It is our immense pleasure to put between your hands the third annual issue of the CeGP newsletter that summarizes the progress and the work being conducted by King Fahd University of Petroleum and Minerals (KFUPM) and Georgia Tech through the Center for Energy and Geo Processing (CeGP), which focuses mainly on signal processing for energy applications including seismic signals. You can note that the content is technically getting more diverse and richer but at the same time you can feel the strong partnership between the two institutes and the unity being developed through this collaboration.

This newsletter will give you closer insight on the latest developments by the center on this field through the joint research projects. Also, through the joint educational projects, you will read about latest developments in education trends. Moreover, the new projects are taking off much quicker than we had in the past. This is an indication of the fact that we are getting into a steady state in the collaboration where we spent the first a few years learning about each other as individuals and as faculty bodies. Now, we can say that we have an ecosystem where a faculty member from either institution can reach out effectively and efficiently across the thousands of miles separating the two institutions geographically, exchange ideas, and brainstorm new concepts.

We look forward to the next a few years where we can showcase the excellent outcomes of this collaboration where more fruits will be reaped. This newsletter gives you a few examples of the many outcomes and if you want to learn more about the work we do at CeGP and talk in person with our passionate faculty members, graduate students, and postdocs, you can join us at the 6th CeGP Workshop taking place in Atlanta on the beautiful Georgia Tech campus between March 20-21, 2017. Visit the link on the left hand side for more information about the workshop.
Table of Contents

Research:
Multiscale Fusion for Improved Instantaneous Attribute Analysis .............................................. 3
Weakly Supervised Seismic Structure Labeling via Orthogonal Non-Negative Matrix Factorization ............................ 4
Comparative Study of Texture Attributes for Characterizing Subsurface Structures in Migrated Seismic Volumes ................................................................. 5
Improved Fault Interpretation from Seismic Geometry Analysis ...................................................... 7
Learning to Detect Salt Domes using Visual Codebooks ................................................................ 8
Fault Detection in Seismic Surveys using Visual Saliency ............................................................... 9
Saliency Detection for Seismic Applications using Multi-Dimensional Spectral Projections and Directional Comparisons ......................................................... 10
A Novel Approach for the Automated Detection of Listric Faults within Migrated Seismic Volumes ............ 11
Interpreter-Assisted Interactive Delineation of Salt Domes Using Phase Congruency and Gradient of Texture Attributes ................................................................. 12
Tracking Salt Dome over 3D Seismic Volumes using a Hidden Markov Model ............................. 13
A Texture-based Interpretation of Salt Domes .............................................................................. 14
Learning Dictionary for Efficient Signal Compression ................................................................ 15
Seismic Data Compression Using Online Double-sparse Dictionary Learning Schemes .............................. 16
Identification of Mixture of Sources from Non-Stationary Data Streams and its Applications in Data Compression ..................................................................................... 17
Seismic Signal Compression Through Time Shift and Entropy Constrained Dictionary Learning ................... 18
Infinite Dimensional Quantization — Potential Applications in Seismic ............................................. 19
Near Optimal Representative Subset Selection from Short Sequences Generated by a Stationary Source 21
Memory-Assisted Seismic Signal Compression Based on Dictionary Learning and Sparse Coding .................. 22
Automatic Microseismic Event Detection Using Constant False Alarm Rate Processing in Time-Frequency Domain ................................................................. 23
Multichannel Sparse Blind Deconvolution of Seismic Data via Spectral Projected-gradient .................... 24
Iterative Interferometry-based Method for Picking Microseismic Events ........................................ 26
Multichannel Event Clustering for Arrival Times Picked on Microseismic Surface Monitoring Array Based on RANSAC Scheme ......................................................... 27
Automated SVD Filtering of Time-frequency Distribution for Enhancing the SNR of Microseismic/microquake Events ........................................................................ 28

Education:
Smart Solar Home Project ............................................................................................................ 29
GREU : Global Research Experience for Undergraduates .................................................................. 30

News and Events
The 5th CeGP workshop in Dhahran .................................................................................................. 31
Georgia Tech President Participates in IAB meeting at KFUPM ...................................................... 35
Dr. Gary May visits KFUPM .......................................................................................................... 35
CeGP Field Trip to S-82 Seismic Crew in Al-Jafurah Area ............................................................... 36
Research Experience for EE Undergraduates: Advisors Workshop .............................................. 38
EE Design Expo at KFUPM .......................................................................................................... 39
Study Abroad Program students at Georgia Tech in Fall 2016 ................................................ 41
CeGP team at the 78th EAGE Conference and Exhibition .............................................................. 43
Lingchen Zhu Earned his PhD Degree from Georgia Tech ............................................................. 43
Asjad Amin Earned his PhD Degree from KFUPM ...................................................................... 44
Zhen Wang Passed The PhD Proposal .......................................................................................... 44

List of CeGP Scholarly Accomplishments ...................................................................................... 45
Workshop Organizing Committee .................................................................................................. 51
Since first introduced, the concept of complex seismic trace has been widely used as one of the most fundamental tools for 2D/3D seismic data interpretation. From the defined complex trace, a suite of mathematics quantities (or seismic attributes) can then be extracted for assisting seismic data analysis, such as instantaneous amplitude and instantaneous phase. In practice, however, these attributes and their derivatives tend to be highly sensitive to noise. Traditionally, such limitation is overcome using a larger processing window and/or post-processing techniques such as filtering. Although such approaches help suppress the noise as well as the associated artifacts, the resolution of the generated attribute is often badly affected with the small-scale seismic features undesirably ignored.

In this work, we propose a new workflow for multiscale seismic attribute analysis to enhance the resolution of the instantaneous attributes, consisting of two components. First, we use the Gaussian pyramid to represent a seismic section at different scales, each of which exploits seismic features from different resolutions. Second, instantaneous attributes are generated from all scales of the pyramid and then fused together through various operators, such as mean and median. The results of the proposed method are superior to the traditional methods in enhancing the quality of the attributes and suppressing noise.

Figure 1. The proposed workflow using a 4-level Gaussian pyramid with median fusion.

Figure 2. Cosine of the phase attribute computed using (a) the conventional method and (b) the proposed multiscale method.
Weakly Supervised Seismic Structure Labeling via Orthogonal Non-Negative Matrix Factorization

Yazeed Alaudah, Haibin Di, Ghassan AlRegib

With the growing demand of high-resolution subsurface characterization from 3D seismic surveying, the size of 3D seismic datasets has been dramatically increasing, and correspondingly, the process of interpreting a seismic dataset is becoming more time consuming and labor intensive.

Additionally, in wide-ranging fields, supervised machine learning has proved to be the most successful machine learning paradigm by far. Supervised machine learning algorithms require labels to perform training. However obtaining labels for large volumes of seismic data is a very demanding task. Furthermore, while the amount of data is continuously growing, the ability of human experts to label data remains limited. Thus, the time and effort saved by techniques based on supervised machine learning can be over-shadowed by the time required to obtain accurate labels from the seismic data.

Weakly-supervised machine learning is the case when the learning is done with missing or few labels or with partially labeled data. In this work, we propose a weakly-supervised framework for labeling seismic structures using Non-Negative Matrix Factorization (NMF) with additional sparsity and orthogonality constraints. Given rough (possibly inaccurate) image-level labels, we iteratively solve an optimization problem that learns a parts-based representation of the data, as well as the corresponding coefficients of this representation. We then use these coefficients and representations to map the image-level labels into pixels. We test this approach on weakly-labeled fault and salt dome images, and show that this method is able to accurately locate the main features of the salt dome boundary as well as the location of the faults, using only a single label per image (see Figures 1-2).

In this work, we show that weakly-supervised learning requires a much smaller number of labels. Furthermore, we show that "rough" image-level labels of specific seismic structures can be mapped into finer more localized locations within the seismic volume. Results obtained by labeling fault regions and salt dome boundaries prove to be very promising.

Reference:
Comparative Study of Texture Attributes for Characterizing Subsurface Structures in Migrated Seismic Volumes

Zhiling Long, Yazeed Alaudah, Muhammad Ali Qureshi, Yuting Hu, Zhen Wang, Motaz Alfarraj, Ghassan AlRegib, Asjad Amin, Mohamed Deriche, and Suhail Al-Dharrab

Extraction of attributes for texture image analysis has been studied extensively in the image processing literature. Given that migrated seismic volumes are textural in nature, such texture attributes should also be helpful for seismic interpretation applications. In particular, we believe texture attributes are suitable for serving as generic descriptors that characterize migrated data in terms of the various structures contained therein. Such descriptors help identify the structures all at once, rather than only a specific structure, thus providing a comprehensive description of the subsurface environment.

