Texas Consortium for Computational Seismology

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Texas Consortium for Computational Seismology • The University of Texas at Austin • Fall 2014 Newsletter

Welcome to the sixth *TCCS Newsletter*!

The Texas Consortium for Computational Seismology is a joint initiative of the Bureau of Economic Geology (BEG) and the Institute for Computational Engineering and Science (ICES) at The University of Texas at Austin. Its mission is to address the most important and challenging research problems in computational geophysics as experienced by the energy industry, while educating the next generation of research geophysicists and computational scientists.

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For sponsorship opportunities, please contact sergey.fomel@beg.utexas.edu.

Fall Meeting

The Fall 2014 Research Meeting of the Texas Consortium for Computational Seismology will take place in Austin on November 3–4. Hosted by the Bureau of Economic Geology, it will be held at The University of Texas at Austin, J.J. Pickle Research Campus. Representatives of participating companies are invited to register for the meeting by following the link at http://www.beg.utexas.edu/tccs/.

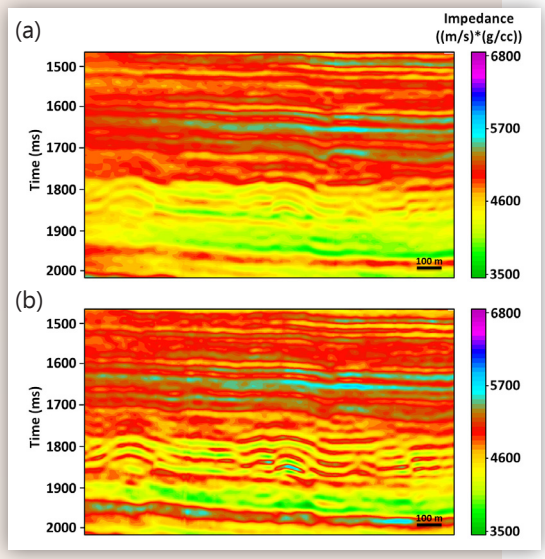
Presentations at SEG in Denver

TCCS members and collaborators will make several presentations at the upcoming SEG 2014 Annual Meeting in Denver.

