Welcome to the sixteenth *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 Sciences (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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Fall Meeting

The Fall 2018 Research Meeting of the Texas Consortium for Computational Seismology will take place in Austin on November 5–6. 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 Anaheim

TCCS members and collaborators made a number of presentations at the SEG 2018 Annual Meeting.

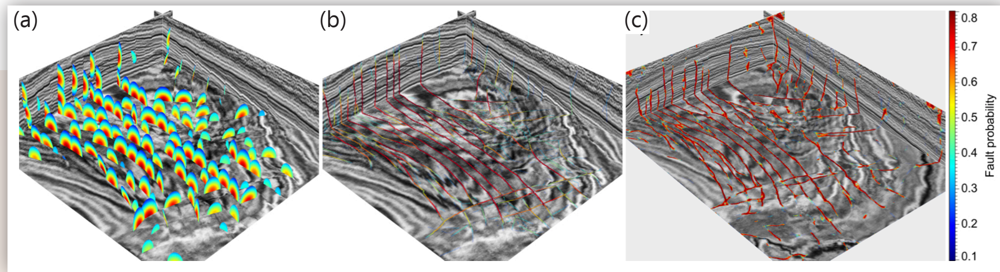
Monday, Oct. 15	1:50 pm	SPMI 1: Enhanced Least-squares Imaging	S. Greer, Z. Xue and S. Fomel	Improving migration resolution by approximating the least-squares Hessian using nonstationary amplitude and frequency matching
	2:15 pm	SVE P1: Algorithms	S. Bader, S. Fomel and Z. Xue	Using well-seismic mistie to update the velocity model
Tuesday, Oct. 16	9:20 am	MLDA 1: Classification for Interpretation 1	X. Wu, Y. Shi, S. Fomel and L. Liang	Convolutional neural networks for fault interpretation in seismic images
	11:00 am	MLDA 1: Classification for Interpretation 1	Y. Shi, X. Wu and S. Fomel	Automatic salt-body classification using deep convolutional neural network
	3:05 pm	SPMNR 2: Noise Attenuation and Regularization	L. Decker and S. Fomel	A finite-element method for blind deconvolution with dynamic frequency wavelets
	3:30 pm	SPMNR 2: Noise Attenuation and Regularization	B. Gremillion and S. Fomel	Improving spatial resolution of seismic stack using inversion to zero-offset with shaping regularization
Wednesday, Oct. 17	8:30 am	INT 4: Faults and Fractures	X. Wu and S. Fomel	Automatic fault interpretation using optimal surface voting
	8:55 am	SPMI 3: Least-squares Imaging Examples and use of Multiples	D. Merzlikin, S. Fomel, and X. Wu	Least-squares diffraction imaging using shaping regularization by anisotropic smoothing
	8:55 am	MLDA 3: Facies Classification and Reservoir Properties 2	N. Pham, S. Fomel, and D. Dunlap	Automatic channel detection using deep learning
	11:00 am	FWI 4: Cycle Skipping and Long-wavelength Updating 2	Y. Yang and B. Engquist	Model recovery below reflectors by optimal-transport FWI
	11:00 am	BG P1: Wireline Logging Technology	S. Bader, K. Spikes and S. Fomel	Missing well-log data prediction using Bayesian approach in the relative-geologic time domain
	2:15 pm	INT 5: Event-picking and Reservoir Characterization	X. Wu and S. Fomel	Least-squares seismic horizons with local slopes and multigrid correlations

Madagascar Working Workshop

In late August, 16 participants from 12 organizations collaborated at the University of Houston to learn to program geophysical applications using Python and Julia. These languages are good for prototyping and applying selected geophysical algorithms. Our goal was to promote more widespread use of these languages.

