CREWES NEWS

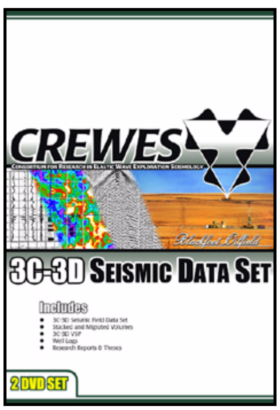
The Consortium for Research in Elastic Wave Exploration Seismology

Introduction to New CREWES Students

As we begin a new academic year, we wish to extend a warm welcome to new members of our group. In particular, we are pleased to have five new graduate students join our ranks. These are **Fuju Chen**, **Marcia Coueslan**, **Yongwang Ma**, **Tingge Wang**, and **Duojun (Albert) Zhang**. We will include biographies of these new students in the next edition of CREWES News to allow sponsors to become acquainted with them and their research interests. In addition, **Linping Dong**, a recent M.Sc. graduate, is returning to pursue doctoral studies with Dr. Gary Margrave. ***CN***

CREWES Group - September 2004

3C-3D Seismic Data Release



In 1995 CREWES acquired a 3C-3D dataset over the Blackfoot oilfield in Alberta. Additional data were collected in 1997 and 1999. These valuable data have played a key role in numerous research studies over the past several years, both within CREWES and in sponsoring companies.

A part of the 1995 dataset has now been assembled into a convenient 2-DVD collection. It is accompanied by the concurrently acquired 3C-3D VSP, various well-logs, research reports, two theses, and other supporting documents.

This collection will be on sale at the SEG Convention Bookmart in Denver. Members of sponsoring companies will receive free copies of this collection at the Sponsors Meeting in November. ***CN***

Four Year NSERC Grant Application Submitted

For the past several years, CREWES and its sponsors have benefitted from substantial matching funds from NSERC, a principle Canadian granting agency. This funding has now expired and we have recently applied for a new four-year grant. We thank all the sponsor representatives who prepared supporting documentation. ***CN***

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In This Issue...

Sponsors Meeting

We wish to remind all members of our sponsoring companies of the Sponsors Meeting to be held November 17-19 in Banff, Alberta. A website with information relevant to the meeting is available at www.crewes.org.

Last year we enjoyed the hospitality of ExxonMobil, who hosted all attendees to a dinner on the second evening of the meeting. If your company might be interested in hosting a similar event this year at the Banff Centre, please contact Louise Forgues (louise@crewes.org, 403-220-8279). ***CN***

CREWES Booth at SEG

CREWES will be hosting a booth at the Colorado Convention Centre for the SEG Convention Oct. 10-14. Please feel free to stop by and visit with us at Booth #2420 (near the International Showcase in Hall A). We look forward to seeing you there! ***CN***

This newsletter is available on the internet at: www.crewes.org

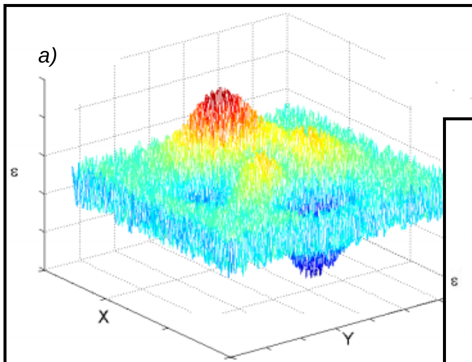
Development of multigrid seismic methods

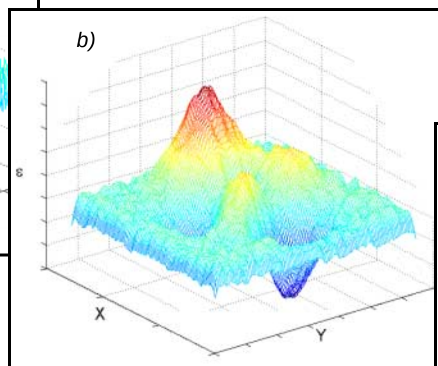
John Millar and John C. Bancroft

Multigrid methods are an efficient and robust means to solve certain classes of inversion problems. While frequently used to solve differential equations numerically in the field of fluid dynamics, they have yet to be used extensively in seismic exploration.

