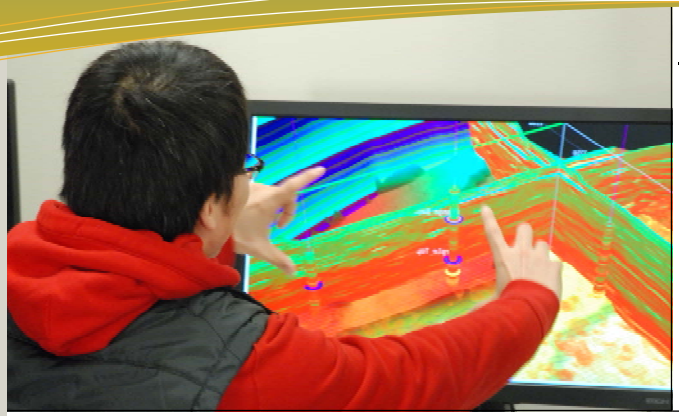
http://cegp.ece.gatech.edu

CeGP Newsletter

Center of Energy and Geo Processing

ISSUE 1 March 2015



In this issue

Upcoming events

4th CeGP Workshop
Georgia Tech
Atlanta, Georgia, USA
March 23-25, 2015

ICASSP 15
IEEE International Conference on Acoustics, Speech and Signal Processing.
Brisbane, Australia
April 19-24, 2015

SPW 15
IEEE Signal Processing & SP Education Workshop
Salt Lake City, Utah, USA
August 9-12, 2015

ICIP 15
IEEE International Conference on Image Processing
Québec City, Canada
September 27-30, 2015

SEG 15
Society of Exploration Geophysicists Annual Meeting
New Orleans, Louisiana, USA
October 18-23, 2015

Foreword by Directors

Prof. **Ali Al-Shaikhi**
Director, CeGP at KFUPM

Prof. **Ghassan AlRegib**
PI & Director, CeGP at Georgia Tech

We are pleased to share with you the first issue of the CeGP newsletter. In this issue, we share progress in research, education, and outreach. As in any global operation, the beginnings are the hardest part. Nevertheless, we are pleased with our progress. We have identified and either started or about to start three research projects on topics related to microcosmic events detection and localization, automated interpretation of very large seismic volumes using machine learning, and in-field compression of seismic data. Similarly, we have started education projects on topics such as Active Learning, Design Expo, and Senior-level DSP Hands-on course. On the Outreach front, this year, we will have two KFUPM faculty members spending a total of 14 months on the Georgia Tech campus working on joint projects as well as building stronger bridges across the two campuses. In fall 2014, we continued to have KFUPM engineering junior/senior-level students spending the fall semester at Georgia Tech participating in various activities besides taking courses. We held a successful workshop in Dhahran in October 2014 and we plan to hold the next workshop in Atlanta in March 2015. We look forward to your participation in the workshop. We welcome new ideas, new projects, and new partnerships that strengthen this joint venture between the two institutes.

Microseismic Event Monitoring

Lijun Zhu, Dr. Entao Liu, Prof. James McClellan, and Prof. Abdullah Al-Shuhail

Microseismic event monitoring has become a primary diagnostic tool of the hydraulic fracturing of the unconventional oil and gas reservoirs. The goal is to provide useful microseismic information, such as when and where did the event occur, and what type of event was it? Engineers can make better decisions

The signals in microseismic monitoring that are recorded by surface or near-surface array typically have rather low amplitudes buried in noise and interference require sophisticated method to provide optimal processing. The goal of this project is to develop novel efficient and reliable microseismic monitoring schemes, such as event detection algorithms, location algorithms, and hopefully moment tensor inversion.

From an application's point of view, the newly developed algorithms and some necessary simulations are planned to be programmed.

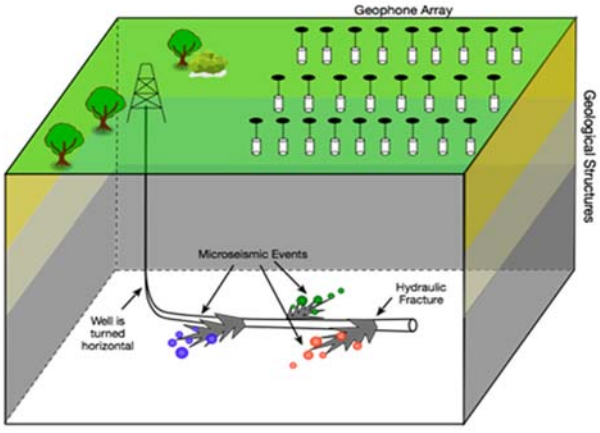


Figure 1. Illustration of microseismic monitoring in field

Microseismic event monitoring is one of the primary diagnostic tools used for hydraulic fracturing in reservoirs (see Figure 1). The signals originated by microseismic events which have rather low amplitudes buried in strong noise and interference require sophisticated designed methods to provide optimal processing. The research project on microseismic detection and inversion (location, origin