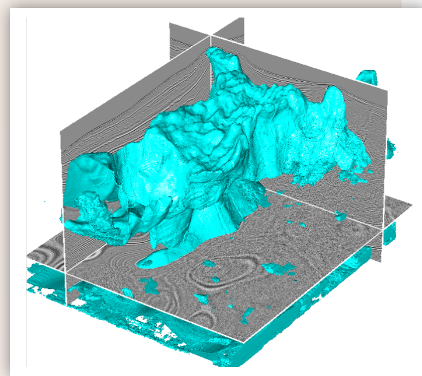
This is the sixth year that TCCS has organized working workshops where small groups collaborate to develop software or conduct computational experiments addressing a particular problem. This year participants were students, academic staff, and industry professionals. Projects included machine learning, 3D plotting, parallel processing, wave equation modeling, and well log analysis: http://www.ahay.org/wiki/HoustonWW2018.

Research Highlights

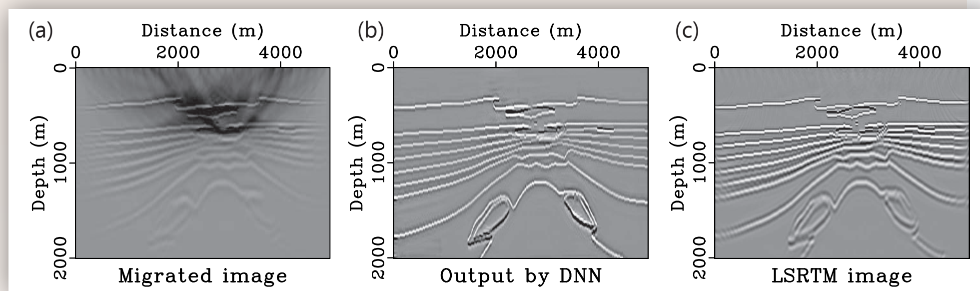


Xinming Wu worked on two CNN (convolutional neural network) methods of Fault-Net3D and FaultSeg3D for 3D fault interpretation. The FautNet3D can simultaneously predict fault probabilities, strikes and dips directly from a seismic image, which is considered as an image classification problem and is achieved by using a common CNN. A subset of anisotropic ellipsoids in (a) are colored by fault probabilities and oriented by the predicted fault strikes and dips. The full set of anisotropic ellipsoids are further stacked to obtain three fault images of probabilities (b), strikes and dips, with which fault surfaces can be automatically constructed. In the FaultSeg3D, fault detection (c) is considered as a binary image segmentation problem of labelling a 3D seismic image with ones on faults and zeros elsewhere.

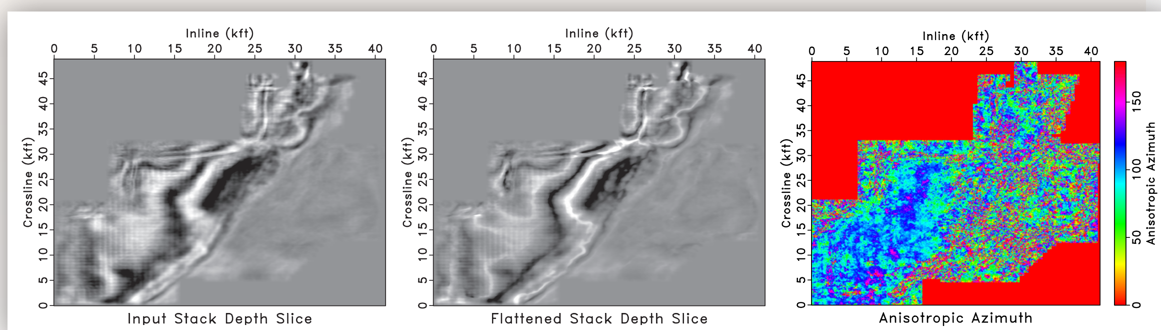
Yunzhi Shi has been working on deep learning techniques to the problem of the salt body detection in seismic images. A multi-layer 3D convolutional neural network is trained to perform salt body classification as an image segmentation. This method based on deep learning provides an end-to-end automatic salt body detection approach in the seismic image. The encoder-decoder architecture allows for extracting essential information from training data. In the tests, the model successfully generalizes to 3D validation dataset and field dataset with accurate salt body prediction.