The basic principal of this method is to seek a solution on a coarse grid, the result of which is then interpolated to a finer grid. This interpolated data becomes the input for the next standard iterative solution. This procedure is repeated until the original grid size is obtained. We choose the Gauss-Seidel method for each iterative solution because it is simple, intuitive, and focuses the error reduction on the high-frequency component of the error.

In Figures 1 and 2, the multigrid method is compared to the conventional fixed grid Gauss-Seidel relaxation. We are solving Laplace's equation in 2-D, in which any non-zero data should iterate to zero. The fixed grid solution is illustrated in Figure 1 with a) the input noise, b) the result after three iterations, in which we see the attenuation of the high frequency noise, and c) the result after 30 iterations, where virtually all of the higher frequencies have been attenuated, but the lower frequency error is still present.





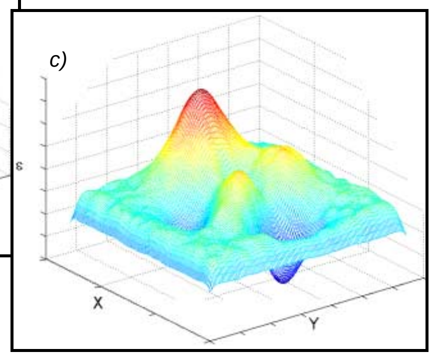
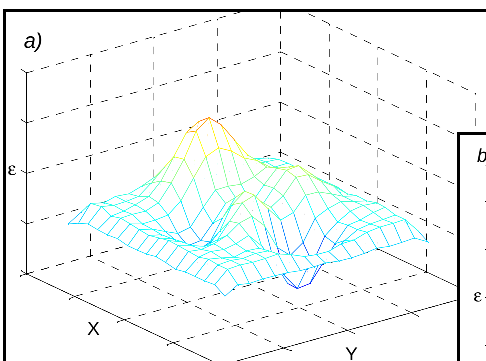
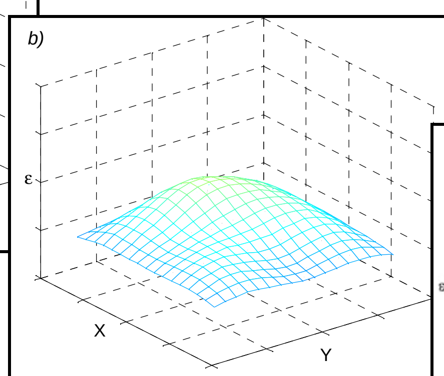


Figure 1. Fixed grid Gauss Seidel solution with a) the input error on the original fine grid b) the error on after 3 iterations and c) the error after 30 iterations.

Normal applications of multigrid would restrict the grid size to be compatible with the lowest frequency of the data and the error would be unperceivable. However, we have chosen a grid size of 16 by 16 to visually illustrate the effectiveness of the coarser grid in Figure 2. The input data are anti-alias filtered (AAF) and down-sampled or restricted, as shown in a), with b) showing the result after three iterations. Note the more effective reduction of the lower frequency energy. The final figure c) illustrates the result of interpolating the data in b). A normal multigrid procedure would start with a coarser grid, say, 3 by 3 points, and iterate by halving the grid interval until the original grid was achieved.





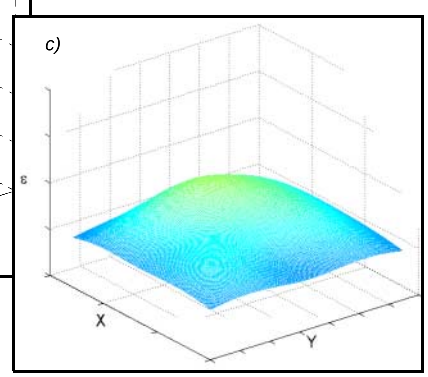


Figure 2. Multigrid Gauss Seidel solution with a) the input error restricted to a 16 by 16 grid, b) the error after 3 iterations, and c) the surface interpolated to the original fine grid spacing.

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Multigrid methods, cont'd

Applications

At this point, multigrid methods have been successfully applied to deconvolution and surface consistent static calculations.

For deconvolution, the multigrid approach converges to the reflectivity series with approximately 1/4 times the number of operations required by a Gauss-Seidel correction. One possible advantage to time domain multigrid deconvolution is the ease with which non-stationary wavelets may be incorporated.