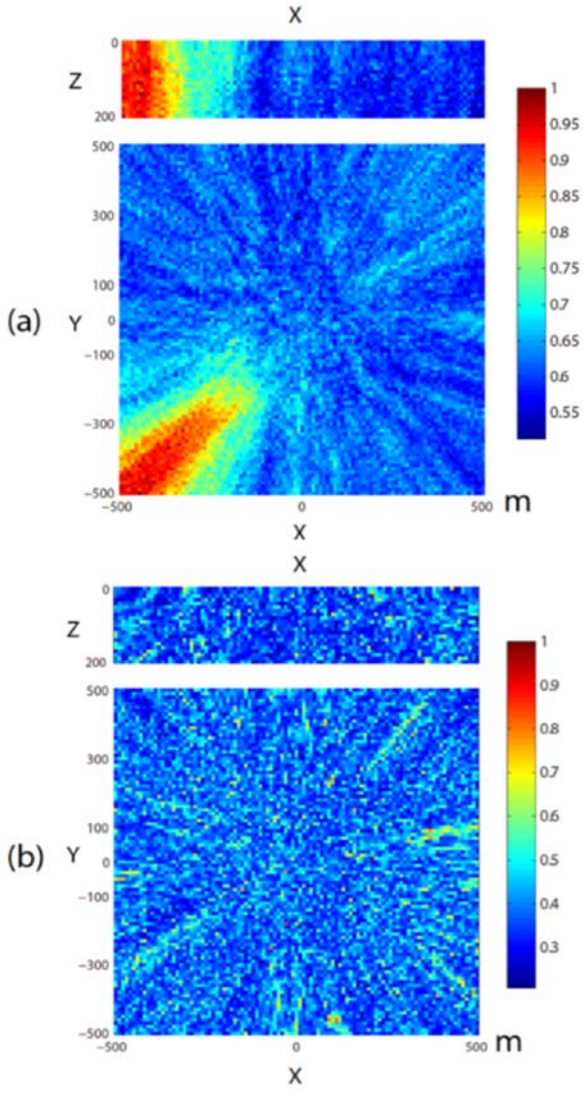


Figure 2. Normalized semblance map of the hypocenter in the corner using (a) 3-C data and (b) 1-C data.

Center for Energy & Geo Processing CeGP

time, and moment tensor) is looking for new numerical schemes, data processing techniques, and sensor array design in order to better monitoring results.

In the literature some techniques based upon arrival time picking have been developed to serve the purpose of seismic events detection and location. However, this method is incapable for microseismic monitoring when the arrival time picking becomes inaccurate in the presence of noise. Even worse, some microseismic events have such low magnitude that one cannot recognize the event by looking at the seismograms.

The ongoing research of microseismic project concentrates on exploiting 3-components (3C) seismic data to obtain finer S-wave detection by horizontal seismograms, which is typically strong in amplitude and can be missed by conventional vertical component sensors. Owing to the 3C data, the polarization of the signal is also preserved, which facilitates moment tensor analysis. A new denoising method of the 3C seismogram based on the polarization estimation has been developed. The simulation shows the denoising method is beneficial to a microseismic location scheme, which utilizes source scanning and semblance. The Figure 2 shows the semblance values for a 3D simulation. The semblance using 3C data (Fig. 2a) has obvious greater value at the true location (southwest corner in xy plane, midpoint of the left boundary in xz plane) and its vicinity than the case using 1C data (Fig. 2b).

Another ongoing topic for the microseismic project is to incorporate the compressive sensing scheme to the microseismic inversion. The interested region is dividing into a grid, each grid point is a potential location of the seismic source. A crucial issue in the microseismic simulation is how to accurately and efficiently generate the Green's function according to different moment tensor. The analytic method and semi-analytic method are adopted for the homogeneous media and layered model, respectively.

A DSP Lab Course.

In this potential project, teams of faculty members from both KFUPM and Georgia Tech plan to design a senior-level DSP lab course where students utilize their knowledge of signal processing to work on various projects. The course will be module based and in each module the students will deal with different types of signals such as speech, audio, image, video, seismic data ... etc. The students will be utilizing hardware modules from National Instruments, Texas Instruments or others as well as software packages such as Matlab® and OpenCV. In three of the modules, team across the continents will be formed.

