Spring 2020 Newsletter

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Texas Consortium for Computational Seismology • The University of Texas at Austin

Welcome to the 19th *TCCS Newsletter*!

The Texas Consortium for Computational Seismology is a joint initiative of the Bureau of Economic Geology (the Bureau) and the Oden Institute for Computational Engineering and Sciences 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.

Hope to see you in Houston

TCCS has submitted 10 expanded abstracts to the **2020 SEG Annual Meeting in Houston**. The submitted papers fall into seven different subject areas: Interpretation, Machine Learning and Data Analytics, Passive Seismic, Seismic Processing: Migration, Seismic Processing: Multiples, Noise and Regularization, Seismic Velocity Estimation, Seismic Processing: Emerging Technologies.

Professional Awards

Sergey Fomel visited 20 locations in California, Canada, Mexico, and Texas on his Spring 2020 SEG Distinguished Lecture tour, presenting "Automating seismic data analysis and interpretation." His next lecture will be given virtually on May 12. You can register for free at https://www.knowledgette.com/p/automating-seismic-data-analysis-and-interpretation.

Sergey was also selected to receive an **Honorary Membership in GSH** (Geophysical Society of Houston).

Xinming Wu, a TCCS postdoc in 2016–2019 and currently a professor at USTC, was selected for the **J. Clarence Karcher award** from SEG. The award is given "in recognition of significant contributions to the science and technology of exploration geophysics by a young geophysicist of outstanding abilities." Xinming is the third TCCS postdoc to receive the Karcher award in the last 3 years, after Tieyuan Zhu (currently at Penn State) in 2018 and Hejun Zhu (currently at UT Dallas) in 2019.

Xinming's SEG Honorary Lecture, "Deep learning for seismic processing and interpretation," is given virtually. You can register for it for free at https://www.knowledgette.com/p/deep-learning-for-seismic-interpretation.

TCCS Sponsors

TCCS appreciates the support of its 2020 sponsors: BP, Chevron, ConocoPhillips, ExxonMobil, Saudi Aramco, Sinopec, Shell, and Total.

Spring Meeting

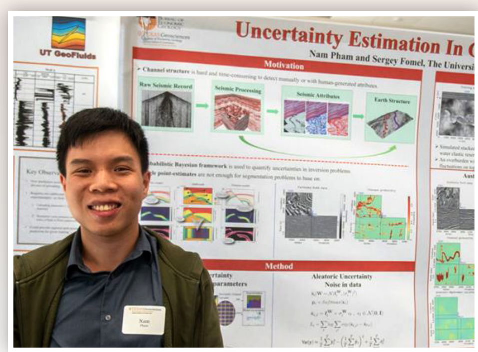
The Spring 2020 Research Meeting of the Texas Consortium for Computational Seismology will take place online in the form of a webinar.

Representatives of participating companies are invited to register for the meeting by following the link at http://www.beg.utexas.edu/tccs/.

Spring 2020 Jackson School Research Symposium

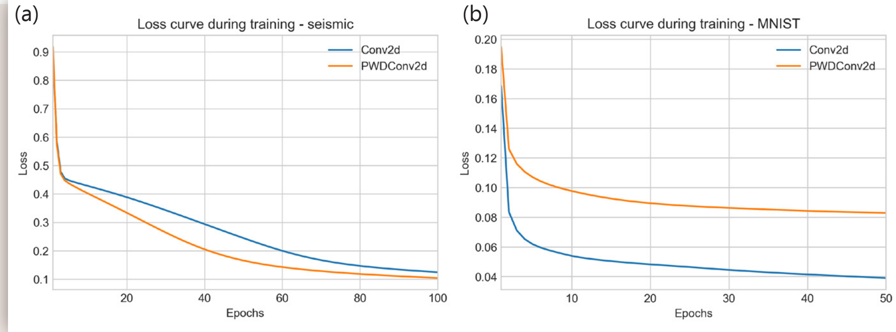
Each spring semester, students of the Jackson School of Geosciences at UT Austin present their research in a day-long poster competition. Throughout the day, faculty, research scientists, and industry representatives evaluate the posters. The goal of the Symposium is to foster cross-disciplinary collaboration among graduate students, undergraduate students, and faculty/research scientists at the Jackson School. The event is sponsored by ConocoPhillips.