Therefore, in this paper, we conduct a comparative study examining texture attributes within the context of structure-based seismic data characterization. To fit for the application, we choose to study typical space-domain attributes that belong to the group of local descriptors. These include LBP [1], CLBP [2], M-CLBP [2],

Figure 1. Labeling results for seismic sections at crossline (left to right) 61, 211, 231, and 281, respectively, in the North Sea F3 block. There are four labels (or classes) defined: Chaotic (blue), Faults (green), Salt Dome (red), and Other (grey). "ORIG." (first row) and "MAN." (second row) refer to the original and manually labeled sections, respectively.
ELBP [3], CLDP [4], and LRI [5]. These attributes present local patterns of variations using binary strings, accomplishing robust and computationally efficient texture representations. In addition, our study also includes two traditional seismic attributes, i.e., the classic GLCM [6] and the semblance [7], both of which have been used for texture-related applications (e.g., salt dome detection).

To evaluate the performance, we adopt a newly-developed framework for interpretation, i.e., seismic volume labeling [8]. With labeling, a data volume is automatically segmented into different structures, each assigned with its corresponding label. The segmentation and label assignment are based on the extracted texture attributes. Thus, the labeling performance reflects the characterizing capability of the attributes. Through labeling, an initial picture is generated with spots of possible interest highlighted to expedite the interpretation process.

Fig. 1 presents our labeling results for example seismic sections in the Netherlands North Sea F3 block dataset [9]. We observe that the main structures are generally highlighted very well with most attributes. The performance of each attribute is relatively consistent across all four seismic sections. Considering the very limited manually labeled exemplars that were used, and the challenging nature of the task, the overall labeling performance with most texture attributes is very promising. Therefore, we conclude that it is feasible to use texture attributes as generic attributes to characterize migrated seismic data. Through the study, we also identify the advantages and disadvantages associated with each attribute.

References:
Improved Fault Interpretation from Seismic Geometry Analysis

Haibin Di and Ghassan AlRegib

Computer-aided fault imaging and interpretation is a fundamental tool for subsurface structure characterization and modeling, and the existing methods are primarily based on seismic discontinuity analysis (e.g., coherence and semblance) that evaluates the lateral variation of waveform and/or amplitude. However, such attributes have a limited resolution on subtle faults without apparent displacements in seismic images, which correspondingly decreases the accuracy of fault detection and interpretation.

We developed a new method for volumetric fault imaging based on seismic geometry analysis consisting of two components. First, the curvature and flexure analysis is performed for fault detection from the perspective of evaluating the changes in the geometry of seismic reflectors, which helps highlight both the major and subtle faults. Then an isolation operator is performed for differentiating the faults from the non-fault features observed in the curvature/flexure volumes. Figure 2 displays the generated fault images, in which the enhanced resolution allows us to identify more lineaments as potential faults.

The added value of the proposed method is verified through applications to two 3D seismic volumes from the offshore New Zealand and the Netherlands North Sea. The results not only clearly depict the faulting complexities with varying sizes and orientations (Figure 3), but also indicates its great potential for improving the semiautomatic/automatic fault extraction from 3D seismic data (Figure 4).

References:
Seismic data, obtained through the reflection of seismic waves from the earth’s subsurface, contains important geological information which is used to identify a number of characteristics of earth layers such as salt domes, faults, horizons, etc. Salt domes are excellent indicators of the presence of important reservoirs such as oil and gas etc.

In this work, we developed a salt dome detection approach based on the concept of visual codebooks. Although codebook-based classification methods have been effectively used in numerous image processing applications, segmentation methods based on such models have not been discussed for salt dome detection. Our work starts by creating a seismic codebook using an optimal set of features computed from the training patches extracted from salt boundary and non-salt boundary regions. The size of the codebook is optimized by applying K-means clustering over the training set. The final codebook only contains the encoded codewords and therefore has a much smaller size than the original dataset. The proposed approach is displayed in Figure 1.

To validate our algorithm, we used real data from the Netherlands F3 block. During the feature extraction stage, we use a combination of GLCM and Gabor filter based attributes to overcome the limitations of amplitude based techniques.

We show in Figure 2 some typical results for salt boundary patches. We see here that most of the boundary patches are correctly classified. Figure 2 shows the ground truth (green) and the salt boundary (red) detected using the proposed codebook-based approach. A number of examples are provided in Figure 3 using the proposed method. Table-1 compares the performance of the proposed algorithm with other state-of-the-art salt dome detection methods. The proposed codebook based salt dome detection method gives an average accuracy of 91% which is 10% higher than the edge-based method, 4% higher than the texture-based method, and 1.4% higher than the dictionary-based method.

<table>
<thead>
<tr>
<th>Detection Method</th>
<th>Accuracy</th>
<th>Precision</th>
<th>Recall</th>
<th>F-measure</th>
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<tr>
<td>Proposed</td>
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<td>98.94</td>
<td>98.63</td>
<td>98.78</td>
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<td>Edge based</td>
<td>81.23</td>
<td>97.67</td>
<td>94.62</td>
<td>96.12</td>
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<td>Texture based</td>
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<td>98.19</td>
<td>95.60</td>
</tr>
<tr>
<td>Dictionary-based</td>
<td>89.74</td>
<td>98.12</td>
<td>97.28</td>
<td>97.60</td>
</tr>
</tbody>
</table>

Table 1. Accuracy, Precision, Recall & F-Measure.
Fault Detection in Seismic Surveys Using Visual Saliency

Abdulmajid Lawal, Suhail Al-Dharrab, Mohamed Deriche, Amir Shafiq, and Ghassan AlRegib

Seismic data acquisition is typically associated with large amounts of data collected from surveys which can easily add up to 3-4 terabytes per day. Such huge amount of data has encouraged the oil and gas industry to invest in discovering alternative solutions to traditional manual interpretation of such surveys. Seismic interpretation is associated with the efficient extraction and identification of special geological structures such as salt domes, faults, and horizons, which can help as indicators for the possible presence of oil and gas reservoirs. In an attempt to tackle this problem, we introduced a saliency based approach that mimics the way humans analyze visually seismic surveys, both in 2D and 3D. The proposed saliency based fault detection approach is capable of highlighting the most important parts of the image, hence, reducing the time and energy an interpreter would spend in analyzing a given seismic image.

In our work, we developed a new bottom-up saliency based approach using different seismic attributes such as coherence, curvature, dip, and gradient. The saliency maps of the aforementioned attributes are computed using the estimated covariance matrix. These are then combined to form a consolidated saliency map that highlights seismic fault regions. The covariance matrix is used to characterize the seismic patches and capture local structures. By thresholding the variance maps and optimizing the binary points for curve fitting, the proposed workflow yields excellent results for faults labelling.

Our extensive experimental results show that the resultant saliency map highlights the fault regions accurately. Figure 1a shows the original seismic inline 256 (from the F3 Block), 1b shows the saliency maps of coherence, curvature, dip and gradient respectively, figure 1c (top) shows the combined saliency map image while 1c (bottom) displays the final overlaid image combining the original image with the saliency map. The final image can help the interpreter in focusing on regions of interest only. Figure 1d shows the detected faults (labelled in green) with the ground truth manually labelled fault (in red). Subjectively, we notice here how the output of the proposed workflow yields fault labels very close to the ground truth, indicating the robustness of the proposed workflow.

References:

Figure 1. (a) Seismic inline #256, (b) Gradient, Curvature, dip, variance-based attributes, (c) Compined single saliency map and the overlaid map on the seismic image (d) Labeled fault using proposed workflow (green) and groundturth (red)
Saliency Detection for Seismic Applications Using Multi-Dimensional Spectral Projections and Directional Comparisons

Muhammad Amir Shafiq, Zhiling Long, Tariq Alshawi, and Ghassan AlRegib

In this work, we propose a novel approach for saliency detection for seismic applications using 3D-FFT local spectra and multi-dimensional plane projections. We develop a projection scheme by dividing a 3D-FFT local spectrum of a data volume into three distinct components, each depicting changes along a different dimension of the data. The saliency detection results obtained using each projected component are then combined to yield a saliency map. To accommodate the directional nature of seismic data, in this work, we modify the center-surround model, proven to be biologically plausible for visual attention, to incorporate directional comparisons around each voxel in a 3D volume. Experimental results on real seismic dataset from the F3 block in Netherlands offshore in the North Sea prove that the proposed algorithm is effective, efficient, and scalable. Furthermore, a subjective comparison of the results shows that it outperforms the state-of-the-art methods for saliency detection.