In the statics application, the long wavelength drifts in the source and receiver statics that are un-resolvable by traditional Gauss-Seidel methods can be estimated.

Both deconvolution and the surface consistent statics serve as good illustrations of the multigrid method, and give valuable insight into the frequency domain behaviour of some of the processes in multigrid, such as restriction, interpolation, and smoothing (correction).

Looking ahead

The true power of multigrid is its ability to solve extremely large non-linear systems, at a fraction of the computational cost of other methods. The number of computations required for one multigrid correction in a one dimensional problem is approximately the same as two relative passes of the conventional method, i.e., when halving the number of gridpoints at each iteration we get the series

$$1+\frac{1}{2}+\frac{1}{4}+\frac{1}{8}+\frac{1}{16}+\ldots=2$$

It appears that the multigrid method will be much more efficient for higher dimensional problems, e.g., for 2D, where the number of relative grid computations will be 1.33 times the full grid number, where the number of gridpoints is reduced by a half-squared, or

$$1+\frac{1}{2^2}+\frac{1}{4^2}+\frac{1}{8^2}+\frac{1}{16^2}+\ldots=1.333^{\bullet}=\frac{4}{3}$$

For a full multigrid 3D, we have a relative factor of 1.14 where

$$1+\frac{1}{2^3}+\frac{1}{4^3}+\frac{1}{8^3}+\frac{1}{16^3}+\ldots=\frac{8}{7}\approx 1.14$$

These timing factors do not take into account the need for AAF and reducing the input data for each grid size. However, since we have approximations at each grid level, inexpensive AAFs can be used effectively.

John Millar will be presenting this material in greater detail at the SEG convention in Denver. The extended abstract of the talk is available to sponsors at www.crewes.org, and includes results of deconvolution and statics applications mentioned in this article. ***CN***

CREWES Presentations at the SEG

Members of CREWES will be giving 23 presentations in Denver. Please feel free to come by and participate.

Poster Presentations (in Exhibit Hall)

Time	Session	Authors	Title	Location
T 9:20	AVO	A.B. Haase	Spherical wave AVO modeling of converted waves in isotropic media	AVO P1.1
T 11:00	Migration	X. Du*, J.Bancroft	2D wave equation modeling and migration by a new finite difference scheme based on the Galerkin method	MIG P2.6
T 11:40	Seismic Processing	C. Montaña*, G. Margrave	Spatial prediction filtering in fractional Fourier domains	SP P1.8
W 1:30	Reservoir Charact.	J. Zhang*, L. Bentley	Reservoir characterization in Leming Lake, Alberta, Canada	RC P2.1
W 1:50	Reservoir Charact.	Y. Zou*, L. Bentley, L. Lines	Integration of geophysical methods with reservoir simulation	RC P2.2

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Monday - Oral Presentations				
2:45 PM	North Sea / Canada	C. Xu*, R. Stewart	Identifying channel sand versus shale using 3C-3D seismic data, VSPs, and horizontal well logs	601/603
3:35 PM	Data Enh. / Resolution	J. Millar*, J. Bancroft	Multigrid deconvolution of seismic data	201/203
4:00 PM	Anisotropy: Theory	C. Xiao*, J. Bancroft, J. Brown	Estimation of anisotropy parameters in VTI media	703
4:25 PM	North Sea / Canada	B. Russell*, D. Hampson, L. Lines	A case study in the local estimation of shear-waves	601/603
4:25 PM	Data Enh. / Resolution	S. Lynch*, L. Lines	Combined attribute displays	201/203
Tuesday - Oral Presentations				
10:10 AM	Seismic Modeling	P. Manning*, G. Margrave	Finite-difference modeling with correction filters in variable velocity	203
1:55 PM	Sig. Proc. / Noise Att.	L. Dong*, G. Margrave, L. Mewhort	Examining the phase property of nonstationary vibroseis wavelet	708/710/ 712
1:55 PM	AVO: New Developm'ts	C. Ursenbach	A nonlinear, three-parameter AVO method that can be solved noniteratively	201
2:45 PM	Sig. Proc. / Noise Att.	D. Henley	Effective noise attenuation and deconvolution in the radial trace domain	708/710/ 712
2:45 PM	AVO: New Developm'ts	J. Downton*, L. Lines	Three-term AVO waveform inversion	201
3:10 PM	4D/ Attenuation	Y. Zou, L. Lines*, K. Hall, J. Embleton	Time-lapse seismic analysis of a heavy oil cold production field, Lloydminster, Western Canada	207
Wednesday - Oral Presentations				
8:30 AM	Migration: Anisotropic	R. Bale*, G. Margrave	Elastic wave-equation migration of HTI seismic data	605/607
8:55 AM	AVO: Methods	F.Mahmoudian G. Margrave	Three-parameter AVO inversion with PP and PS data using offset binning	702/704/ 706
9:20 AM	Multiple Attenuation	J. Bancroft*, Z. Cao	Multiple attenuation using the space-time Radon transform and equivalent offset gathers	201/203
10:35 AM	AVO: Methods	A. Royle, J. Logel, L. Lines	AVO investigation of the Ben Nevis reservoir at the Hebron asset	702/704/ 706
10:35 AM	Res. Char.: General Technology	S. Chen*, L. Lines, P. Daley	Do wormholes play a role in heavy oil cold production?	601/603
1:30 PM	Migration: Algorthmic Improve-ments	K. Liu*, H. Geiger, J. Bancroft, G. Margrave	Adaptive tapering in the wavefield extrapolation	702/704/ 706
Thursday - Oral Presentations				
10:35 AM	VSP: General	A. Haase* R. Stewart	Attenuation estimates from VSP and log data	207