Ben Gremillion with his poster "Seismic image interpolation from scattered locations to a regular grid."

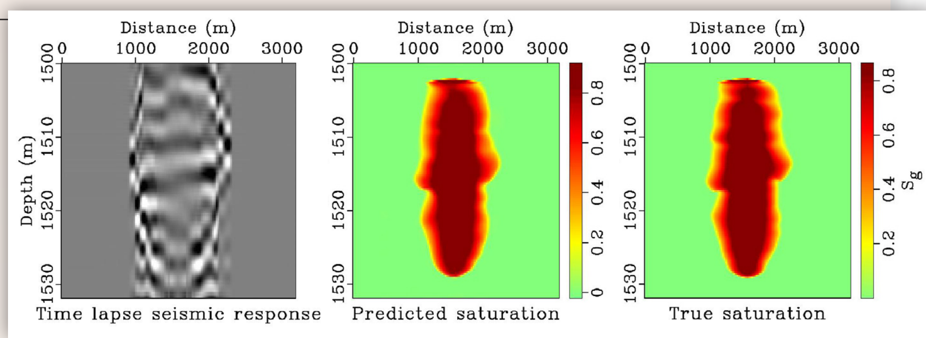


Nam Pham with his poster "Uncertainty estimation in channel detection."

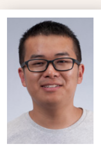
Research Highlights

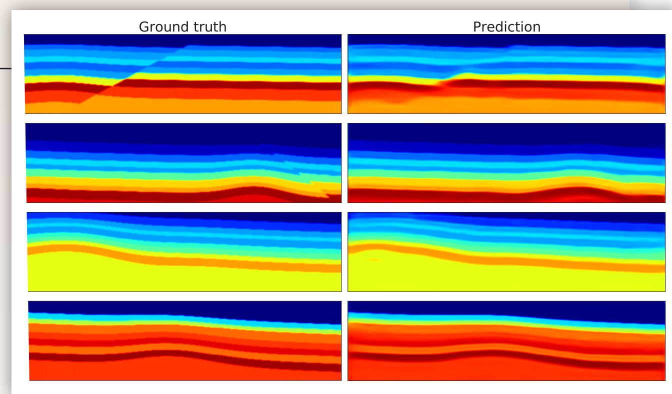


Yunzhi Shi has been working on a network architecture of plane-wave neural networks (PWNN), combining plane-wave destruction (PWD) filters and CNN into a single architecture. PWNN integrates a customized convolution kernel into the network. This specialized kernel has a meaningful parameter—slope—which represents the dipping slope of seismic plane-wave reflections. As shown in the figure, the loss curves in (a) show faster and better convergence of PWNN over vanilla CNN because the proposed architecture makes use of the heuristic structure in seismic images. However, in the test using MNIST data, a handwritten digit image dataset, the loss curves in (b) show vanilla CNN outperforms PWNN.

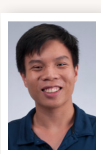


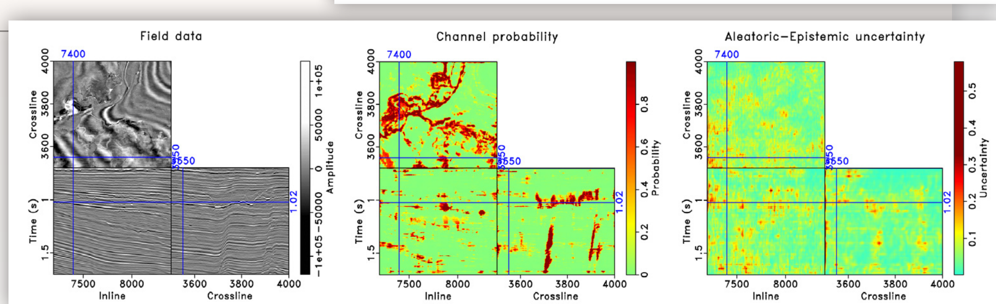
Harpreet Kaur has been working on designing a deep learning framework for carbon dioxide (CO_2) saturation monitoring to determine the geological controls on CO_2 storage. Using a distribution for porosities and permeabilities for a given reservoir, saturation and velocity models are generated. The network is trained with a few time-lapse seismic images and their corresponding changes in saturation values for a particular CO_2 injection location. The network learns the mapping from change in time-lapse seismic response to change in saturation during the training phase. The learned model can then be applied to the test datasets, which comprise different time-lapse seismic image slices generated using different porosity and permeability distributions that are not a part of training, to estimate the CO_2 saturation values as well as plume extent. The proposed algorithm provides a framework for directly estimating CO_2 saturation values with time-lapse seismic data.