Reference:


Figure 1: The output of the various saliency detection algorithms on a typical seismic inline section. Red arrows and ellipses highlight the areas, which demonstrate the excellence of the proposed saliency detection algorithm.
A Novel Approach for the Automated Detection of Listric Faults within Migrated Seismic Volumes

Muhammad Amir Shafiq, Haibin Di and Ghassan AlRegib

In this work, we propose a texture-based interpretation workflow for the automated delineation of major listric faults in a 3D migrated seismic volume. In the first step, we compute an attribute map using a seismic attribute, three-dimensional gradient of textures (3D-GoT), which describes the texture dissimilarity in a three dimensional space. The 3D-GoT yields an attribute map by computing the textural dissimilarity between neighboring cubes around each voxel in seismic volume across time or depth, crossline, and inline directions. In the second step, we calculate an adaptive global threshold and apply it to the 3D-GoT map to obtain a binary map, which highlights the probable boundary regions of the listric faults. Finally, we apply post-processing to the obtained binary maps, which include morphological opening and curve fitting to yield a delineated listric fault within the migrated seismic volume. The experimental results on a real seismic dataset from the Stratton field in the Texas Gulf coast show the effectiveness of the proposed workflow.

References:


Salt domes are an important diapir shaped geophysical structures in the Earth’s subsurface that are impermeable and contain hints about petroleum and gas reservoirs. Therefore, determining the accurate location of the salt domes within migrated seismic volumes in one of the key steps in the exploration projects. Subsurface object detection (e.g., faults, gas chimneys and salt domes) is a fundamental tool for reservoir exploration and production from three-dimensional (3D) seismic surveying, and a set of methods have been developed based on edge detection and/or texture analysis of seismic signals. In this work, we first present two new attributes to assist the delineation of salt domes from a 3D seismic volume, the phase congruency (PC) and the gradient of texture (GoT), both of which help quantify the variations of reflection intensity and seismic texture in the presence of salt domes. In particular, the PC attribute evaluates the congruency of phase in Fourier components and is capable of detecting the subtle discontinuities with varying contrast in seismic reflection intensity, and the GoT attribute measures the perceptual dissimilarity of seismic texture and is capable of detecting the subtle structures in the absence of strong seismic reflectors. Then, based on the generated PC and GoT maps, we further propose an interpreter-assisted workflow for salt dome delineation and demonstrate its applications to the SEAM dataset featured with salt domes as well as complex subsalt structures. The results show not only the capability of the proposed method in delineating the salt domes in an effective and accurate manner, but also its potential for computer-aided extraction of other geologic features associated with weak reflection intensity, varying texture, illumination, and contrast from a seismic volume. Compared to the GoT-based workflow, the PC-based one is computationally inexpensive and is expected to serve as a handy tool in the interpreter’s toolbox for geological structure delineation from 3D seismic datasets.

Figure 1. The block diagram of the proposed workflow.

Figure 2. The results of salt dome delineation using (a) phase congruency (PC) and (b) gradient of texture (GoT).
Tracking Salt Dome over 3D Seismic Volumes Using a Hidden Markov Model

Asjad Amin, Mohamed Deriche, and Bo Liu

Salt domes are excellent indicators of the presence of important reservoirs such as oil and gas etc. Salt bodies are mushroom shaped geologic structures that have the capabilities to trap oil and gas around them. Unfortunately, salt dome detection is a difficult and a time consuming task especially in the case of 3D seismic volumes. The accuracy of detection is also linked with the expertise of human interpreter.

Here, we developed a novel salt dome detection method using a Hidden Markov Model (HMM). HMMs have traditionally been used as powerful models for tracking changes in speech data. In this paper, we borrow this concept of tracking with that of Higher Order Singular Value Decomposition (HOSVD) for extraction and tracking robust features. The optimal parameters of the HMM are obtained using the backward-forward algorithm (EM algorithm). Viterbi algorithm is used to compute the hidden states which are then used to delineate the salt boundaries.

We tested the proposed algorithm on the Netherlands offshore F3 block. Our algorithm, using a small feature set, produces excellent results as compared to the existing edge-based, texture-based, and the hybrid edge-texture based methods. Note that a single HMM is needed and the classical classification stage is avoided making the overall approach computationally very efficient. The overall structure of the proposed algorithm and the feature extraction phase are shown in Figures 1 and 2.

We show in Figure 3 the salt boundary detected for Inline # 375 using the proposed HMM-based algorithm with HOSVD based features. The proposed method is able delineate the salt boundary with excellent accuracy. The proposed method gives an average accuracy of 98.70% which is 3% higher than the texture-based method, 2% higher than the edge-based method, and 1.2% better than the hybrid edge-texture method.

The novelty of the proposed approach resides in using a single HMM model instead of an HMM for each class. Contrary to existing work, we use here the concept of states to describe whether certain patch is a salt or a background patch.

Figure 1. The proposed algorithm.

Figure 2. The Feature extraction stage using tensors

Figure 3. Salt boundary detected for Inline # 375, Ground Truth = Green, Detected boundary = Red.
Salt domes are an important diapir shaped geophysical structures in the Earth’s subsurface that are impermeable and contain hints about petroleum and gas reservoirs. Therefore, determining the accurate location of the salt domes within migrated seismic volumes in one of the key steps in the exploration projects.

In this work, we propose and demonstrate the robustness of a three dimensional texture-based method, Gradient of Texture (3D-GoT), for salt dome delineation in the presence of various types of random and non-coherent noise. The noise robustness of GoT is inherent from the perceptual dissimilarity measure function that evaluates the dissimilarity between neighboring cubes in GoT along inline, crossline and time directions. The noise causes a shift in dissimilarity and hence the GoT map which is countered by the adaptive global threshold in the GoT post-processing. The experimental results of the synthetically induced noise on the real dataset from the North Sea, F3 block show the effectiveness of 3D-GoT to various types of noise. The original seismic section inline #372 and the results of 3D-GoT with different noise types are shown in Figure 1. The output of 3D-GoT is labelled in red color, whereas the green color depicts the reference manually labelled by a Geophysicist. Subjectively, it can be observed that the boundaries detected by 3D-GoT in all seismic sections contaminated by noise are very close to ground truth. The majority of edge-based and texture-based algorithms fail to yield any results in current experimental setup, whereas GoT successfully delineates the salt domes with a minimal degradation in its performance.

References:

Figure 1: Experimental results of 3D-GoT on inline #372. Green: Ground Truth, Red: 3D-GoT
(a) Original seismic section
(b) Gaussian(0, 0.05) noise
(c) Poisson noise
(d) Speckle noise
(e) Salt and pepper noise
(f) Combination of random noises
Learning Dictionary for Efficient Signal Compression
Afshin Abdi, Ali Payani, and Faramarz Fekri

As modern sensing applications generate excessive amount of data, it is required to have a large bandwidth for transmission and a large repository for storage. As an example, a typical seismic survey may generate tens of terabytes of data. Hence, compression at the sensor before transmission become an essential part in many data acquisition applications, especially in wireless systems.

Numerous algorithms have been developed for efficient signal compression. A large class of such algorithms is based on transforming data into a new domain, that represents data more efficiently, in a way that discarding the ‘least important’ information in the transform domain has an insignificant effect on the quality of the data. Examples of such transforms include discrete cosine transform (DCT) and wavelets which have been successfully used for image compression in JPEG and JPEG2000 standards. Since, the transform is fixed and not adapted to a specific desired class of signals, the resulting compression may not perform very well for the intended class of signals.

In recent years, many algorithms have been proposed for designing signal-dependent transforms or (over-complete) dictionaries, especially for the sparse representation [3,4]. We suggested a novel approach to design the dictionaries that are adapted to the available data and result in good compression performance, especially for the class of seismic signals. Our approach is different in the sense that the main objective is designing a dictionary and devising an algorithm to find a representation of the signal in the transform domain such that the required bit-rate for transmission or storage of the data becomes significantly less than the original data [1]. This is a departure from conventional dictionary learning methods, whose objective is to design dictionaries for sparse signal representation or feature extraction, instead of directly optimizing for compression.