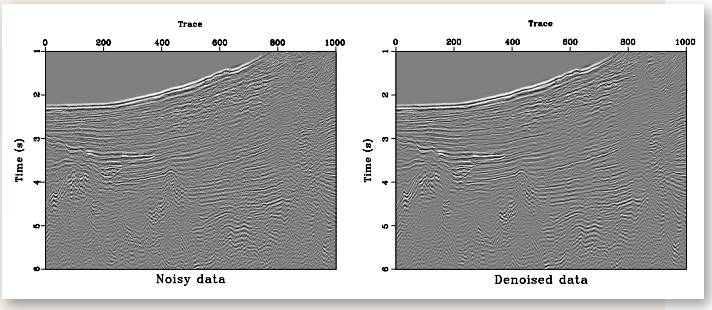
Monday, Oct. 27	1:55 pm	SPMI E-P1: Least Squares	J. Sun, S. Fomel, and J. Hu	Least-squares reverse-time migration using one-step two-way wave extrapolation by non-stationary phase shift
	2:20 pm	AVO 1: New Wrinkles on Old Techniques	M. Gupta, K. Spikes, M. Far, D. Sava, and B. Hardage	Statistical AVO intercept-gradient analysis of direct S-waves: A methodology for quantitative fracture characterization
	2:20 pm	SS 1: Recent Advances and the Road Ahead	S. Fomel	Recent advances in time-domain seismic imaging
	3:35 pm	SPMI E-P1: Least Squares	Z. Xue, Y. Chen, S. Fomel, and J. Sun	Imaging incomplete data and simultaneous-source data using least-squares reverse-time migration with shaping regularization
	4:00 pm	SPMI E-P1: Least Squares	J. Sun, T. Zhu, and S. Fomel	Viscoacoustic modeling and imaging using low-rank approximation
Tuesday, Oct. 28	8:30 am	ST E-P1: 2D Modeling	S. Fomel	Transforming prestack seismic data by Gardner continuation
	8:30 am	ANI P1: Orthorhombic= Layers+Cracks	Y. Sripanich and S. Fomel	Anelliptic approximations for qP velocities in orthorhombic media
	8:55 am	INT E-P2: Attribute and Visualization	Y. Chen, T. Liu, X. Chen, J. Li, and E. Wang	Time-frequency analysis of seismic data using synchrosqueezing wavelet transform
	8:55 am	SPMI E-P2: Computational Aspects of RTM	J. Gao, P. Yang, and B. Wang	Using the effective boundary-saving strategy in GPU-based RTM programming
	1:30 pm	ACQ 3: Deblending Simultaneously Sourced Marine Data	Y. Chen	Deblending using a space-varying median filter
	4:25 pm	ANI 2: Azimuthal Amplitudes and Fractures	M. Far and B. Hardage	Comparison of PP and PS reflectivities for fracture characterization
Wednesday, Oct. 29	8:30 am	SPMUL E-P1: Various Aspects	Y. Liu and S. Fomel	Separation of primaries and multiples using VD-seislet frame
	8:30 am	SPMI 4: Imaging Applications	T. Zhu	An approach to compensate for attenuation effects in reverse-time migration
	11:25 am	SPIR E-P1: Complex Geometry and Aliasing	K. Chen, Y. Chen, P. Shi, and Y. Wang	Irregular seismic data reconstruction using a percentile-half-thresholding algorithm
	1:30 pm	SM 3: Ray Tracing and Wavefield Extrapolation	Y. Sripanich and S. Fomel	Two-point seismic ray tracing in layered media using bending
	2:20 pm	SPNA E-P3: Random Noises and Signal Q Compensation	Y. Chen, S. Gan, T. Liu, J. Yuan, Y. Zhang, and Z. Jin	Random noise attenuation by a selective hybrid approach using f-x empirical mode decomposition
	2:45 pm	SPNA E-P3: Random Noises and Signal Q Compensation	Y. Chen and S. Fomel	Random noise attenuation using local similarity
	3:10 pm	SPNA E-P3: Random Noises and Signal Q Compensation	W. Yang, R. Wang, J. Wu, and Y. Chen	Random noise attenuation using a new spectral decomposition method
	3:35 pm	SPMI 5: Kirchhoff and Beam Migrations	L. Decker and A. Klokov	Diffraction extraction by plane-wave destruction of partial images
Thursday, Oct. 30	8:30 am	ANI E-P2: Theory	Y. Sripanich and S. Fomel	Modified anelliptic approximations for qP velocities in transversely isotropic media
	9:20 am	SVE E-P1: Theory and Applications	L. Decker and S. Fomel	Diffraction imaging and velocity analysis using oriented velocity continuation
	10:10 am	SPMI 6: Special Applications for Imaging	S. Li, S. Fomel, and H. Zhu	Frequency-domain reverse-time migration with a sparse-frequency sampling
	11:00 am	SVE E-P1: Theory and Applications	T. Liu, X. Chen, and Y. Chen	Velocity analysis using similarity-weighted semblance
	1:30pm	W-9: Latest Developments in Time-Frequency Analysis	S. Fomel	Time-frequency analysis using regularized nonstationary regression
Friday, Oct. 31	8:30 am	W-15: Seismic Attenuation and Scattering	T. Zhu	Key aspects of Q-compensated RTM
	8:30 am	W-21: Past, Present and Future of SEAM	K. Schleicher, L. Wu, and A. Aghayan	SEAM Phase I 2D Classic Data used at the Madagascar Working Workshop