Zhicheng Geng has been working on deep learning for velocity model building with common-image gathers (CIGs). The convolutional neural network is able to figure out the relation between shifted images and curved events in CIGs due to an inaccurate velocity model and the corresponding correct velocity model. Pairs of synthetic input CIGs and output target velocity models are used to train the network. Test results for other synthetic models show the potential of deep learning in velocity modeling building.





Nam Pham has been working on quantifying the uncertainties for automatic channel detection using a Bayesian convolutional neural network. The network is trained with synthetic datasets to output the channel probability, epistemic uncertainty, and aleatoric uncertainties volumes. Tests on field datasets prove that the epistemic uncertainties are related to model parameter uncertainties and the lack of stratigraphic structures in the training data, whereas aleatoric uncertainties are related to noise in the seismic volumes. With channel probability and uncertainty volumes, interpreters can successfully pick 3D channel geobodies in seismic volumes, understand the mispicks of model, and enhance the results from neural network.

Papers Accepted and Published 2019–2020

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

Accepted

L. Decker and Q. Zhang, Quantifying and correcting residual azimuthal anisotropic moveout in image gathers using dynamic time warping: Geophysics, accepted.

B. Engquist, K. Ren, and Y. Yang, The quadratic Wasserstein metric for inverse data matching: Inverse Problems, accepted.

Z. Geng, X. Wu, Y. Shi, and S. Fomel, Deep learning for relative geologic time and seismic horizons: Geophysics, accepted.

H. Kaur, N. Pham, and S. Fomel, Improving resolution of migrated images by approximating the inverse Hessian using deep learning: Geophysics, accepted.

D. Merzlikin, S. Fomel, and X. Wu, Least-squares diffraction imaging using shaping regularization by anisotropic smoothing: Geophysics, accepted.

N. Pham, X. Wu, and E. Z. Naeini, Missing well log prediction using convolutional long short-term memory network: Geophysics, accepted.

Published 2020

Z. Geng, X. Wu, S. Fomel, and Y. Chen, 2020, Relative time seislet transform: Geophysics, v. 85, V223–V232.

Y. Shi, X. Wu, and S. Fomel, 2020, Waveform embedding: Automatic horizon picking with unsupervised deep learning: Geophysics, v. 85, WA67–WA76.

Y. Sripanich, S. Fomel, J. Trampert, W. Burnett, and T. Hess, 2020, Probabilistic moveout analysis by time warping: Geophysics, v. 85, U1–U20.

X. Wu, Z. Geng, Y. Shi, N. Pham, S. Fomel, and G. Caumon, 2020, Building realistic structure models to train convolutional neural networks for seismic structural interpretation: Geophysics, v. 85, WA27–WA39.

Q. Xu, B. Engquist, M. Solaimanian, and K. Yan, 2020, A new nonlinear viscoelastic model and mathematical solution of solids for improving prediction accuracy: Scientific Reports, v. 10, Article 2202.

Z. Zhong, A. Sun, and X. Wu, 2020, Inversion of time-lapse seismic reservoir monitoring data using CycleGAN: A deep learning-based approach for estimating dynamic reservoir property changes: Journal of Geophysical Research: Solid Earth, v. 125, e2019JB018408.