We verified the performance of the proposed algorithm on real seismic traces, available at [2] and compared it with the existing methods. A sample result is shown in Figure 1. The experimental results showed that at the same quality (or signal to noise ratio), the proposed method requires much less bits to represent each sample.

Figure 1. Comparison of Rate-Distortion curves for different algorithms

References:
Seismic data (traces) usually demonstrate high correlation. We propose a scheme based on online dictionary learning, which explores the resemblance among local seismic traces to facilitate compression for communication. In order to alleviate the transmission overhead caused by the slow convergence of online dictionary scheme, sparse constraints and a sliding window mechanism are applied to the incremental components of the dictionaries, which significantly improve the performance of online dictionary learning scheme in the sense of communication cost.

To reconstruct at the decoder, we require the updated dictionary for each encoded window. On the encoder, the kth data window is sparsely represented using dictionary , i.e. . We adopt the double sparsity method for the increment of dictionaries , where and are specific generic transforms. In each iteration, an alternating sparse constrained optimization is applied to update and . As such, only the sparse coefficients and are transmitted to recover on the decoder and the burden of dictionary transmission is mitigated. We compared the performance of the proposed sparse increment online dictionary learning (SIODL) with the K-SVD method and conventional online dictionary learning. The data we process are segments whose length are 32. This sliding window mechanism is illustrated in Figure 1. The size of this sliding window is one of the adjustable parameters. In Figure 2 and 3, the SNR versus compression performance is given for different parameter values.

Figure 2. Efficiency of SIODL compared with

Figure 3. Effect of dictionary size in the proposed algorithm
Identification of Mixture of Sources from Non-Stationary Data Streams and its Applications in Data Compression

Afshin Abdi and Faramarz Fekri

Modeling data generation and source identification is a fundamental problem in various applications, ranging from pattern recognition to data compression. However, the main assumption in most identification algorithms is the stationarity of data stream, i.e., the statistics of the signal does not change over time. But in many applications, such as seismic data acquisition, this is not a valid assumption. For example, in a single seismic trace, different parts of the signal exhibit different properties.

Identification of the source model has been investigated by many authors when a long sequence from an ergodic stationary source is observed, and Minimum Description Length principle or Bayesian Information Criterion (BIC) have been successfully applied [3].

When multiple independent short sequences have been observed from a source or a mixture of different sources, in [1] we have showed that it is possible to identify the models of the sources with high probability and developed an algorithm for that purpose.

In this work, we extend the results in [1] to the more general case. We assume that every observed signal comprised of different parts, each part has a different statistical property, i.e., each part of the signal is generated by a different (virtual) source with different statistical properties. In our setup, neither change times nor the probabilistic models are known a priori.

We showed that under some assumptions, it is still possible to determine the sources’ models from the observed signals. Further, we developed an iterative application of the EM and BIC to estimate the models and parameters of the mixture and showed that it can recover true sources’ models when sufficient number of sequences are available [2].

To verify our algorithm, we applied it on an artificial database generated from a mixture of i.i.d. and Markov sources. After detecting the number of sources, their models and associated parameters, we used those statistics to efficiently compress data using memory [4] and compared the compression performance with some of the existing methods. An example of the results is given in Table 1. The compression redundancy is measured by how many extra bits is required for representing data compared to the ideal (entropy) of the signal. We showed that our proposed method is close to the entropy limit for data compression.

<table>
<thead>
<tr>
<th>Compression Algorithm</th>
<th>Redundancy (bits/1K samples)</th>
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<td>Proposed</td>
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<tr>
<td>PAQ8</td>
<td>19.2</td>
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<tr>
<td>Zip</td>
<td>277.7</td>
</tr>
</tbody>
</table>

Table 1. Performance of the proposed method versus PAQ8 and Zip algorithms.

References:


Seismic Signal Compression Through Time Shift and Entropy Constrained Dictionary Learning

Xin Tian, Entao Liu, Afshin Abdi, and Faramarz Fekri

A seismic survey which collects a huge amount of seismic data from the field, is a primary strategy utilized for the oil and gas exploration. A typical seismic survey may generate tens of Terabytes of seismic data on a daily basis. The data compression is highly desirable to reduce the costs of the storage and transmission, especially for wireless seismic signal acquisition. We studied the lossy compression techniques based on efficient sparse dictionary learning.

Seismic wave patterns with high resemblance are likely to be observed at sensors with the close proximity. Likewise, two waveforms associated with two adjacent source shots (i.e., at two different times) when recorded at the same sensor are likely to present significant similarities, although shifted in time. Therefore, using the time-shifted seismic data may squeeze more redundancy out of the data, which results in a sparser representation for a given dictionary. However, using all shifts of all dictionary atoms would not be suitable for compression applications as too many time shift parameters must be transmitted to the receiver (i.e., the decoder), reducing the compression performance. Therefore, in this work, time shift is applied to the input data such that a balance of the rate and distortion is achieved. In a dictionary-based compression, the coefficients are quantized and encoded by an entropy coding algorithm. Although, sparse coefficients is intuitively favorable for compression, they are not equivalent. As such, reducing the entropy of the quantized coefficients is more essential.

We incorporated these three major compression steps (i.e., sparse coding, quantization, and entropy coding) with a novel time-shift dictionary learning scheme. It implies that the encoded bits are generated with a learned dictionary and probability mass function, rather than the sparse constraint. Based on the above ideas, a seismic compression framework is established that might be divided into two steps: offline training and online testing. The dictionary and probability mass function for compression are learned from the training data. Then, the online testing step is sparse coding with the given dictionary and the probability mass function. The main contributions of this work includes a novel compression scheme for seismic signals that incorporates the following features: (1) the dictionary is learned with time shifts of inputs. (2) A flexible rate distortion control method is proposed by using entropy constrained dictionary learning. A balance between rate and distortion is controlled by a parameter.

Figure 1. Compression results of different methods

Reference:

Seismic images offer opportunities and challenges for compression. One thing that makes a seismic image easy to compress is the high amount of memory in the image because within traces, across traces and across shots. The challenging part is the high dynamic range and high levels of noise in raw seismic data from the geophones. Also, a statistical characterization of seismic images is lacking, in terms of good analytical models that can describe general seismic sources. This makes it difficult to design compression algorithms that require knowledge of the source distribution. One way out of this difficulty is to use universal compression algorithms, where a compression algorithm is designed to work optimally for a class of source rather than a specific source. However, universal compression algorithms work well only under the condition that the source alphabet is small compared to the sequence to be compressed [Ref]. Because of the high dynamic range of the traces in a 2D image and because source letters with high amplitude do occur with small but non-vanishing probabilities, universal compression leads to poor compression ratios (usually about 3-4), specially under lossless setting.

The primary ingredient in our proposed solution is the use of functional quantization. Functional quantization is the transposition of the finite dimensional vector quantization problem to the infinite dimensional case. It has recently been studied by researchers in financial mathematics to obtain a quantized approximation to, for example, the sample path followed by a stock value price. It also has application to numerics and stochastic calculus problems. The viewpoint taken is that of functional analysis, where the sample paths of a random process are mapped into functions, the new “code points”, of a certain function space. In summary, the main results that have been established thus far include the existence of an optimum quantizer in the mean square error sense, the asymptotic decay rates for the error and greedy and universal algorithms for the design of functional quantizers. To date and to the best of our knowledge there has been no effort to apply the functional quantization paradigm to data compression. There are a number of advantages to be gained from this approach, the primary being that the encoding complexity of the quantizer reduces from being exponential to polynomial in functional quantization. The cost is of course, loss of quality, as the fine structure of the signal is lost because for universal functional quantization, code points are obtained through averaging—an operation which smooths out the functional code points. However, for the proposes of classification, a term we introduce in what follows, functional quantization proves to be an effective technique.

The proposed methodology is summarized as follows:

1. Select integers N and . Select an initial collection of functions In our case this set will be randomly selected from a database of seismic waveform traces.
2. Select number of training realizations from the training dataset traces.
3. For gather together in the set all realizations of that are closer to than to any other, relative to the -norm. If the set is empty, do nothing; otherwise, compute the average of all realizations in and assign this average to . The new along with the unchanged (i.e. when is empty) form the new collection of functions.
4. If the new collection of functions meets the convergence criterion, terminate the algorithm; otherwise, return to Step 2 and repeat.