Harpreet Kaur worked on estimating migrated images with meaningful amplitudes similar to least-squares inverse images by approximating the inverse of Hessian using generative adversarial networks (GANs) in a conditional setting. The proposed algorithm uses conditional CycleGAN such that mapping from migrated image to true reflectivity is subjected to attribute condition of velocity. This approach gives results similar to iterative inversion by approximating inverse of Hessian at a much reduced cost. (a) Low rank RTM image for BP 2004 gas cloud model (b) Image estimated after applying the inverse Hessian computed by deep neural network (DNN) to RTM image (c) Image obtained after 100 iterations of least-squares RTM.



Luke Decker worked with Qunshan Zhang during his summer internship at Repsol to develop and implement an efficient and highly parallel algorithm using Dynamic Time Warping (DTW) to flatten residual HTI anisotropic moveout in seismic gathers and determine the principal, or fast, direction of anisotropy, leading to sharper images with richer frequency spectra. Left figure shows a depth slice generated by stacking gathers prior to DTW flattening. Center figure shows a depth slice generated by stacking gathers after DTW flattening. Right figure shows the principal direction of anisotropy's azimuth at the same depth slice.



Papers Accepted and Published 2017–2018

http://www.beg.utexas.edu/tccs/publications

Accepted

A. Stovas and S. Fomel, 2018, Generalized velocity approximation: Geophysics, accepted.

Published 2018

Y. Chen and S. Fomel, 2018, EMD-seislet transform: Geophysics, v. 83, A27-A32.

B. Engquist and H. Zhao, 2018, Approximate separability of the Green's function of the Helmholtz equation in the high frequency limit: Communications on Pure and Applied Mathematics, v. LXXI, 2220–2274.

S. Greer and S. Fomel, 2018, Matching and merging high-resolution and legacy seismic images: Geophysics, v. 83, V115-V122.

Q. Xu and B Engquist, 2018, A mathematical model for fitting and predicting relaxation modulus and simulating viscoelastic responses: Proceedings of the Royal Society A, v. 474, 20170540.

Y. Sripanich and S. Fomel, 2018, Fast time-to-depth conversion and interval velocity estimation with weak lateral variations: Geophysics, v. 83, S227–S235.

G. Wu, S. Fomel, and Y. Chen, 2018, Data-driven time-frequency analysis of seismic data using nonstationary Prony method: Geophysical Prospecting, v. 66, 85-97.

X. Wu and S. Fomel, 2018, Automatic fault interpretation with optimal surface voting: Geophysics, Geophysics, v. 83, O67-O82.

X. Wu and S. Fomel, 2018, Least-squares horizons with local slopes and multi-grid correlations: Geophysics, v.83, IM29–IM40.

X. Wu, S. Fomel, and M. Hudec, 2018, Fast salt boundary interpretation with optimal path picking: Geophysics, v. 83, O45–O53.

X. Wu, Y. Shi, S. Fomel, and F. Li, 2018, Incremental correlation of multiple well logs following geologically optimal neighbors: Interpretation, v. 6, T713–T722.

Z. Xue, S. Fomel, and J. Sun, 2018, Increasing resolution of reverse-time migration using time-shift gathers: Geophysical Prospecting, v. 66, 726-735.

Z. Xue, J. Sun, S. Fomel, and T. Zhu, 2018, Accelerating full-waveform inversion with attenuation compensation: Geophysics, v. 83, A13-A20.

Z. Xue, X. Wu, and S. Fomel, 2018, Predictive painting across faults: Interpretation, v. 6, T449–T455.

Y. Yang and B. Engquist, 2018, Analysis of optimal transport and related misfit functions in full-waveform inversion, Geophysics, v. 83, A7-A12.