SeiSIM: Structural Similarity Evaluation for Seismic Data Retrieval

Dr. Zhiling Long, Zhen Wang, and Prof. Ghassan AlRegib

Structural similarity evaluation is a critical step for retrieving existing databases to find matching records for a given seismic data set. The objective is to enable the re-use of historical findings to assist exploration with new survey data. Currently there are very few structural similarity metrics specifically designed for seismic data, especially seismic survey maps.

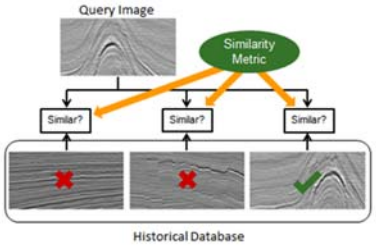


Figure 3. Illustration of the seismic retrieval problem.

In this paper, we propose a metric, SeiSIM, that combines texture similarity (STSIM-1) and geological similarity (DM, which is derived from discontinuity maps). We test the seismic similarity metric in a retrieval application involving 12 images and 4 seismic structures. The successful results indicate that our approach is promising.

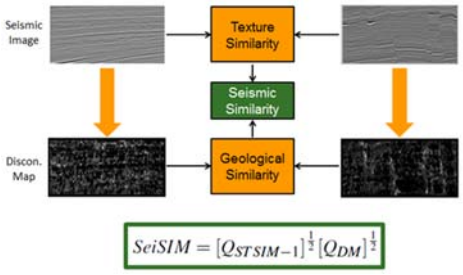


Figure 4. Diagram illustrating the SeiSIM metric.

Metric	P@1	MRR	MAP
SSIM	0.33	0.73	0.46
CW-SSIM	0.67	0.94	0.72
STSIM-1	0.92	0.99	0.91
DM	0.50	0.88	0.65
CW-SSIM + DM	0.92	0.97	0.82
SeiSIM	1.00	1.00	0.97

Table 1. Retrieval performance using different similarity metrics.

CeGP Acquires a New Cluster at Georgia Tech

Over the summer, CeGP acquired a new cluster from PSSC Labs, which is a top provider of turn-key computing cluster solutions. The cluster is currently placed at CeGP at Georgia Tech in a room that is equipped with the necessary power, HVAC and security measures. The plan is to expand the computing, memory and storage capacity of the new cluster every year for the next few years. The initial configuration includes 44 physical cores (88 with hyper-threading enabled), 192 GB of total memory, and 30 TB in total storage, all distributed over one head node and two computing nodes. The cluster is currently utilized by students and researchers at CeGP to run simulations and advanced seismic processing algorithms using Matlab®, MPI, and MatlabMPI.

Texture Attributes for Detecting Salt Bodies in Seismic Data

Dr. Tamir Hegazy and Prof. Ghassan AlRegib

Texture-based methods have proven to be useful in the detection of salt bodies in seismic data. In this work, we present three computationally inexpensive texture attributes that strongly differentiate salt bodies from other geological formations.

The proposed method combines the three texture attributes along with region boundary smoothing for delineating salt boundaries. Our first proposed attribute is *directionality*, which differentiates between regions where texture lacks any specific direction (potentially, salt) and areas with directional texture. The second attribute is the *smoothness* of texture, while the third is based on *edge content*. Our results show that the directionality attribute effectively detects salt bodies in all the seismic images used in testing. The other two attributes correct the false positives detected by the directionality attribute.

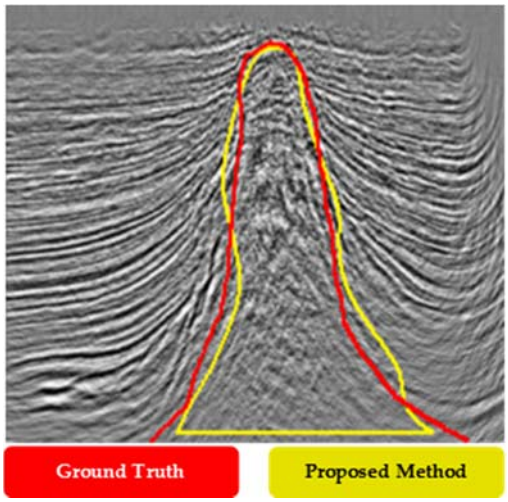


Figure 5. Detected salt body by the proposed method and ground truth.

The overall results show that the proposed method can fairly detect salt regions when compared to manual interpretation. A related publication was presented at the 2014 SEG Annual Meeting, Denver, Colorado, Oct. 26-31, 2014.