The problem with FQ applied to seismic traces is that it loses the fine structure of the waveform as can be seen below. This is so because FQ waveforms are obtained through averaging which smooths them out. The idea is to perform what is called a Classified Vector Quantization (CVQ) [3] coding on the waveform. The FQ codepoints are used as classes, within each class there is again a re-quantized. The final quantization step is a shape gain VQ using regular finite dimensional quantization. In this way we achieve superior performance through constrained VQ versus a full search VQ.

References:


Near Optimal Representative Subset Selection from Short Sequences Generated by a Stationary Source

Ali Payani, Afshin Abdi, and Faramarz Fekri

In recent years, there has been a huge increase in available seismic data, requiring lots of resources and bandwidth for processing and transmission of information.

In transmitting a large number of short sequences from data acquisition site to the remote data storage location, when the data generation model is unknown at the decoder (or both sides), the common approach for encoding and decoding is the universal compression algorithms such as LZ and CTW. However, universality of the compression incurs a large overhead penalty especially for the short sequences. To mitigate the compression redundancy, the viable approaches are:

- estimating the model from short sequences at the encoder and sending it to the decoder prior to encoding/transmitting the sequences.
- starting from a fixed model, both encoder/decoder update the model as more sequences are transmitted.
- selecting a few sequences that can best describe the model and transmitting those first.

In this task, we adopt the last approach and assume the data is generated by a probabilistic model described as a stationary tree information source and formulate the problem of selecting a representative subset of samples drawn from this source. We show the original formulation of the optimization problem based on KL divergence of the distribution estimated from the representative set and the distribution that is estimated from all the data points leads to a nonlinear binary optimization which is NP-Hard, and given the scale of the data, is not feasible to solve directly. Instead, we propose a quadratic approximation to the original problem. Further, we compare the results of the proposed algorithm with the greedy search method as well as random selection. Although the greedy search algorithm achieves near optimal solution, it is too slow. The experimental results depict that the proposed quadratic approximation method achieves nearly the same performance as the greedy search algorithm with much less complexity and it is far superior than the random selection method. Further, it was shown that this quadratic approximation method can be used iteratively to find a near optimum solution comparable to that of the greedy search. This is a viable approach especially in cases where the solution to the quadratic problem is not sparse enough. Figure 1 shows the performance of the proposed method in terms of the KL divergence measured between the distribution of the representative set and the real distribution of data compared to the near-optimal greedy search and the random selections.

![Figure 1](image)

**References:**

Memory-Assisted Seismic Signal Compression Based on Dictionary Learning and Sparse Coding

Xin Tian, Afshin Abdi, Entao Liu, and Faramarz Fekri

Seismic traces recorded in a single sensor from multiple shots demonstrate significant correlation. We propose a memory-assisted seismic signal compression method based on dictionary learning and sparse coding that would explore this correlation. Different from traditional offline methods, the dictionary used for compression is learned online, generated and updated by the statistical information extracted from the common memory between the sender (sensor) node and the receiver node. Experimental results demonstrate that our method outperforms other alternative techniques. Compared to the offline method (without memory), the average data rate gain will be more than 30%.

In previous compression methods based on dictionary learning, an offline step is always included to learn a dictionary from the training dataset, which is used for online data’s sparse coding. We call this method as offline dictionary learning and online testing (OffDLOnT). Therefore, the compression performance highly depends on the correlation of the training dataset and the new testing dataset. Finding a suitable online dataset for the training process is a difficult problem in real applications. Another choice is to use the online’s data for dictionary learning and sparse coding, then the learned dictionary is sent to the decoder. It is called as online dictionary learning and online Indolent. The weakness of OnDLOnT is the necessity of transmission for the online learned dictionary. It leads to additional cost of rate.

In this work, we utilize a memory-assisted technique in seismic data compression based on sparse dictionary learning. The adaptive learned dictionary used for target signals are generated based on statistical information of the spatially close and correlated signals in the common memory (from the previously transmitted seismic traces between the encoder and the decoder), which improves the compression performance. Moreover, with a common memory, an online dictionary could be updated at both the encoder and the decoder without the need to transmit a new dictionary. The diagram and performance comparison with several popular methods are schematically shown in Figure 1 and Figure 2, respectively.

Reference:
Detecting and monitoring microseismic events arising from hydraulic fracturing plays a key role in enhancing the oil production in reservoirs. Automatic and reliable detection of microseismic events is highly important for accurate real-time monitoring. This is also important in the off-line analysis of acquired microseismic data, as manual detection of the microseismic event from the huge volume of data can be very challenging. However, the poor signal-to-noise ratio (SNR) conditions of surface sensors, as well as time-varying noise levels, make microseismic event detection a challenging problem. The traditional microseismic detection approaches such as STA/LTA, utilize a user-defined threshold and these methods do not offer a way of measuring the expected performance with regard to false picks or any control over the probability of false positives (i.e., the false alarm rate) of the detector. The dependence between noise level and false alarm rate negatively affects the reliability of the detector. A detector that can maintain its false positive rate to a specified level offers more confidence for practical application and is more reliable.

In [1] we proposed a scheme for reliable and automatic detection of microseismic events based on Constant False Alarm Rate (CFAR) processing in the time-frequency (TF) domain. The TF domain provides improved localization of the events of interest by concentrating the microseismic signal energy and spreading out the noise energy. The CFAR detector automatically adapts the threshold to varying noise levels and achieves reliable performance by designing this threshold such that the false positive rate is kept to a user specified level. The noisy time domain trace is converted to the TF domain by scaling the squared magnitude of STFT to form an estimate of the Power Spectral Density, and then the CFAR detector is applied on the TF image. The proposed method has the following advantages: It offers a way to specify and control the probability of false positives, resulting in a reliable performance in realistic noise conditions. Secondly, it provides automatic detection by adaptively adjusting threshold in a dynamic noise environment. Finally, it mimics the human decision process by using the TF and CFAR combination to uncover and detect the events localized in time and frequency.

The performance of the method has been evaluated using both synthetic and field data (Figure 1: low-magnitude earthquake data). Results prove the capability of the proposed scheme to perform automatic microseismic event detection similar to human visual thresholding.

Reference:
Seismic deconvolution is a standard procedure in seismic data processing to estimate the wavelet and then remove its effect as much as possible, which also attenuates reverberations and short-period multiples. Seismic deconvolution is an important step in the pre- and post-stack seismic processing work now, because it produces a more interpretable seismic section. Deconvolution techniques are widely adopted in seismic exploration and seismology applications. A common challenge in seismic deconvolution is blind deconvolution where the blurring kernel, i.e., the seismic source wavelet, is unknown. In a seismic survey, the convolution of the source wavelet with the subsurface reflectivity series is recorded as seismic traces at receivers. In a multichannel scenario, the seismic traces are typically modeled as convolutions of the same waveform with multiple reflectivity models.

In seismic applications, conventional multichannel methods cannot be applied directly. The major cause is the great similarity between neighboring reflectivity sequences, which makes the problem either numerically sensitive or, at worst, ill-posed and impossible to solve.

In order to tackle this issue, a sparsity promoting regularization approach has been proposed. The prevailing methods, called sparse multichannel blind deconvolution (SMBD) and its variant modified SMBD, perform well for both synthetic and real data sets. However, their computational complexity is proportional to the square of the number of traces which constrains

Figure 1 Comparison among SMBD, F-SMBD, and SMBD-SPG for different attributes of the synthetic data example. (a) Recovered wavelet (by SMBD-SPG) and true wavelet when SNR = 10 dB; (b) Simulation time vs. number of traces with SNR = 10 dB, each trace contains 350 samples; (c) Normalized correlation coefficient gamma vs. SNR; (d) Quality metric Q vs. SNR. We can see our method is the fastest and yields the best deconvolution results.
them from being applied to large data sets directly. The other alternative is a series of variants of the deconvolution filtering design method, such as the widely adopted predictive deconvolution, and the fast algorithm for sparse multichannel blind deconvolution (F-SMBD). These approaches yield a deconvolution filter according to some criteria such as least-squares, or the smoothed norm of the deconvolved signal.

In this work [1] we propose an efficient blind deconvolution scheme based on basis pursuit type of optimization and wavelet estimation which takes advantages of the multichannel nature of a seismic section and band-limited characteristics of the seismic source wavelet. The basis pursuit here is implemented by spectral projected-gradient (SPG) algorithm, which is fast, suitable for large scale problems, and applicable for complex values. But even more important, using SPG mitigates the tricky issue of choosing a good regularization parameter, using instead a constraint with physical meaning. In both synthetic and field data set, our method shows accurate deconvolution results in a very fast speed compared to the existing methods. Please see Figure 1 and 2 for details.