Research Highlights

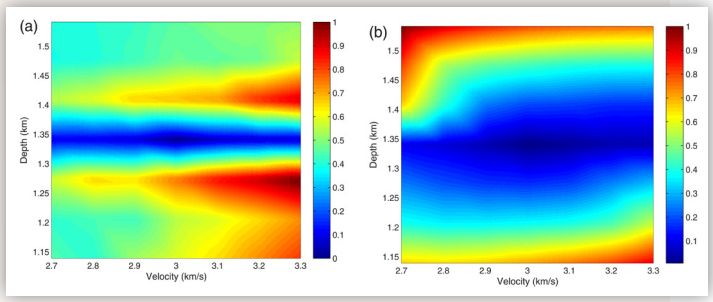
Parvaneh Karimi has developed a coordinate system, stratigraphic coordinates, in which geometry follows the shape of each reflector and the vertical direction corresponds to normal reflectivity. After seismic data are transformed into stratigraphic coordinates, seismic horizons should appear flat, and seismic traces should represent the direction normal to the reflectors. Applications of the stratigraphic coordinate system are not limited to seismic image flattening and can be extended to many interpretation tasks, such as impedance inversion and spectral decomposition, in which the vertical direction is commonly assumed to be normal to reflection boundaries. Parvaneh has improved the accuracy of impedance cube by employing the stratigraphic coordinate system for impedance inversion. The figures show the impedance result from inversion in the stratigraphic coordinate system (b) compared to the impedance result using the conventional Cartesian coordinate system (a).



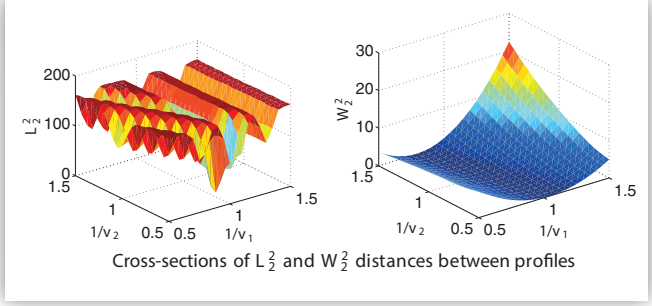
Yangkang Chen developed a novel approach to random noise attenuation that eliminates remaining coherent signal in the removed noise by employing local signal-and-noise orthogonalization. Local signal-and-noise orthogonalization can retrieve the leakage signal in the initial noise section of traditional denoising approaches by locally orthogonalizing signal and noise components, and thus can help reduce the loss of valuable information when applying any random-noise attenuation techniques.



Hejun Zhu is working on designing new misfit functions for full waveform inversion. It is well known that misfit functions based on least-squares waveform differences suffer from cycle skipping and local minima issues. A new misfit function based on local similarities between data and synthetics may allow us to avoid local minima. A simple three layered model is used to compare the behavior of misfit functions on the basis of least-squares waveform differences (a) and local similarities (b).



Brittany Froese has developed a numerical method for solving the optimal-transportation problem. This enables the computation of the Wasserstein metric, which can be used to measure the misfit between seismic profiles. The Wasserstein distance appears much more suitable for minimization than traditional L2-based metrics. The optimal transportation problem also provides a correspondence between the profiles, which can be used for seismic registration.

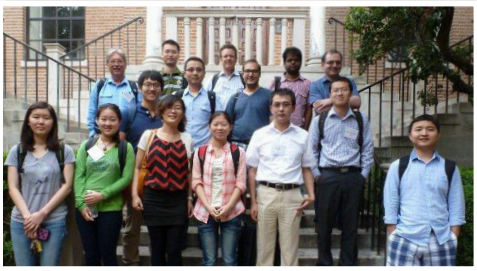


Cross-sections of L_2^2 and W_2^2 distances between profiles

Professional Awards

At the SEG Annual Meeting in Denver, new TCCS member **Tieyuan Zhu** and TCCS alumnus **Luke Decker** will receive awards for Best Student Presentation and Best Student Poster Presentation for their respective papers *Application of seismic boundary-preserving constrained inversion for delineating reservoir body*, and *Comparison of seismic diffraction imaging techniques: plane wave destruction versus apex destruction*, presented at the 2013 SEG Annual Meeting in Houston.

Madagascar Working Workshop



Several TCCS members participated in the Second Madagascar Working Workshop, which took place in Houston on July 31–August 2 and was hosted by Rice University. The workshop attracted 26 participants from 11 different organizations. The participants divided into teams of 2–3 people, pairing experienced Madagascar developers with novice users. Each team worked on a small project related to high-performance parallel computing. The participants used Stampede, the world's seventh most powerful supercomputer, provided by the Texas Advanced Computing Center at UT Austin, for their computational experiments.

Papers accepted and published 2013–2014

http://www.beg.utexas.edu/tccs/pubs.php

Accepted

T. Alkhalifah, S. Fomel, and Z. Wu, 2014, Source-receiver two-way wave extrapolation for prestack exploding-reflector modeling and migration: Geophysical Prospecting, accepted.