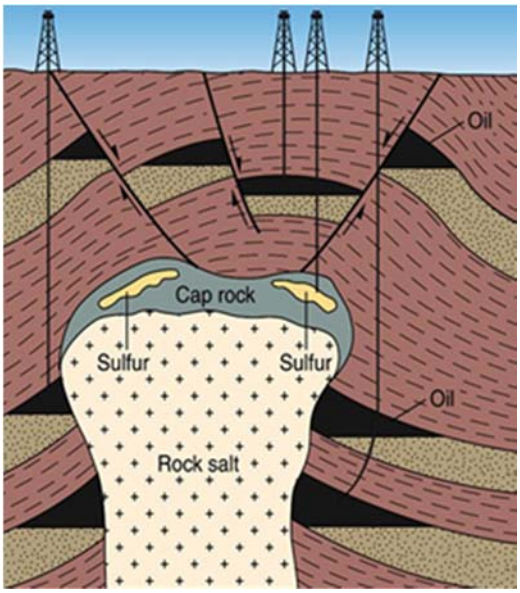


Figure 6. Salt domes are clues for oil and gas traps. The figure below is an illustration that shows oil traps around a salt dome. Drilling offshore for oil through a salt dome can lead to disasters as happened in 1980 in Lake Peigneur, Louisiana when water caused the salt to melt and the whole lake was drained into the drilling hole. Locating salt domes accurately is important for the drilling process.

S3I: Seismic Survey and Seismic Imaging

Lingchen Zhu, Lijun Zhu, Dr. Entao Liu, Prof. James McClellan, and Prof. Ghassan AlRegib,

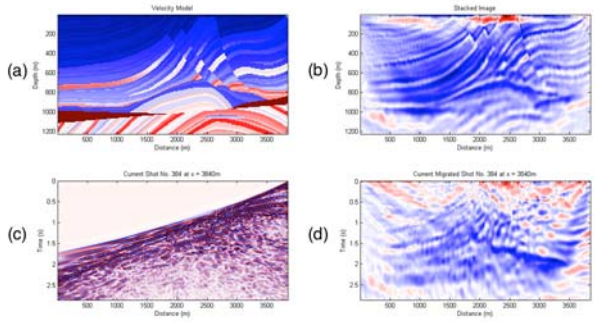


Figure 7. RTM result of the Marmousi model: (a) True velocity model, (b) stacked migrated image, (c) Shot record for a certain shot, (d) migrated image for this particular shot.

SSSI is a toolbox that was developed at CeGP. It can be used as simulation and tutorial platform of seismic survey, data acquisition, and seismic imaging process such as pre-stack Kirchhoff migration, reverse time migration (RTM), least - square RTM (LSRTM), full waveform inversion (FWI), etc.

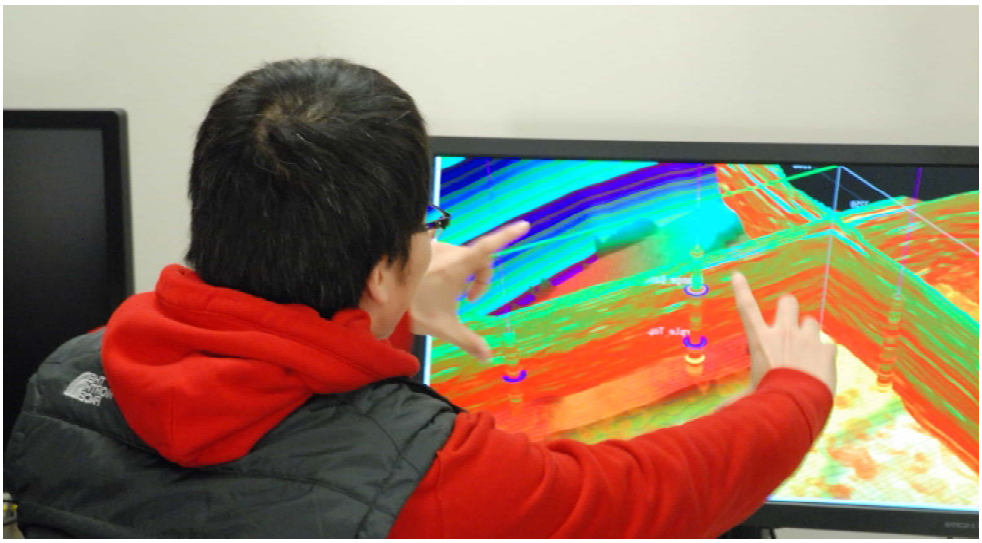
In exploration geophysics, man-made sources generate vibrations. When waveform going downwards meets perturbations in the geophysical structures, reflections and refractions occurs and be recorded by receivers on surface. The SSSI numerically simulates the physical process for acoustic/ elastic waves by solving the wave equation in given model using finite difference method on a staggered-grid up to arbitrarily high order of approximation. Moreover, the open boundary of the simulated region is taken care of by a perfectly matched layer (PML). For the readability of the codes and the tutorial purpose, MATLAB is chosen to be the coding platform of SSSI. In order to enhance its computational performance, several basic functions in SSSI is implemented with C MEX-file. There are a number of imaging conditions to form a migrated image from the received data on the receiver array. Commonly used Kirchhoff and reverse time migration are implemented.