Reference:

Figure 2. Deconvolution results on field data. (a) Stacked CMP data for 3 s and 500 traces. Deconvolution results for (b) SMBD, (c) F-SMBD, (d) SMBD-SPG (5 iterations).
Iterative Interferometry-based Method for Picking Microseismic Events

Abdullatif A. Al-Shuhail, Naveed Iqbal, SanLinn I. Kaka, Entao Liu, Anupama Govinda Raj, and James H. McClellan

Continuous microseismic monitoring of hydraulic fracturing is commonly used in many engineering, environmental, mining, and petroleum applications. Microseismic records, especially those recorded at the surface, suffer from excessive noise that complicates first-break picking affecting subsequent data analysis. We present a new first-break picking algorithm that employs concepts from seismic interferometry and time-frequency (TF) analysis. The algorithm first uses a TF plot to manually pick a reference first break. The algorithm next iterates the steps of cross-correlation, alignment, and stacking to enhance the signal-to-noise ratio of the relative first breaks. The reference first break is then used to calculate final first breaks from the relative ones. Testing on synthetic and real data sets at high levels of additive noise shows that the algorithm enhances the first-break picking considerably. Furthermore, results show that only two iterations are needed to converge to the true first breaks. Indeed, iterating more can have detrimental effects on the algorithm due to increasing correlation of random noise.

Figure 1. Synthetic data example. (a) noiseless data; (b) noisy data; (c) TF panel; (d) picks versus iteration; (e) SSE versus iteration
Locations of microseismic events provide important information about the conditions of the reservoir during hydraulic fracturing (Duncan, 2005). Zhu et al. (2016) took advantage of the moveout pattern formed on a group of receivers when events are present to recover the true arrival times from many false picks under low SNR condition using random sampling scheme (Fischler and Bolles, 1981).

The proposed method was tested on both synthetic dataset and real dataset. In synthetic simulation (Figure 1), the proposed method successfully distinguishes true picks that form a valid moveout curve from false picks due to noise. More importantly, it automatically separates the arrival times from p- and s-wave phase into two distinct groups. Using the properly labeled arrival times, later localization algorithms can take advantage of the false-pick-free data and make more accurate location estimation.

The proposed method was also tested on the true surface data. Due to the limited availability of exploration data, it was applied on natural earthquake dataset using large number of surface geophones (Figure 2). The proposed method finds the true moveout curve among a large number of false pick as shown in Figure 2a. The estimated event location overlaps with the true event location nicely and confirms with other method that this is a surface event instead of deep earthquake.

**References:**

Automated SVD Filtering of Time-frequency Distribution for Enhancing the SNR of Microseismic/microquake Events

Naveed Iqbal, Azzedine Zerguine, SanLinn Kaka, and Abdullatif Al-Shuhail

Recently, there has been a growing interest in continuous passive recording of passive microseismic experiments during reservoir fluid-injection monitoring, hydraulic-fracture monitoring, and fault-movement monitoring, to name a few. The ability to accurately detect and analyze microseismic events generated by these activities is valuable in monitoring them. However, microseismic events usually have very low signal-to-noise ratio (SNR), especially when monitoring sensors (receivers) are located at the surface where coherent and non-coherent noise sources are overwhelming. Therefore, enhancing the SNR of the microseismic event will improve the localization process over the reservoir. In this study, a new method of enhancing the microseismic event is presented which relies on one trace per receiver record unlike other methods. The proposed method relies on a time-frequency representation and noise eliminating process which uses the singular-value decomposition (SVD) technique. Furthermore, the SVD is applied on the matrix representing the time-frequency decomposition of a trace. In previous works [1][2] and the references therein, a threshold or a constant needs to be defined, which requires human intervention. In this study, an automated SVD filtering is proposed. The SVD filtering utilizes the cross-correlations to avoid defining the threshold. In this way, the SVD filtering becomes observation-driven instead of user-defined.

Automated SVD has two important outcomes: first it makes the method suited for large amount of data like those available from surface arrays used to monitor the hydraulic fracturing activity; second, it makes the process more robust because less dependent to the subjective choices of the different users.

References:
Smart Solar Home Project

One of the main objectives of the Saudi vision 2030 is to create a sustainable economy by diversifying the investments and increasing the utilization of renewable resource. The vision has a commitment to increase the utilization of renewable energy resources in the country through the King Salman Renewable Energy Initiative that will structure the regulatory framework to enable the private sector to invest in the renewable energy field, as well as to localize the industry and produce the necessary skill-sets. The potential of renewable resources in the kingdom, as well as the high and increasing consumption of electrical energy loads drive this research to contribute to the Saudi Vision 2030.

A smart solar home is a home that incorporates advanced information and communication technologies to provide “smart” monitoring and control over the house’s functions such as lighting, heating, ventilation, air conditioning, and security, as well as home appliances. The house uses solar energy as the only energy source and is equipped with the technology that permits maximum efficiency and sustainability. This project aims to design, build and operate smart solar self-sufficient house considering the weather conditions in Saudi Arabia, such as seasonal heat, dust and high humidity.

Moreover, postgraduates and undergraduates around the world, as well as at KFUPM, are commonly facing a challenge of not having opportunities to contribute to any practical aspect of their chosen discipline. Current approaches to the education of undergraduates and graduate students are not up to this challenge. Hence, we have to develop a new approach that integrates education, design and research in electrical engineering. The Smart Solar House Project (SSHP) offers the time and context necessary for students to learn and practice many different professional skills. It also provides more depth in the educational and research experience for both graduate and undergraduate students and allow them to better solve real-world problems.

The SSHP creates and supports teams of faculty, graduate students, and undergraduate students that work together on a multidisciplinary, long-term, and large-scale project. This project is expected to provide several advantages, such as:

- Promoting innovation and development through a combination of multidisciplinary participants working on a challenging project.
- Students learn from different perspectives because of multidisciplinary nature of the projects such as project planning and management, as well as social and professional skills.
- The commercial nature of the project attracts industry and helps the job prospects of participating students.
- Enables future major projects that make a difference.
- Opens up multidisciplinary research and educational opportunities.

A two years KFUPM/GT joint educational project will serve as the umbrella for the development of design-based learning program. Team KFUPM consist of faculty and students from Architecture, Electrical Engineering, Mechanical Engineering, and Physics. This effort will be integrated into several education programs, including the capstone senior design and graduate research. In addition, support will be pursued through new and existing partnerships with the industry. For Georgia Tech faculty and students, this project will provide an excellent opportunity to work in global long-term design project that will open new dimensions in research and collaboration. Moreover, the design aspects will be more challenging due to weather, economical, and social challenges in the kingdom. The final outcome of the project will be a home that is will be used in competitions, as well as for education, research, and innovation.
GREU : Global Research Experience for Undergraduates

During the second term of 2015 (term 152), the first undergraduate research experience was offered for the Electrical Engineering (EE) students at KFUPM. The experience was offered through a special topics course EE499. Four groups participated in the experience and generated four conference papers that will appear in IEEExplore. The paper are listed below.


Currently we are working on the proposal for requesting a permanent elective 3 credits course under the EE curriculum. We have also started the campaign of offering the same experience through special topics course EE499 in the coming semester (162). The course will be instructed by Dr. Samir Alghadhban and more faculty members will be involved with diversity of topics.

A professionally video was developed to share the experience of our students in the first batch. Kindly like and share the video at this link: [https://youtu.be/6smgUI9URa8](https://youtu.be/6smgUI9URa8)
The 5th CeGP Workshop in Dhahran

The 5th annual workshop, themed “Seismic Processing and Interpretation” was held by the Center for Energy and Geo Processing (CeGP) at KFUPM from March 27th to March 30th 2016. The workshop addressed various aspects of geo-signal processing and interpretation through panel discussions with experts from both oil and gas industries as well researchers from the center at Georgia Tech and KFUPM.

The first day of 5th CeGP workshop consisted of breakout sessions, addressing the progress of various educational projects and the potential development of new ones. Dr. Ali Muqaibel presented the first breakout session of the day, on GREU-presented Global Research Experience for Undergraduates the first breakout session. He gave a brief idea about the motivation and the implementation of the “undergraduate research” at KFUPM and summarized the current system at Georgia Tech. Objectives, implementation, and future directions were discussed in this session. The goal is to settle the structure of undergraduate research at EE/KFUPM and its integration into the curriculum. A pilot group of undergraduate researchers were invited to share their feedback.