W. Burnett, A. Klokov, S. Fomel, R. Bansal, E. Liu, and T. Jenkinson, 2014, Seismic diffraction interpretation at Piceance Creek: Interpretation, accepted.

L. Decker, X. Janson, and S. Fomel, 2014, Carbonate reservoir characterization using seismic diffraction imaging: Interpretation, accepted.

S. Fomel, 2014, Reproducible research as a community effort: Lessons from the Madagascar project: Computing in Science and Engineering, accepted.

J. Hu, S. Fomel, and L. Ying, 2014, A fast algorithm for 3D azimuthally anisotropic velocity scan: Geophysical Prospecting, accepted.

P. Karimi and S. Fomel, 2014, Stratigraphic coordinates, a coordinate system tailored for seismic interpretation: Geophysical Prospecting, accepted.

S. Li and S. Fomel, 2014, A robust approach to time-to-depth conversion and interval velocity estimation from time migration in the presence of lateral velocity variations: Geophysical Prospecting, accepted.

Published 2014

G. Ariel, B. Engquist, S. J. Kim, and R. Tsai, 2014, Iterated averaging of three-scale oscillatory systems: Communications in Mathematical Sciences, v. 12, 791–824.

J.-D. Benamou, B. D. Froese, and A. M. Oberman, 2014, Numerical solution of the optimal transportation problem using the Monge-Ampère equation: Journal of Computational Physics, v. 260, 107–126.

A. R. Benson, J. Poulson, K. Tran, B. Engquist, and L. Ying, 2014, A parallel directional fast multipole method: SIAM Journal on Scientific Computing, 36(4), C335–C352.

Y. Chen, S. Fomel, and J. Hu, 2014, Iterative deblending of simultaneous-source seismic data using seislet-domain shaping regularization: Geophysics, v. 79, V179–V189.

Y. Chen and J. Ma, 2014, Random noise attenuation by f-x emprical mode decomposition predictive filtering: Geophysics, v. 79, V81–V91.

Y. Chen, J. Yuan, Z. Jin, K. Chen, and L. Zhang, 2014, Deblending using normal moveout and median filtering in common-midpoint gathers: Journal of Geophysics and Engineering, v. 11, 045012.

J. Cheng and S. Fomel, 2014, Fast algorithms for elastic wave-mode separation and vector decomposition using low-rank approximation for anisotropic media: Geophysics, v. 79, C97–C110.

G. Fang, S. Fomel, Q. Du, and J. Hu, 2014, Lowrank seismic wave extrapolation on a staggered grid: Geophysics, v. 79, T157–T168.

M. Far, J.S.S. de Figueiredo, D. Han, R. R. Stewart, J. P. Castagna, and N. Dyaur, 2014, Measurements of seismic anisotropy and fracture compliances in synthetic fractured media: Geophysical Journal International,v. 197, 1845–1857.

M. Far and B. Hardage, 2014, Interpretation of fractures and stress anisotropy in Marcellus shale using multicomponent seismic data: Interpretation, 2(2), SE105–SE115.

M. Far, B. Hardage, and D. Wagner, 2014, Fracture parameter inversion for Marcellus shale: Geophysics, 79(3), C55–C63.

S. Fomel and E. Landa, 2014, Structural uncertainty of time-migrated seismic images: Journal of Applied Geophysics, v. 101, 27–30.

S. Fomel and M. van der Baan, 2014, Local skewness attribute as a seismic phase detector: Interpretation, v. 2, SA49–SA56.

R. H. Herrera, S. Fomel, and M. van der Baan, 2014, Automatic approaches for seismic to well tying: Interpretation, v. 2, SD101–SD109.

J. Poulson, L. Demanet, N. Maxwell, and L. Ying, 2014, A parallel butterfly algorithm: SIAM Journal on Scientific Computing, v. 36, C49–C65.

P. Tsuji, J. Poulson, B. Engquist, and L. Ying, 2014, Sweeping preconditioners for elastic wave propagation with spectral element methods: ESAIM Mathematical Modelling and Numerical Analysis, v.48, 433–447.