Parallel computing based on the distributed memory model is naturally supported in SSSI. One can run our code on a computing cluster across multiple computing nodes. Each node has its own independent processor(s) and memory, takes charge of its own imaging process for a local partition on the velocity model and communicates the required boundary cell values with its direct neighboring nodes. The final global result will be gathered after all nodes finish calculations of their own partitions.

Please see the user guide in the package or visit the website http://cegp.ece.gatech.edu/s3i for more technical details.

Seismic Fault Detection and Tracking

Zhen Wang, Dr. Zhiling long, Prof. Mohamed Deriche, and Prof. Ghassan AlRegib.



In the past year, at the CeGP, we focused on the semi-automatic detection of faults in the seismic datasets. Faults, an important geological structure, are significant displacements along fractures in the subsurface. As effective structural traps, faults may seal reservoir rocks and contribute to the formation of petroleum reservoirs. Therefore, for the identification of reservoir regions, the labeling of faults in seismic volumes is of great importance. Although interpreters can help label the structures of faults, the growing amount of seismic data make manual interpretation more time consuming and more labor intensive. To improve interpretation efficiency, we proposed interactive fault detection methods using image techniques such as the Hough transform and tracking vectors. On the basis of collected seismic datasets, we attempted to detect either fault lines in 2D seismic sections or fault surfaces in seismic volumes. Fig. 1 illustrates the detection of fault lines in 2D seismic sections. We first divided seismic sections into two groups, one contains reference sections, and the other contain predicted sections. In reference sections, we applied the 2D Hough transform to detect line features, and after noisy feature removal, we connected the remaining features by involving seismic attributes. Fig. 2 shows the process of fault detection. To avoid the tweaking of parameters, in the predicted sections, we tracked the fault lines from two neighboring reference sections by involving tracking vectors. The bi-directional tracking process is illustrated in Fig. 3. Except for the detection of fault lines in 2D seismic sections, we also proposed to detect fault surfaces from the clouds of fault points using 3D Hough transform, as shown in Figs. 4 and 5.

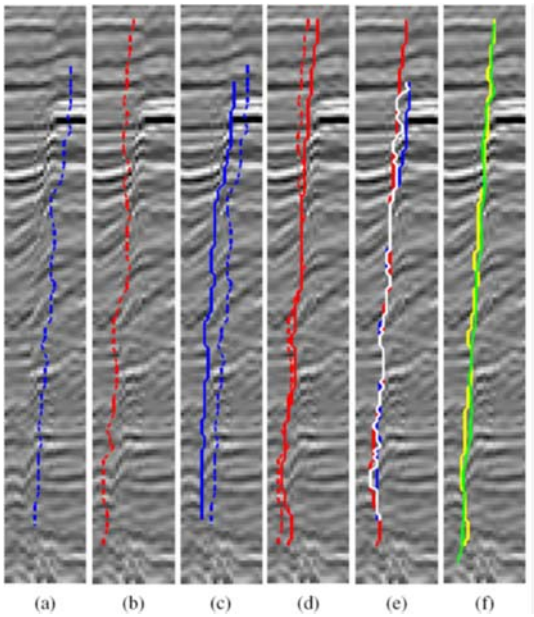


Figure 8. The process of fault tracking.

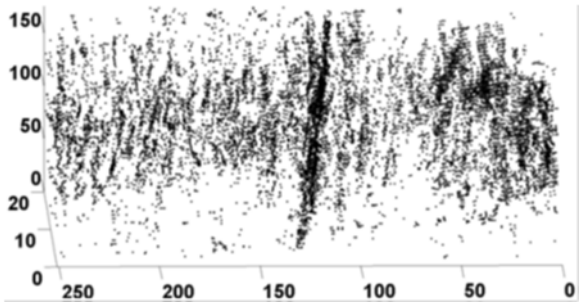


Figure 9. The clouds of likely fault points in the seismic volume.