Dr. Wajih Abu-Al-Saud presented his session on ‘Development of MOOCS Learning’ directly afterwards. His talk discussed the prospect of developing Massive Open Online Courses (MOOCs) by CeGP as a future educational project. Dr. Wajih A. Abu-Al-Saud is a faculty member in the EE department and the Director of the e-Learning Center at KFUPM. The session concluded with the following conclusions: A MOOC that is developed jointly between KFUPM and GT through the CeGP should be, 1. A topic that is not covered by other MOOCs that currently exist on the net. Possible topics may be Geo-Signal Processing, Oil & gas exploration and drilling. 2. Developed and offered by authorities in the selected field, and preferably by experts from the industry. 3. Developed by professional team(s) using high quality production equipment. 4. Certified by both institutions.

The third breakout session was on “DSP Lab Development” delivered by Dr. Azzedine Zerguine. His developed course will cover topics ranging from speech processing to radar applications, to name a few. Covering such wide range of topics will give the student a broad understanding of the different applications that benefit
from signal processing and communications, as well as strengthening their theoretical background.

Dr. Mohammad Al-Muhaini presented the last breakout session of the first day on ‘Capstone Senior Design Project’. This session was a brainstorming session to address the potential collaboration between KFUPM and Georgia Tech in capstone design projects. Open discussion and the wrap-up session were supervised by Dr. Ali Al-Shaikhi and Dr. Ghassan Al-Regib.

The second day featured seminars open to the public, which focused on the industrial enhancement and the research trend of interpretation of the seismic imaging. Various research projects and tutorials were also discussed throughout the second day. On the last day of the workshop, participants attended a tutorial on “Seismic Numerical Simulation” in the morning. In the afternoon, they visited the “Exploration and Petroleum Engineering Center - Advanced Research Center” (EXPEC ARC), and the “upstream professional development center” (UPDC) at Saudi Aramco to discuss advancement in seismic image interpretation and possible collaborations. The workshop theme fell in line with CeGP’s focus areas, signal processing, seismic data processing, and application of modern signal processing to geo-energy related data. In addition, it contained an educational focus that lead to the development of new curriculum and new learning methodologies.

The second day of workshop was mainly devoted to technical seminars and industry talks. The day started with a brief workshop overview by Dr. Ali Muqaibel and Dr. Ali Al-Shaikhi, CeGP Director, Chairman, EE, KFUPM. The first technical presentation was delivered by Dr. Ghassan AlRegib and Dr. Mohammed Deriche on their joint CeGP Research Project with title: “Interactive Computer- Aided Seismic Interpretation.”

Dr. Nasher AlBinHassan, senior Geophysicist at Saudi Aramco, gave an industry talk on “Automation in Seismic Interpretation” that was followed by the CeGP Research Project on “Microseismic Signal Enhancement and Arrival Time Picking Correction” which was delivered by Dr. Abdellatif Al-Shuhail. Dr. Wail Mousa then presented his research work on “Efficient Under-Sampled High Resolution Radon transform”.

The second half of the day started with another industry talk, this time by Dr. Mohammed Badri on “The Role of Seismic Technology in the Characterization of Unconventional Reservoirs”, followed by an academic talk on “Real-time wireless seismic data acquisition” by Dr. Ahmed Bader, research scientist for KAUST. Briefly afterwards the CeGP Research Project on “In-Field Processing for Seismic Data Acquisition”
was delivered by Dr. Mohamed Mohandes. The day was concluded with an industry panel to allow representatives of various firms to share their feedback and consultation on CeGP research projects.

Among the activities of the workshop, the management team of CeGP at GT, Dr. Ghassan AlRegib and Dr. Larry J. Jacobs, met with KUFPM administration. On Monday March 28, the team met with KFUPM rector Dr. Khalid Al-Sultan, to strengthen the bond between KFUPM and GT. The team also met with Dr. Sahel Abduljauwad, KFUPM vice rector for research to highlight the outcomes of KFUPM-GT research collaborations and to discuss its overall progress. The team took a tour in Dhahran Techno Vallie (DTV) and visited Dr. Samir Al-Baiyat, KFUPM supervisor for technology Transfer innovation and Entrepreneurship.

**Selected Photos**

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**Center for Energy & Gas Processing**

**CeGP**
Hierarchical topology is most optimal.

A proprietary wireless backhaul pipeline has been prototyped and tested.

Early results show that 2x833 geophones per line with <2kg per channel is quite possible.
Georgia Tech President Participates in IAB meeting at KFUPM

Dr. G.P. “Bud” Peterson participated in the 20th International Advisory Board (IAB) meeting at KFUPM in Dhahran, Saudi Arabia, October 2016.

Dr. Gary May Visits KFUPM

Dr. Gary S. May, Dean of the College of Engineering at the Georgia Tech, visited KFUPM on May 30th, 2016. Dr. May gave a talk on “Active Learning and the Future of Engineering Education”. He also visited CeGP at KFUPM.
CeGP Field Trip to S-82 Seismic Crew in Al-Jafurah Area

CeGP organized a field trip on February 11, 2017 to a seismic crew in Al-Jafurah area, 130 km south of Dhahran, to gain insights into the current practices in seismic land acquisition. This field trip succeeds our previous exciting visit to a survey area near Hafr Al-Batin. Dr. Abdullatif Al-Shuhail, Associate Professor in Earth Sciences Department at KFUPM and CeGP member, arranged with Saudi Aramco for the visit to WesternGeco seismic crew performing land seismic acquisition in that area. CeGP members: Dr. Abdullatif Al-Shuhail, Dr. SanLinn Ismail Kaka, Dr. Mohamed Deriche, Dr. Ali Muqaibel, Dr. Wessam Mesbah, Dr. Suhail Al-Dharrab, Dr. Naveed Iqbal and Dr. Bo Liu, and a group of undergraduate students from Earth Sciences Department at KFUPM participated in this trip.

Crew S-82 is an exploration crew collecting seismic data that can be interpreted to discover oil and gas reservoirs. It was a high-channel count crew compared with the conventional 3D using many vibroseis trucks (vibs), around 70,000 geophones and ADUs (Analog Digital Units), and many trucks/vehicles adapted for the challenging desert terrain for junior workers and senior engineers. Some high productivity acquisition methods were implemented to survey a total area of approximately 1,500 SqKm. Around 85% of that area was completed and the crew was still working on Al-Jafurah Block 1, which is expected to be completed soon this year.

Main aim of this field trip was twofold. First, it offered a good learning opportunity for the students in the field. Second, it played a major role as a platform for researchers in current CeGP projects at KFUPM and engineers from industry to exchange information. The field trip group departed campus in the early morning and arrived at the seismic survey camp, which was located between Hofuf City and the Arabian Gulf, after an hour and a half bus ride. Then, the seismic survey engineers presented a brief introduction of Crew S-82 and delivered a short presentation on safety, survey layout (such as receiver lines, channels per line, shot or vibration points (VPs), source density, and nominal fold) and data collection and delivery. Engineers also discussed their methods of simultaneous shots using multiple vibroseis trucks where interference is negligible and does not affect their target time range. Some of the bad shots were noticed due to a 6.3 magnitude earthquake in Pakistan. Before the group head to the survey site, the crew engineers gave a demonstration of the vibrator operation in a vibroseis truck.
The group took an hour off-road drive across the desert inside a crew truck to reach the seismic acquisition site, which was around 30 km far from the base camp. The group was invited to the recording truck and presented with real-time quality control (QC) monitoring procedure. Usually, recorded seismic data tape is transferred to the base camp roughly twice a day for initial field processing. Later, CeGP members discussed with the survey engineers more details on seismic geophone communication topology.

In the afternoon, the group came back to the base camp where the seismic crew gave a tutorial and demonstration on the initial field processing, QC, and geophone tests in the workshop. CeGP members and the seismic survey engineers discussed the seismic data storage and delivery aspects. At the end of the visit, CeGP members appreciated the efforts of the crew and the organizer for this exciting and informative field trip.
Research Experience for EE Undergraduates: Advisors Workshop

On May 24, 2016, Dr. Ali Muqaibel presented a workshop to the EE department faculty members. The workshop titled: “Research Experience for EE Undergraduates: Advisors Workshop” covered the ongoing educational project of (Co-I: Dr. Samir Alghadhban (KFUPM), Dr. Ghassan Alrigeb (GT) and Mr. Saleh Alawsh (KFUPM,))

The main objective of the workshop was to assure the sustainability of the undergraduate research program at EE/KFUPM. The attendees were updated on the current efforts in integrating undergraduate research with the EE curriculum. The faculty members were introduced to how things started and were then taken through the journey that our students go through in the last offering of EE499: Special Topics III: Undergraduate Research. A detailed survey was conducted on the students who participated in that course and the results were discussed with the faculty members. Finally, future plans on how faculty members can contribute was discussed. Attending faculty members provided both oral and written input, which will be used to improve future offerings and generate faculty guidelines.