R. Zhang, X. Song, S. Fomel, M. K. Sen, and S. Srinivasan, 2014, Time-lapse prestack seismic data registration and inversion for CO2 sequestration study at Cranfield: Geophysical Prospecting, v. 62, 1028–1039.

Published 2013

G. Ariel, B. Engquist, S. Kim, Y. Lee, and R. Tsai, 2013, A multiscale method for highly oscillatory dynamical systems using a Poincaré map type technique: Journal of Scientific Computing, v. 54, 247–268.

Y. Cai, S. Fomel, and H. Zeng, 2013, Automated spectral recomposition with application in stratigraphic interpretation: Interpretation, v. 1, SA109-SA116.

Z. Chen, S. Fomel, and W. Lu, 2013, Omnidirectional plane-wave destruction: Geophysics, v. 78, V171–V179.

Z. Chen, S. Fomel, and W. Lu, 2013, Accelerated plane-wave destruction: Geophysics, v. 78, V1–V9.

J. Chu, B. Engquist, M. Prodanovic, and R. Tsai, 2013, A multiscale method coupling network and continuum models in porous media II: single- and two-phase flows: Advances in Applied Mathematics, Modeling, and Computational Science, v. 66, 161–185.

B. Engquist, B. Froese, and R. Tsai, 2013, Fast sweeping methods for hyperbolic systems of conservation laws at steady state: Journal of Computational Physics, v. 255, 316–338.

B. Engquist and L. Ying, 2013, A fast algorithm for reiterated homogenization: Communications in Mathematical Sciences, v. 11, 635–649.

M. Far, L. Thomsen, and C. Sayers, 2013, Seismic characterization of reservoirs with asymmetric fractures: Geophysics, v. 78, N1–N10.

M. Far, C. Sayers, L. Thomsen, D. Han, and J. Castagna, 2013, Seismic characterization of naturally fractured reservoirs using amplitude versus offset and azimuth: Geophysical Prospecting, v. 61, 427–447.

S. Fomel, P. Sava, I. Vlad, Y. Liu, and V. Bashkardin, 2013, Madagascar open-source software project: Journal of Open Research Software, v. 1, e8.

S. Fomel, L. Ying, and X. Song, 2013, Seismic wave extrapolation using lowrank symbol approximation: Geophysical Prospecting, v. 61, 526–536.

S. Fomel and R. Kazinnik, 2013, Nonhyperbolic common reflection surface: Geophysical Prospecting, v. 61, 21–27.

S. Fomel, 2013, Seismic data decomposition into spectral components using regularized nonstationary autoregression: Geophysics, v. 78, O69–O76.

B. D. Froese and A. M. Oberman, 2013, Convergent filtered schemes for the Monge-Ampère partial differential equation: SIAM Journal on Numerical Analysis, v. 51, 423–444.

J. Hu, S. Fomel, L. Demanet, and L. Ying, 2013, A fast butterfly algorithm for the hyperbolic Radon transform: Geophysics, v. 78, U41–U51.

S. Li and S. Fomel, 2013, Kirchhoff migration using eikonal-based computation of traveltime source-derivatives: Geophysics, v. 78, S211–S219.

Y. Liu and S. Fomel, 2013, Seismic data analysis using local time-frequency transform: Geophysical Prospecting, v. 61, 516–525.

J. Poulson, B. Engquist, S. Li, and L. Ying, 2013, A parallel sweeping preconditioner for high frequency heterogeneous 3D Helmholtz equations: SIAM Journal on Scientific Computing, v. 35, C194–C212.

J. Poulson, B. Marker, R. A. van de Geijn, J. R. Hammond, and N. A. Romero, 2013, Elemental: a new framework for distributed memory dense matrix computations, ACM Transactions on Mathematical Software, v. 39, 13:1–13:24.

C. Saragiotis, T. Alkhalifah, and S. Fomel, 2013, Automatic traveltime picking using instantaneous traveltime: Geophysics, v. 78, T53–T58.

X. Song, S. Fomel, and L. Ying, 2013, Lowrank finite-differences and lowrank Fourier finite-differences for seismic wave extrapolation: Geophysical Journal International, v. 193, 960–969.