Published 2019

S. Bader, X. Wu, and S. Fomel, 2019, Missing log data interpolation and semiautomatic seismic well ties using data matching techniques: Interpretation, v. 7, T347–T361.

D. Merzlikin, S. Fomel, and M. Sen, 2019, Least-squares path-summation diffraction imaging using sparsity constraints: Geophysics, v. 84, S187–S200.

N. Pham, S. Fomel, and D. Dunlap, 2019, Automatic channel detection using deep learning: Interpretation, v. 7, SE43–SE50.

Y. Shi, X. Wu, and S. Fomel, 2019, SaltSeg: Automatic 3D salt segmentation using a deep convolutional neural network: Interpretation, v. 7, SE113–SE122.

Y. Sripanich, S. Fomel, and A. Stovas, 2019, Effects of lateral heterogeneity on time-domain processing parameters: Geophysical Journal International, v. 219, 1181–1201.

A. Stovas and S. Fomel, 2019, Generalized velocity approximation: Geophysics, v. 84, C27–C40.

C. Wang, Z. Zhu, H. Gu, X. Wu and S. Liu, 2019, Hankel Low-Rank Approximation for Seismic Noise Attenuation: IEEE, v. 57, 561–573.

X. Wu, L. Liang, Y. Shi, and S. Fomel, 2019, FaultSeg3D: Using synthetic data sets to train an end-to-end convolutional neural network for 3D seismic fault segmentation: Geophysics, v. 84, IM35–IM45.

X. Wu, L. Liang, Y. Shi, Z. Geng, and S. Fomel, 2019, Multitask learning for local seismic image processing: Fault detection, structure-oriented smoothing with edge-preserving, and seismic normal estimation by using a single convolutional neural network: Geophysical Journal International, v. 219, 2097–2109.

X. Wu, Y. Shi, S. Fomel, L. Liang, Q. Zhang, and A. Z. Yusifov, 2019, FaultNet3D: Predicting fault probabilities, strikes, and dips with a single convolutional neural network: IEEE Transactions on Geoscience and Remote Sensing, v. 57, 9138–9155.

X. Wu and Z. Guo, 2019, Detecting faults and channels while enhancing seismic structural and stratigraphic features: Interpretation, v. 7, T155–T166.

Z. Xue, H. Zhang, Y. Zhao, and S. Fomel, 2019, Pattern-guided dip estimation with plane-wave destruction filters: Geophysical Prospecting, v. 67, 1798–1810.

Z. Zhong, T. Carr, X. Wu, and G. Wang, 2019, Application of a Convolutional Neural Network (CNN) in permeability prediction: A case study in the Jacksonburg-Stringtown Oil Field, West Virginia, USA: Geophysics, v. 84, B363–B373.

TCCS Staff

The TCCS group consists of people from five countries. Our research staff includes two principal investigators and six Ph.D. students.

Luke Decker (Ph.D. 4th year)
Björn Engquist (PI)
Sergey Fomel (PI)
Zhicheng Geng (Ph.D. 3rd year)
Ben Gremillion (Ph.D. 1st year)
Harpreet Kaur (Ph.D. 3rd year)
Nam Pham (Ph.D. 1st year)
Yunzhi Shi (Ph.D. 5th year)

TCCS group members and family at Austin's Emma Long Metropolitan Park for a weekend barbeque.

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

Testimonial

Xinming Wu

I did not realize that I left TCCS about 1 year ago until I start writing this testimonial. I miss TCCS, where I worked for about 4 years first as a visiting Ph.D. student and then as a postdoc. I would say those 4 years were my best time for research. I was so fortunate to be able to work with the friendly and talented people at TCCS, including Sergey, Yunzhi, Zhicheng, Zhiguang, Junzhe, Tieyuan, Zone, Luke, Dimitrii, Nam, Sean, Harpreet, Ben, and so on. I enjoyed collaborating with every one of them and learned a lot from them. I recall the years that I worked with TCCS as among my most productive and enjoyable. TCCS is not a big group but it is one of the best research groups for geophysics. Here, people are encouraged to work freely on open research topics, generously share their creative ideas, and collaborate with each other. Sergey especially encouraged me to always work on challenging new research topics and try to collaborate with experts in different areas. This is why I developed successful scientific collaborations with Nathan Bangs at UTIG and Hongliu Zeng, Xavier Janson, Mike Hudec, and Jake Covault at the Bureau. Like every former TCCS member, I have so many warm memories of TCCS. I wish I could come back in the future and attend the weekly TCCS group meeting that always starts with Sergey's question of "what's new?"