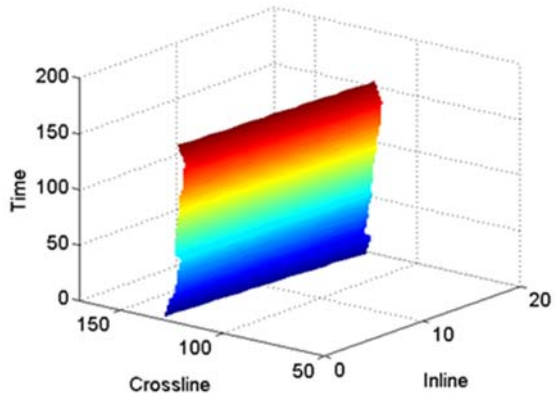


Figure 10. : The fault surface detected from the clouds of fault points.

Related Publications:

- Zhen Wang and Ghassan AlRegib, "Automatic fault surface detection using 3D Hough transform," to be presented at 2014 SEG Annual Meeting, Denver, Colorado, Oct. 26-31, 2014.
- Zhen Wang, Zhiling Long, Ghassan AlRegib, A. Asjad, and M. A. Deriche, "Automatic fault tracking across seismic volumes via tracking vectors," to be presented at IEEE International Conference on Image Processing (ICIP) , Paris, France, Oct. 27-30, 2014.
- Zhen Wang and Ghassan AlRegib, "Fault detection in seismic datasets using Hough transform," Proc. IEEE Intl. Conf. on Acoustics, Speech and Signal Processing (ICASSP), Florence, Italy, May 2014.

CeGP Awareness Workshop

Under the direction of His Excellency Dr. Sahel Abduljauwad, Vice Rector for Applied Research at KFUPM, the Center for energy and Geo-Processing (CeGP) in the Electrical Engineering Department at KFUPM conducted a workshop on 15th September 2014 to raise the awareness of KFUPM and Georgia Tech collaboration. This workshop had the motive to popularize the research center among faculty members at KFUPM, as well.

A Curvelet-Based Distance Measure for Seismic Images

Yazeed Alaudah and Prof. Ghassan AlRegib

Modern seismic surveys produce extremely big data. There are great challenges in terms of processing, classifying, and organizing such big data. Efficient and robust distance measures are required to enable the quantification of the difference between two datasets or images in a way that is meaningful. One application of these seismic distance measures is that they make it possible to retrieve datasets that contain similar seismic structures, leading to increased efficiency in storage, compression, and processing. It can also be particularly useful for clustering big seismic data, where typical distance measures such as the mean square error (MSE) do not describe the data very well.

We introduced a new curvelet-based distance measure for migrated seismic data. The measure exploits the highly directional content of seismic images. The curvelet transform is a directional multiscale decomposition. It provides an efficient way to represent images with high directional content. Our proposed measure calculates the Curvelet transform of the two images after normalization. For each wedge in the curvelet transform, the coeffecients are denoised using a threshold based on the content of that wedge. Then, the squared chord distance is calculated between the histograms of the curvelet coefficients. This is done over all curvelet scales and orientations.

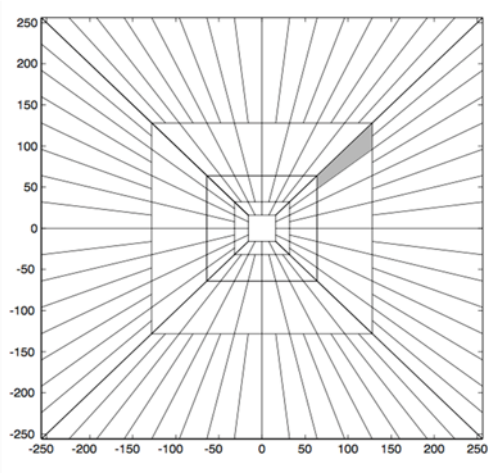


Figure 11. Multi-scale Curvelet tiling

The performance of the proposed distance measure was evaluated using a simple image retrieval test on a database of 54 images and 3 classes (18 images per class), and comparing its performance to well-known image distance or similarity measures. In the retrieval test consisting of 918 retrieval instances, the proposed method successfully retrieves all images. This was not achieved by other methods in the literature. Furthermore, in comparison to the state-of-the-art, the proposed method requires 79% less computation time. Retrieval performances was evaluated using basic criteria used in the literature for such tests as shown in table 2.