New Theses Available Online

Theses corresponding to the abstracts below are now available at www.crewes.org. They, along with other new theses, will also be provided on CD to attendees of the Sponsors Meeting in November.

Traveltime Tomography in Isotropic and Transversely Isotropic Media (M.Sc. Thesis)
Marco Perez

This thesis builds two types of velocity models through crosswell and surface experiments using traveltime tomography. One is isotropic, consisting of estimating P-wave velocities, and the other is transversely isotropic, estimating Thomsen's weak anisotropy parameters of α, ε and δ.

Traveltimes are modelled using a finite-difference scheme in simple isotropic and transversely isotropic models and used to determine tomographic resolution capabilities for crosswell and surface geometries. Results show that crosswell tomography can accurately detect vertical velocity variations as well as provide a reasonable estimate for ε while surface tomography can accurately detect horizontal velocity variations and provide a reasonable estimate for δ.

Two different quasi-null space inversion stabilization techniques are also introduced in this thesis. The first stabilizes the inversion result by smoothing unreliable results while the second integrates two different seismic experiments based on their relative reliability. Results show that tomogram accuracy is improved when using these two techniques.

The application of multivariate statistics and neural networks to the prediction of reservoir parameters using seismic attributes (Ph.D. Thesis)
Brian H. Russell

In this dissertation, I develop a number of new ideas for the statistical determination of reservoir parameters using seismic attributes. These ideas combine the classical techniques of multivariate statistics and the more recent methods of neural network analysis. I apply these techniques to both full seismic volumes and to maps derived from intervals averaged through these volumes, largely using the Blackfoot dataset from central Alberta. I show that multilinear regression often provides too simple a solution to the parameter estimation problem, and that the traditional feedforward neural network often provides a solution that is overly complex. My proposed solution is to use radial basis function neural networks for the prediction of reservoir parameters, since this approach combines the power of the multilinear regression technique with the nonlinearity of neural networks. I also show how the radial basis function neural network can be considered as a generalization of the generalized regression neural network, which has been previously used in this type of parameter estimation. My conclusions are illustrated using both an AVO classification problem and the Blackfoot seismic and well log dataset.

In addition to the application of the radial basis function neural network to the prediction of reservoir parameters, several new ideas are presented for the analysis of well log and seismic data. First, I derive an improved regression formula for the prediction of S-wave sonic logs from combinations of other logs. Second, I apply a new approach to data clustering, which I call Mahalanobis clustering, to the interpretation of AVO crossplots and to the delineation of optimal clusters for the radial basis function neural network with centres method. Finally, I develop a new approach to map analysis that combines geostatistics with multiattribute transforms. This technique uses multivariate statistics and neural networks to improve the secondary dataset used in the collocated cokriging technique.

Making Contact...

Contact Note: *Readers wishing to contact staff and students should add the domain, @ucalgary.ca, to the usernames listed below.*

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