Ph.D. Dissertations

Name	Year	Title	Current Employer
Yunzhi Shi	2020	Deep Learning Empowers the Next Generation of Seismic Interpretation	Amazon
Yunan Yang	2018	Optimal Transport for Seismic Inverse Problems	New York University
Dmitrii Merzlikin	2018	Diffraction Imaging by Path-Summation Migration	Schlumberger
Zhiguang Xue	2017	Regularization Strategies for Increasing Efficiency and Robustness of Least-squares RTM and FWI	CGG
Yanadet Sripanich	2017	Seismic Anisotropy Analysis Using Muir-Dellinger Parameters	PTTEP
Junzhe Sun	2016	Seismic Modeling and Imaging in Complex Media Using Low-rank Approximation	ExxonMobil
Yangkang Chen	2015	Noise Attenuation in Seismic Data from the Simultaneous-Source Acquisition	Zhejiang University
Parvaneh Karimi	2015	Seismic Interpretation Using Predictive Painting	Occidental Petroleum
Christina Frederick	2014	Numerical Methods for Multiscale Inverse Problems	Georgia Institute of Technology
Vladimir Bashkardin	2014	Phase-Space Imaging of Reflection Seismic Data	BP
Siwei Li	2014	Imaging and Velocity Model Building with Linearized Eikonal Equation and Upwind Finite-Differences	Chevron
Jack Poulson	2012	Fast Parallel Solution of Heterogeneous 3D Time-Harmonic Wave Equations	Hodge Star Scientific Computing
Xiaolei Song	2012	Application of Fourier Finite Differences and Lowrank Approximation Method for Seismic Modeling and Subsalt Imaging	BP
Paul Tsuji	2012	Fast Algorithms for Frequency-Domain Wave Propagation	Lawrence Livermore National Laboratory
William Burnett	2011	Multiazimuth Velocity Analysis Using Velocity-Independent Seismic Imaging	ExxonMobil

M.S. Theses

Ben Gremillion	2019	Seismic Data Interpolation With Shaping Inversion to Zero Offset and Least-Squares Flattening	University of Texas at Austin
Nam Pham	2019	Automatic Channel Detection Using Deep Learning	University of Texas at Austin
Sean Bader	2018	Seismic and Well Log Data Integration Using Data-Matching Techniques	EOG
Mason Phillips	2017	Geophysical Data Registration Using Modified Plane-Wave Destruction Filters	DownUnder GeoSolutions
Kelly Regimbal	2016	Improving Resolution of NMO Stack Using Shaping Regularization	ExxonMobil
Ryan Swindeman	2015	Iterative Seismic Data Interpolation Using Plane-Wave Shaping	Enthought
Luke Decker	2014	Seismic Diffraction Imaging Methods and Applications	University of Texas at Austin
Shaunak Ghosh	2013	Multiple Suppression in the t-x-p Domain	CGG
Salah Alhadab	2012	Diffraction Imaging of Sediment Drifts in Canterbury Basin	Saudi Aramco
Yihua Cai	2012	Spectral Recomposition and Multicomponent Seismic Image Registration	Shell

B.S. Honors Theses

Sarah Greer	2018	A Data Matching Algorithm and Its Applications in Seismic Data Analysis	MIT
Lubna Barghouty	2013	Surface-Related Multiple Elimination and Velocity-Independent Imaging of a 2D Seismic Line from the Viking Graben Dataset	MIT
Yanadet Sripanich	2013	An Efficient Algorithm for Two-Point Seismic Ray Tracing	PTTEP

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