X. Song and T. Alkhalifah, 2013, Modeling of pseudo-acoustic P-waves in orthorhombic media with lowrank approximation: Geophysics, v. 78, C33–C40.

R. Zhang, X. Song, S. Fomel, M. K. Sen, and S. Srinivasan, 2013, Time-lapse seismic data registration and inversion for CO2 sequestration study at Cranfield: Geophysics, v. 78, B329–B338.

TCCS Staff

The TCCS group consists of people from seven different countries who have come together to move science forward. Our research staff includes principal investigators, postdocs, Ph.D. students, M.S. students, and a senior research fellow:

Yangkang Chen (Ph.D., 3rd year)
Björn Engquist (PI)
Sergey Fomel (PI)
Brittany Froese (Postdoc)
Parvaneh Karimi (Ph.D., 5th year)
Mark Lai (Postdoc)
Dmitry Merzlikin (Ph.D., 1st year)
Kelly Regimbal (M.S., 1st year)
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Junzhe Sun (Ph.D., 3rd year)
Ryan Swindeman (M.S., 2nd year)
Zhiguang Xue (Ph.D., 2nd year)
Hejun Zhu (Postdoc)
Tieyuan Zhu (Postdoc)

For more information, see http://www.beg.utexas.edu/tccs/staff.php.

New faces

Yenming (Mark) Lai received his BSEE from Rice University in 2004 and Ph.D. in Applied Mathematics from the University of Maryland in 2014. From 2006–2008, Lai was an Algebra I high school teacher at Lanier High School in Austin, Texas. Lai's research interests include large-scale sensor-array optimization, beam-pattern design, and compressed sensing. His work is focused on being not only reproducible but immediately applicable to industrial needs.

Tieyuan Zhu is a Distinguished Postdoctoral Fellow in the Jackson School of Geosciences at the University of Texas at Austin. He received his Ph.D. from Stanford University in 2014. Tieyuan is an exploration seismologist who seeks to solve challenging energy and environment problems using seismic-waves. His interests include advancing understanding of physics of seismic wave propagation in real-Earth media, time-reversal imaging, seismic inversion and imaging, and time-lapse monitoring.

Dmitry Merzlikin is currently a Ph.D. student, and received his master degree in Geophysics from Lomonosov Moscow State University in June 2014. In his master's thesis, he focused on application of different migration techniques to high-resolution seismic data. In his bachelor's project at the same university, he was engaged in processing seismic data with low signal-to-noise ratio. In 2011, Dmitry was a participant of the 18th TTR "Floating University" cruise in the Barents Sea. His current main research interest is seismic diffraction imaging.

Kelly Regimbal received her Bachelor of Science degree in mathematics with minors in geology and statistics from Colorado Mesa University. She worked with Dr. Dan Schultz-Ela on seismic-data processing and imaging using a reversible transform. Kelly is currently a M.S. student working with Sergey Fomel. She chose TCCS for the challenging research opportunity and superior resources. She hopes to acquire a position in the oil industry after graduation.

Testimonials

Pengliang Yang

For its good reputation and strong research force in the geophysical community, I moved to UT Austin and carried out my visiting research in TCCS last year. In this group, I was able to use the powerful supercomputer Stampede to deepen my high-performance computing studies. TCCS tries to challenge the unknown realm in the spirit of reproducible research, based on the open software Madagascar. The team members were always ready to help me solve difficult computational seismology problems with new approaches and mathematical perspectives. Besides the research activities on the Pickle research campus, TCCS provide me flexible time schedule and opportunities to explore interesting courses. I am happy to contribute my research work to Madagascar project and share the precious experience with many others!

Mehdi E. Far

I had the honor of working at TCCS as a postdoc. Sergey has created a great working environment where everybody is willing to help one another. At TCCS I met some of the most brilliant geophysics students. TCCS students and researchers address some of the most challenging problems in exploration geophysics and the overall scientific productivity of the group is simply outstanding.

Jingwei Hu

TCCS is a perfect platform for interdisciplinary research and collaboration among geophysicists, mathematicians, and computational scientists. It also provides a unique opportunity for direct interaction with industry partners. I was lucky to be part of the TCCS family for the past three years. Now that I am starting my career as an independent researcher, I hope the group continues to develop more and am looking forward to future collaborations.

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