جامعة الملك عبدالله
للعلوم والتقنية
King Abdullah University of
Science and Technology

Course Syllabus: Advanced Seismic Inversion I - ErSE 328

Division	Physical Science and Engineering Division
Course Number	ErSE 328
Course Title	Advanced Seismic Inversion I
Academic Semester	Spring
Academic Year	2016/2017
Semester Start Date	01/22/2017
Semester End Date	05/18/2017
Class Schedule (Days & Time)	09:00 AM - 12:00 PM | Tue

Instructor(s)

Name	Email	Phone	Office Location	Office Hours
Tariq Ali Alkhalifa	tariq.alkhalifah@kaust.edu.sa	+966128080282		Tuesday & Wednesday 3:00pm - 4:00pm

Teaching Assistant(s)

Name	Email

Course Information

Comprehensive Course Description	Fully simulating our seismic experiment with all its acquisition variables, medium properties and the physical behavior of waves to reproduce the observed seismic data is an ultimate objective we all seek to achieve. Not with standing the computational limitations and the physical approximations, inverting for the medium properties (i.e. seismic velocities) is at the heart of waveform inversion. Thus, full seismic waveform inversion (FWI) is fast becoming the premiere research focus in Geophysics, with many academic and industry labs devoting a lot of resources to the problem. Many of the current tools used to perform FWI were known since the 1980's, but only recently did our computational capability allow us to implement FWI with higher resolution and speed, albeit we are still focused on 2D acoustic media models. Despite the recent advances, the remaining challenges are three fold: 1) The highly nonlinear nature of the objective (data misfit) function due to the sinusoidal nature of the wavefield and the complex Earth reflectivity, which renders gradient methods useless in some cases as we get trapped in local minima, or requiring a very accurate initial velocity model, 2) The acoustic, isotropic and 2D simplification of the medium, which unlike imaging, can cause tremendous problems to FWI, taking into account that the alternative can induce tremendous Null space into the problem, 3) Finally, the high computation cost of FWI as each iteration is equivalent to 3-5 imaging steps, and the iterations to go up to the hundreds. In this Graduate level course, we will focus on Full waveform inversion (FWI) starting by covering it's fundamentals, including an introduction to inverse theory, and getting an understanding on the philosophy behind FWI, trying to pick the mind of it's introducer to our field Albert Tarantola. We next look at the components of FWI, including the model and data space, their connection, and definition, including the physics of modeling and medium considerations. The objective of FWI is simply given by reducing the misfit between the observed data from an experiment (in our case a seismic one), and what we can generate using our computing devices. If we got the physics and the experiment parameters right, then most probably the model used to obtain the synthetic data that fits the observed (field) data is accurate. We will look at how do we measure such misfit, and what we do when the synthetic data do not resemble the observed data: the model update process. This will include covering the calculation of the gradient (the Frechet derivative), and for more advanced convergence components, the Hessian. The course will discuss the challenges we face in FWI and potential solutions to such challenges, and the uncertainties involved. In summary, the course starts by introducing the fundamentals of full waveform inversion (FWI) starting from it's basic definition. It soon focuses on the model update issues and provides analysis of it's probable success in converging to a plausible model. In the course, we will discuss the many challenges we face in applying FWI on seismic data, and introduce modern day proposed solutions to these challenges. In FWI a very simple, but important, fact resonates: We can only invert what the simulation (many approximate) assumptions and the acquired sinusoidal nature of our data with limited regional coverage allow us to estimate, so we have to make sure that we take these limitations into account. **This challenge, despite the many advances, will remain a topic of research for the industry and academia alike, including a topic attractive to graduate student's research and dissertation projects.** **Course Objectives:** Upon completion of the course, students will be knowledgeable in: -The scientific foundation behind Full waveform inversion. -The FWI algorithms -The FWI challenges -The uncertainties involved **General Course Outline:** -Introduction to seismic inversion: 1. What is inversion? 2. What do we mean by full waveform inversion? 3. The Algorithm. -The elements of seismic waveform inversion: 1. Model and data. 2. The objective function. 3. The update. 4. The sensitivity kernel. 5. The nonlinear issue. 6. Examples. -Seismic Anisotropy (maybe): 1. Definition and parameters. 2. The acoustic anisotropic wave equation. 3. Fundamental issues. -FWI and anisotropy (maybe): 1. Multi-parameter inversion.