- The covered topics were:
- Why Undergraduate Research? What motivate students and faculty?
- How things started… Future plans and how can you help.
- The magical recipe for mentor-mentee relationships…Understanding your role.
- The undergraduate research experience journey.
- Advisor guidelines and involvement in assessments
- Survey Results
- How to control the registration? GPA, interview, proposal?
- Additional discussion Items
- Summary and Conclusions
In its continuous attempts to enrich the social activities of KFUPM society, the center for energy and Geo Processing (CeGP) planned and participated in organizing the 3rd EE Senior Design Expo on April 28, 2016 at the KFUPM Mall. After its success and wide acceptance in the KFUPM community, the EE-expo continues to celebrate and showcase the innovative projects designed by the students of EE department. The first EE Expo took place on May 9th 2015 as a result of the visit of Dr. Amit Jariwala, Director of Design & Innovation at Georgia Tech, to KFUPM under the social activities of CeGP.

The 3rd EE-design is no longer limited to the projects of the course “Senior Design Project EE 411”; it has been extended to include other courses as well. The new courses joined this event are: EE311 “Fundamentals of EE Design”; EE 206 “Intro to Electrical Systems & Computation”, and the “Undergraduate research” course. More than 110 students in 36 teams have participated in the Expo under different categories. Prizes totaling 16000 Saudi Riyal were given for the top three projects of each course.

The event was honored by the visit of Dr.Mohammad Al-Homoud, KFUPM Vice-Rector for Academic Affairs and Dr. Omar Al-Swailim, former-Dean of College of Engineering Sciences. The EE expo has become the focus of attention for local companies and authorities. Over 25 industry experts attended the event and served as judges for the expo and they were thrilled with the level of creativity and talent of the students. The expo was mainly sponsored by Saudi Aramo, other sponsors are: National Instrument, SSSEE, CeGP. The Expo has paved the way for further collaboration between KFUPM students and faculty and the local industry especially the company of Dhahran Techno Vallie (DTV). It has, also, given KFUPM students the chance to interact with many employers of local companies show their innovation and skills.

The EE student club of KFUPM played an essential role in the execution of the event under the leadership of Dr. Mohammad Al-Muhaini. Several faculty and staff members within the EE department of KFUPM under the leadership of Dr. Ali Al-Shaikhi has paid tremendous efforts to make this event possible. The CeGP leadership thanks the support and coordination provided by Mohammad Tamim Alkhodary for his selfless service to the collaboration in logistic help that create creative educational experience through the CeGP project. The expo continues to send a message within KFUPM to celebrate student success and innovation and to inspire more industry engagement with KFUPM.
Dr. Al-Homoud and the organizing committee

Outlook of the event.

Dr. Al-Hamoud and Dr. Al-Shaikhi in their tour during the Expo

Dr. Al-Homoud honored CeGP for their efforts in organizing the 3rd EE Expo.
“Studying at Georgia tech was a great experience to me. I want to thank the Office of International Cooperation (OIC) at King Fahd University of Petroleum & Minerals and the Office of International Education (OIE) at Georgia Tech for their efforts to help us. I learned new things at Georgia tech. I learned that being a university student is not only being in classes but being involved in some activities outside classes is critical. I gained many skills by participating in activities that I would not have been able to gain in a classroom. I had the chance to meet people from all over the world and I made new friends. Finally, I want to thank all people at Georgia tech who helped to have wonderful semester”

- Khaled Almuytairi

“It was a good experience to study at GaTech. Georgia Tech has a different way of teaching. It took me some time adapt. Also, students here at Tech tend to study in groups. I wish I can transfer this cluster to KFUPM. “

- Mohammed Alnakhli
“During my exchange semester at Georgia Tech, I learned a lot; on the educational and cultural aspects. I took an interesting classe on astronomy in which we did a little project of imaging the sun and making observations about its location, temperature and other properties. It was fun. Also, we visited some good places and museums in Atlanta such as Georgia aquarium and the museum of Arts which is the largest and one of most visited museums in the United States. We also had the chance to go to New York during the Fall break and visited the famous empire state building and explore central park in a very cold weather”

- Othman Badawoud

“ I was pursuing in a double major track at KFUPM in electrical engineering and physics. I was told by friends that joining the Study Abroad Program might delay my graduation. However, I made a choice to join and I am glad that I did. Everyday at Georgia Tech was fun. I liked that the library at Tech is open 24 hours a day for students. I remember having two exams in the next day and I had to spend the night in the library in order to make it to the exams on time the next morning and I did. I had a great time here at Georgia Tech. I would like to thank everyone who made my trip possible. Special thanks to the Office of International Cooperation (OIC) at KFUPM, Ministry of Education in Saudi Arabia and the Office of International Education (OIE) at GT. I was honored by this opportunity to be an exchange student at Georgia Tech and would recommend all my colleagues at KFUPM to maintain a high GPA to be selected for this program.”

- Abdullah Al-Nafisah
CeGP Team at the 78th EAGE Conference and Exhibition

CeGP Team participated and presented 7 papers at the 78th European Association of Geoscientists & Engineers (EAGE) Conference and Exhibition in Vienna, Austria.

Lingchen Zhu Earned his PhD Degree From Georgia Tech

Lingchen Zhu, graduate student of Professor James McClellan at Georgia Tech and a member of CeGP, graduated with a PhD degree in Electrical and Computer Engineering. His dissertation, “Sparse Seismic Signal Processing using Adaptive Dictionaries,” can be accessed at https://smartech.gatech.edu/handle/1853/56234
Asjad Amin Earned his PhD Degree from KFUPM

Asjad Amin, graduate student of Dr. Mohamed Deriche at KFUPM and a member of CeGP, completed his Ph.D. defense on November 9th, 2016. The title of his dissertation was “Automatic Approaches for Salt Dome Detection From 2D and 3D Seismic Data”.

Zhen Wang Passes The PhD Proposal

Zhen Wang, PhD student of Professor Ghassan AlRegib at Georgia Tech and a member of CeGP, passed his Ph.D proposal on 12/7/2017. The title of his proposal was: “Computational Seismic Interpretation Using Geometric Representation and Tensor-based Subspace Learning”.
List of CeGP Scholarly Accomplishments

Datasets

Large North-Sea Dataset of Migrated Aggregated Seismic Structures (LANDMASS).

Software

Seismic Simulation, Survey, and Imaging (S3I)

Salt Dome Interpretation Tool.

Journal Publications

[2017]

M. Alfarraj, Y. Alaudah, Z. Long, G. AlRegib, and M. Deriche “Multiresolution Texture Attributes for Seismic Interpretation,” submitted to Interpretation


H. Di, M. Alfarraj, and G. AlRegib, “3D curvature analysis of seismic waveform and its interpretational implications,” submitted to Geophysical Prospecting


H. Di and G. AlRegib, “3D dip vector-guided autotracking of weak seismic reflectors,” submitted to Interpretation

H. Di and G. AlRegib, “Semiautomatic fault/fracture interpretation based on seismic geometry analysis,” submitted to Interpretation


L. Zhu, E. Liu, and J. H. McClellan, “A multi-channel approach for automatic microseismic event localization using RANSAC-based arrival time event clustering (RATEC),” submitted to Geophysical Prospecting

[2016]


X. Tian, E. Liu, A. Abdi, and F. Fekri, Seismic Signal Compression Through Time Shift and Entropy Constrained Dictionary Learning, submitted to Signal Processing

X. Tian, A. Abdi, E. Liu, and F. Fekri “Memory-Assisted Seismic Signal Compression based on Dictionary Learning and Sparse Coding” submitted to IEEE Geoscience and Remote Sensing Letters


Conference Publications

[2014]


A. Abdi and F. Fekri, “Mixture Source Identification in non-Stationary Data Streams with Applications in Compression,” The 42nd IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP). The Internet of Signals, March 5-9, 2017, New Orleans, USA.

[2016]


[2015]


[2014]


[2013]


[2012]

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