Y. Yang, B. Engquist, J. Sun, and B. Hamfeldt, 2018, Application of optimal transport and the quadratic Wasserstein metric to full-waveform inversion: Geophysics, v. 83, R43-R62.

Published 2017

T. Bai, I. Tsvankin, and X. Wu, 2017, Waveform inversion for attenuation estimation in anisotropic media: Geophysics, v. 82, WA83-WA93.

H. Chen, H. Zhou, Q. Zhang, and Y. Chen, 2017, Modeling elastic wave propagation using k-space operator-based temporal high-order staggered-grid finite-difference method: IEEE Transactions on Geoscience and Remote Sensing, v. 55, 801-815.

L. Decker, D. Merzlikin, and S. Fomel, 2017, Diffraction imaging and velocity analysis using oriented velocity continuation: Geophysics, v. 82, U25-U35.

B. Engquist, C. Frederick, Q. Huynh, and H. Zhou, 2017, Seafloor identification in sonar imagery via simulations of Helmholtz equations and discrete optimization: Journal of Computational Physics, v. 338, 477–492.

P. Karimi, S. Fomel, and R. Zhang, 2017, Creating detailed subsurface models using predictive image-guided well-log interpolation: Interpretation, v. 5, T279-T285.

D. Merzlikin and S. Fomel, 2017, Analytical path-integral imaging of seismic diffractions: Geophysics, v. 82, S51-S59.

M. Phillips and S. Fomel, 2017, Plane-wave Sobel attribute for discontinuity enhancement in seismic images: Geophysics, v. 82, WB63-WB69.

Y. Sripanich, S. Fomel, A. Stovas, Q. Hao, 2017, 3D generalized nonhyperboloidal moveout approximation: Geophysics, v. 82, C49-C59.

Y. Sripanich, S. Fomel, J. Sun, and J. Cheng, 2017, Elastic wave-vector decomposition in heterogeneous anisotropic media: Geophysical Prospecting, v. 65, 1231–1245.

A. Stovas and S. Fomel, 2017, The modified generalized moveout approximation, a new parameter selection: Geophysical Prospecting, v. 65, 687-695.

J. Sun, S. Fomel, Y. Sripanich, and P. Fowler, 2017, Recursive integral time extrapolation of elastic waves using low-rank symbol approximation: Geophysical Journal International, v. 211, 1478-1493.

X. Wu, 2017, Building 3D subsurface models conforming to seismic structural and stratigraphic features: Geophysics, v. 82, IM21-IM30.

X. Wu, 2017, Directional structure-tensor based coherence to detect seismic channels and faults. Geophysics, v. 82, A13-A17.

X. Wu, 2017, Structure-, stratigraphy-, and fault-guided regularization in geophysical inversion: Geophysical Journal International, v. 210, 184-195.

X. Wu and G. Caumon, 2017, Simultaneous multiple well-seismic ties using flattened synthetic and real seismograms: Geophysics, v. 82, IM13-IM20.

X. Wu and X. Janson, 2017, Directional structure tensors in estimating seismic structural and stratigraphic orientations: Geophysical Journal International, v. 210, 534-548.

X. Wu and Z. Zhu, 2017, Methods to enhance seismic faults and construct fault surfaces: Computers & Geosciences, v. 107, 37-48.

Z. Xue, H. Zhu, and S. Fomel, 2017, Full waveform inversion using seislet regularization: Geophysics, v. 82, A43-A49.

R. Zhang and S. Fomel, 2017, Time variant wavelet extraction with spectral decomposition for seismic inversion: Interpretation, v. 5, SC9-SC16.