Metric	MAP	Retrieval Accuracy	CPU time (s)
MSE	0.6608	54.14 %	**0.0017**
SSIM	0.7049	58.93 %	0.0155
Adaptive curvelet	0.8192	75.27 %	1.9158
SeiSIM	0.9949	98.69 %	1.5814
Proposed	**1**	**100 %**	0.3384

Table 2. Retrieval performance results

Videoconference Tutorial Series at KFUPM

Dr. Al-Shuhail conducting the tutorial to KFUPM audience (left) and Georgia Tech audience (right)

Center for energy and Geo-Processing (CeGP) at KFUPM have conducted live seminars and tutorials jointly with Georgia Tech to expose the interested audience to seismic signal acquisition and the technologies for processing. The 3rd joint live tutorial on 16th October 2014 was presented by Dr. Abdullatif Al-Shuhail, Earth Sciences Department at KFUPM, where he introduced the seismic exploration and focused on the data acquiring. Dr. Al-Shuhail defined the crucial type of seismic wave for data acquisition, the geophones and the rationale behind them in different environment with extending the acquisition form 2-D to 3-D and the recently used 4-D, with time as the fourth dimension-time lapse acquisition. Mr. Azizur Rahman Khan, Geophysical Consultant, Geophysical Data Acquisition (GDAD) in Saudi Aramco, conducted the 4th joint live tutorial on 10th November 2014 where he shed more light on the data acquisition in marine environment and the challenges in these environments. The talk linked as well the financial consideration as one of the motives for picking a method of acquisition over another. Mr. Khan described the design of seismic sensors and seismic data recording systems for the offshore environment as well as the challenging problems like positioning and navigation during the process. Dr. Ibrahim Hoteit, Earth Science and Engineering, King Abdullah University of Science and Technology (KAUST), will deliver the 6th joint live seminar on 8th December 2014 titled, Enhanced Reservoir Characterization and Uncertainty Quantification: A Multi-Data History Matching Approach.

The 3rd CeGP Workshop at King Fahd University of Petroleum and Minerals in Dhahran

The Center for energy and Geo-Processing (CeGP) at King Fahd University of Petroleum and Minerals (KFUPM) was privileged to host the 3rd CeGP workshop on 19-21 October 2014 in Dhahran, Saudi Arabia. His Excellency Dr. Sahel Abduljauwad, Vice Rector for Applied Research at KFUPM, inaugurated the CeGP workshop, with the theme Seismic Data Acquisition, and gave the opening remarks. The university was delighted to have the visitors from Georgia Tech (GT), Dr. Ghassan AlRegib, CeGP Director at GT, Dr. Faramarz Fekri, Dr. Laurence Jacobs, and Dr. Douglas Williams. The workshop was enriched by prominent speakers from King Abdullah University of Science and Technology (KAUST), University of Campinas, Saudi Aramco, Schlumberger, and National Instruments.

On the first day of the workshop, Dr. Ali Al-Shaikhi, CeGP Director at KFUPM and Chairman of Electrical Engineering Department, gave an introduction to the Center at KFUPM, and an overview of the various activities of CeGP at KFUPM. He also provided a summary of current research and educational projects, and plans for potential projects under the collaboration with GT. Dr. Al-Regib, presented an overview and updates on CeGP activities at Georgia Tech. He discussed the personnel, computing, and data resources at the Center and ongoing and planned projects in both tracks, i.e. research and education.

Dr. Gerard Schuster, Professor in Earth Science & Engineering, at KAUST, delivered his talk on Futuristic Seismology Today: Boomless Seismology. He explained how the signals include body waves and surface wave reflections can be used to image the smooth velocity structure of the earth, which is

a revolution for 21st century seismology. Dr. Schuster showed that ambient noise seismology can be used to image the sharply varying structures in the earth based on recent results from KAUST and University of Utah revealing hidden fault structures below Los Angeles and North America.

Dr. Renato Lopes, Assistant Professor at University of Campinas, Brazil, delivered a talk titled Travel Times for Data Acquisition Topography. In his talk, Dr. Renato reviewed some effects of the topography on seismic processing algorithms, as well as some classical solutions, such as static corrections. He also discussed the preliminary results for an ongoing research on a travel time equation that provides an interesting solution to the topography problem by directly including the elevation information in the travel time.

Dr. Ibrahim Al-Hokail, Exploration Operations Department, Saudi Aramco, delivered a talk titled Simulation of Single-Sensor Seismic Acquisition with Conventional Seismic Recording Systems. Dr. Al-Hokail gave an overview of conventional seismic recording systems, high-productivity techniques, and their limitations. He showed that high-channel-high-productivity conventional seismic recording systems can be used to satisfy most modern seismic acquisition requirements for comparable data quality, faster turn-around time and lower cost.

