approach is to recover the local scattering pattern (local scattering matrix defined in the local angle domain) by removing the

propagation and acquisition-aperture effects. An important component of true-reflection imaging is to have a true-amplitude propagator for the imaging. We apply a localized WKBJ correction to the regular one-way propagator, so that the correct geometric spreading can be calculated in generally heterogeneous media. In the true-reflection imaging process, first local image matrices are obtained by decomposing the wave fields into local plane waves (beamlets) and applying the imaging condition in the local angle domain. Then amplitude factors for acquisition aperture correction are derived based on the directional illumination analysis and applied to the local image matrices. The final images can be presented either as a total strength image field, or as common reflection-angle image (CRI) gathers at the image points. The CRI gathers of the true-reflection imaging have the correct angle-dependence of reflection coefficients and therefore can be used for local AVA analysis and local inversion. Numerical results, including the 2D SEG/EAGE salt model, indicate that the overall image quality is greatly improved by the acquisition-aperture corrections. However, the localized WKBJ correction has only limited but noticeable improvement on the image amplitude. The relation between the true-amplitude imaging and the scattering tomography (linear inversion) is also discussed.