TCCS Staff

The TCCS group consists of people from five countries. Our research staff includes 2 principal investigators, 4 Ph.D. students, 2 M.S. students, a postdoc, a senior research fellow, and a visiting scholar:

Björn Engquist (PI)
Sergey Fomel (PI)
Luke Decker (Ph.D. 3rd year)
Zhicheng Geng (Ph.D. 2nd year)
Ben Gremillion (M.S. 2nd year)
Harpreet Kaur (Ph.D. 2nd year)
Nam Pham (M.S. 2nd year)
Karl Schleicher (Senior Research Fellow)
Yunzhi Shi (Ph.D. 4th year)
Yuhan Sui (Visiting Scholar)
Xinming Wu (Postdoc)

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

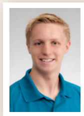
Testimonials

Dmitrii Merzlikin

TCCS has a unique research environment, which fosters independent thinking, problem solving and results' presentation skills among students. The research process is highly organized and efficient thanks to Madagascar: the technology transfer and scientific collaboration is painless, easy and fast due to the reproducibility of the results. I was lucky enough to be the part of TCCS. I strongly believe that the experience I gained will help me throughout my career.

Sarah Greer

I am incredibly grateful that I had the opportunity to work with TCCS during my undergraduate studies at UT Austin. Dr. Sergey Fomel is a phenomenal advisor who creates a welcoming environment conducive for collaboration and producing cutting-edge research. Through Sergey's guidance and the opportunities he has given me, he has helped me to realize how much I truly enjoy learning, showed me the importance of reproducible computational research, introduced me to new ways of thinking about and approaching problems, and inspired me to continue my studies in graduate school.



Sean Bader

During my time with TCCS, I had an opportunity to work with several of my colleagues to understand and solve extremely challenging, but interesting, problems; it was amazing to see how productive and encouraging my colleagues were even as the problems grew more complex. Dr. Fomel is extremely kind and approachable; he allows us to work on projects that interest us, providing guidance and insight when we need it. Dr. Fomel's breadth and depth of knowledge is incredible, and he encouraged us to understand our research problems at a very deep level and to test the bounds of what is known in geophysics. I hope that TCCS will always be the welcoming family that inspires a passion for research in geophysics.

Left to right: Sarah Greer, Sean Bader, Sergey Fomel and Zhiguang Xue

Professional Awards

TCCS members received a number of professional awards at the 2018 SEG Meeting in Anaheim.

Sean Bader (left), was awarded the Best Student Poster Paper for his presentation "Semiautomatic seismic well ties and log data inter polation" at the 2017 Annual Meeting. This is the third time in the last five years that the Best Student Poster award goes to a student from TCCS. **Dmitrii Merzlikin** received Award of Merit, Best Student Paper, for his presentation "Diffraction-based migration velocity analysis using double-path summations". This is also the third time a TCCS student wins an Award of Merit.

Sergey Fomel (left), shared the Best Paper in "Interpretation", as a co-author of the 2017 paper "Time variant wavelet extraction with spectral decomposition for seismic inversion". **Rui Zhang** (right) from UL Lafayette, the first author of this paper, presented this work at the TCCS meeting in Houston in 2016.

Tieyuan Zhu (right), a TCCS postdoc in 2014–2016 and currently an assistant professor at Penn State, received the J. Clarence Karcher Award, a major SEG award for young geophysicists.

The Bureau of Economic Geology, the TCCS host organization, was presented with the Distinguished Achievement Award. This award is given "from time to time to a company, institution, or other organization for a specific technical contribution or contributions that have substantially advanced the science of exploration geophysics." The citation says "The Bureau of Economic Geology is an ideal recipient for SEG's Distinguished Achievement Award for several notable contributions, including: (1) earliest recognition of reflection seismology and seismic stratigraphy concepts; (2) transferring 3D seismic technology to independent producers; (3) public release of 3D digital seismic data sets; (4) managing the Devine Geophysical Test Site; (5) establishing a robust program for educating K–12 students in the geosciences; (6) running the largest U.S. subsurface core repository system; and (7) developing and managing TexNet, Texas' statewide seismological array. The list of SEG offices, awards, and honors distributed among several notable Bureau researchers is testimony that, as a collective group, Bureau geophysicists have made invaluable contributions to the SEG."