	2. The right set of parameters. 3. The anisotropic sensitivity kernels. 4. Getting an initial model. 5. Anisotropy and MVA. TENTATIVE SCHEDULE: Lecture 1, Jan 24th: Introduction to inversion: What was Albert thinking? The background We will meet Thursday 1 PM, special case because of travel. Lecture 2, Jan 31st: Perturbation Theory and the Born Series Lecture 3, Feb 7th: Full waveform inversion (FWI), the gradient approach Lecture 4, Feb 14th: Full waveform inversion (FWI), the gradient approach 2 Lecture 5, Feb 21th: Review: Modeling in the time and frequency domain Lecture 6, Feb 28th: The update and the adjoint state (The Lagrange formulation) Lecture 7, March 7th: Understanding the update, presentations assignment 1 Lecture 8, March 14th: FWI issues and the model wavenumber Lecture 9, March 21st: FWI issues and examples Lecture 10, March 28th review and presentations Lecture 11, April 11th: Algorithms and more on the Hessian Lecture 12, April 18th: FWI and Anisotropy Lecture 13, April 25th: Project result presentations and submission Lecture 14, May 2nd: Project result presentations and submission
Course Description from Program Guide	Knowledge of linear inversion and exploration seismology is helpful. Consent of instructor is required.Overview of non-linear seismic inversion methods that invert for earth parameters from seismic data. The inversion procedure is a multiscale iterative method (typically, non-linear conjugate gradient) that employs preconditioning and regularization. Solution sensitivity is analyzed by model covariance matrices, the slice-projection theorem, and the generalized Radon transform. Methods for waveform inversion, wave path traveltime tomography, and least squares migration are presented.
Goals and Objectives	**Course Objectives:** Upon completion of the course, students will be knowledgeable in: -The scientific foundation behind Full waveform inversion. -The FWI algorithms -The FWI challenges -The uncertainties involved
Required Knowledge	Seismic imaging 260, or equavalent knowledge of Seismic imaging.
Reference Texts	Full waveform inversion in anisotropic world
Method of evaluation	**50.00**% - Research Project **50.00**% - Homework /Assignments
Nature of the assignments	homeworks, and projects
Course Policies	20% off for late homeworks and projects
Additional Information	

Tentative Course Schedule *(Time, topic/emphasis & resources)*		
Week	**Lectures**	**Topic**
1	Tue 01/24/2017	Introduction to inversion: What was Albert thinking? The background
2	Tue 01/31/2017	Perturbation Theory and the Born Series
3	Tue 02/07/2017	Full waveform inversion (FWI), the gradient approach
4	Tue 02/14/2017	Full waveform inversion (FWI), the gradient approach 2
5	Tue 02/21/2017	Review: Modeling in the time and frequency domain
6	Tue 02/28/2017	The update and the adjoint state (The Lagrange formulation)
7	Tue 03/07/2017	The update and the adjoint state (The Lagrange formulation)
8	Tue 03/14/2017	Understanding the update, presentations assignment 1
9	Tue 03/21/2017	FWI issues and the model wavenumber
10	Tue 03/28/2017	project proposal presentations and submission
11	Tue 04/04/2017	Spring break
12	Tue 04/11/2017	Algorithms and more on the Hessian
13	Tue 04/18/2017	FWI and Anisotropy
14	Tue 04/25/2017	Project result presentations and submission
15	Tue 05/02/2017	Project result presentations and submission
16	Tue 05/09/2017	Review
17	Tue 05/16/2017	Project sumbission deadline
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Note

The instructor reserves the right to make changes to this syllabus as necessary.