Mr. Tim Perrin, a Chief Geophysicist in Schlumberger in Saudi Arabia, delivered a talk titled Seismic Acquisition. So Just What Data Is on Your Field Tape?. He talked about the exponential rise in the number of traces recorded per shot, number of shots per day and the petabytes of data per year. Mr. Perrin, in his talk, looked briefly at some of the fundamental choices when recording seismic data and the implications for high production recording in particular. After that he showed the importance of managing time and spatial distribution of shots to avoid cross record interference.

Mr. Andre Hajjar, Business Development Manager in National Instruments, delivered his talk on the Need for Real Time Seismic Data Acquisition. Mr. Hajjar addressed the issue of automated seismic measurements and system analysis, and the challenges in obtaining reliable measurements in extreme environments. He presented a case study of "Burj Khalifa" in Dubai.

On the second day of the 3rd CeGP workshop, there was a discussion of the ongoing and potential research and educational projects. First session started with updates on joint research project of Dr. Abdullatif Al-Shuhail and Dr. SanLinn Kaka, Earth Sciences Department at KFUPM, Dr. AlRegib on Semi-Automatic Interferometry-Based Method to Improve the SNR of Micro-seismic Events were shared. Dr. Mohammed Deriche, Electrical Engineering Department, KFUPM, and Dr. AlRegib then presented their research project progress on Interactive Computer-Aided Seismic Interpretation. Dr. Faramarz Fekri, Professor at Georgia Tech,

delivered a talk on data gathering and in-field processing for seismic data acquisition. In the second session, the ongoing and potential educational projects were presented. Dr. Azzedine Zerguine, Electrical Engineering Department at KFUPM, and Dr. AlRegib presented an educational project on Senior -Level DSP Lab Course. Dr. Deriche and Dr. AlRegib discussed their proposal of an Integrated Design Program for EE Students.

On the last day of the workshop, the morning session was dedicated for two Breakout Sessions discussing the ongoing research and educational projects progress and brainstorming for future projects. The Center at KFUPM arranged for the visitors from Georgia Tech, invited speakers, faculty members and graduate students at KFUPM a visit to the Geophysical Data Processing Division, EXPEC Building, in Saudi Aramco. The participants had a presentation on seismic data processing for non-geophysicists, and a demonstration of a typical processing flow at Saudi Aramco.

Pilot Program for Active Cooperative Learning (ACL)

The widespread and growing adoption of active and cooperative learning (ACL) techniques is changing education. Rather than simply attending lectures and taking notes, students spend much of the class period interacting with each other and with the instructor to solve problems relevant to the course's subject matter. Conceptually, ACL is particularly well suited for engineering courses, which typically already have strong connections to applications. By allowing the problems to drive the learning process, students tend to be more engaged in their education and more quickly see the relevance of the engineering tools and techniques they are learning. This project intends to design the introductory course in a way that introduces the various disciplines of electrical engineering, emphasizes the role of engineering in society, introduces engineering skills that are important to industry, stresses engineering design concepts, and allows students to practice teamwork at an early stage. A full set of course materials will be created along with training materials aimed at faculty who will be teaching the course. This project started in September 2014.

CeGP booth at IEEE GlobalSIP 2014

CeGP had a booth at the IEEE GlobalSIP Conference in Atlanta between December 3-5, 2014. The booth highlighted projects within CeGP as well as KFUPM's programs and activities. Dr. Ali Al-Shaikhi and Dr. Mohamed Deriche represented KFUPM at the booth besides the Georgia Tech side of CeGP personnel.

12 KFUPM undergraduate students spend Fall'14 at Georgia Tech

As part of the "Study Abroad" program at KFUPM that started in 2012, twelve junior-level EE students spent one semester at Georgia Tech.

Center for Energy & Geo Processing CeGP

Georgia Tech President Visits KFUPM for IAB Meeting

In September 2014 and February 2015, Georgia Tech president, Bud Peterson, visited KFUPM for the International Advisory Board (IAB) meeting.

Dr. Ali Al-Shaikhi Visits CeGP at Georgia Tech

In May 2014, Dr. Ali Al-Shaikhi visited Georgia Tech, where researchers and graduate students at CeGP at Georgia Tech presented to him their research work at the CeGP lab.

Center for Energy & Geo Processing
CeGP

Center for Energy and Geo Processing (CeGP) at KFUPM and Georgia Tech

Department of Electrical Engineering
King Fahd University of Petroleum and Minerals
Dhahran, Saudi Arabia

School of Electrical and Computer Engineering
Georgia Institute of Technology
75 5th St. NW, Atlanta, GA 30308, USA

http://cegp.ece.gatech.edu