Geophysics 9701B:
WAVEFORM TOMOGRAPHY - An introduction to theory and practice

Lecturer: Dr. R. Gerhard Pratt

Tues: 12:30 pm – 2:30 pm (lecture)
Wed: 8:30 am – 10:30 pm (lab)
Location: BGS 0179

Course Description

Geophysical imaging with seismic waveform data may be characterized as an inverse problem, in which we formally invert the forward relationship between the subsurface elastic parameters and the data from a controlled source seismic survey. Sometimes known as “Full Waveform Inversion”, or FWI, this approach has been used successfully to yield high resolution, quantitative images of the subsurface in a range of applied geophysical applications, including deep crustal seismic imaging in subduction zones, geophysical exploration for oil and gas, the mapping of mineral deposits, and the monitoring of embankment structures in geotechnical engineering.

This course covers all aspects of waveform tomography, from theoretical developments, software implementation, data conditioning and application to real data. Students in the course are given full access to existing FWI software and use the software to form images, initially using simple examples designed to demonstrate key scientific concepts and culminating in a practical mini-project using example data from a large scale example.

Pre-requisites

Students taking this course must be familiar with upper year mathematical physics methods, including linear algebra, partial differential equations, numerical methods, Fourier Transform methods. A course in Inverse Methods is highly desirable. Some numerical computing experience using a language such as Matlab, C, and/or Fortran is also highly desirable.

Students must be prepared to install the course software on their own personal Linux computing environment, using standard installation procedures. A full installation of the free software package “Seismic Unix” is also required.

Because of these pre-requisites special permission from the instructor is required to enroll in the course. Unless you have written special permission from the instructor to enroll in it, you may be removed from this course and it will be deleted from your record. This decision may not be appealed. You will receive no adjustment to your fees in the event that you are dropped from a course for failing to have the necessary prerequisites.

Course resources

Students taking the course will be provided with a 180 page course text (PDF format) written by the instructor, as well as software and data for the class computer exercises. The course text provides a number of references to the research literature and students are expected to read widely in the subject.

Course schedule for 2015

Note on homework exercises: These will be distributed during each week's lab, and are due before the following week's lecture. Solutions will be discussed during the following lab.

Week 1 (Jan 13th)
- Lecture – Introduction to tomography with examples, ray theory
- Lab – Software installation, distribution of first exercises (Section 2.5)

Week 2 (Jan 20th)
- Due: Section 2.5 exercises (1, 2, 3)
- Lecture – Scattering theory, matrix inversion schemes
- Lab – discussion of solutions to Section 2.5 exercises (1, 2, 3)

Week 3 (Jan 27th)
- Due: Section 2.5 exercises (4, 5)
- Lecture – cancelled due to instructor absence
- Lab – used for lecture instead: Frequency domain finite differences

Week 4 (Feb 3rd)
- Due: Section 3.5 exercises (Question 1 only, without parts a)-g))
- Lecture – Implications of frequency domain modelling
- Lab – Computer exercise: Frequency domain modelling
  - Discussion of homework solutions

Week 5 (Feb 10th)
- Due: Section 3.5 exercises (remaining questions)
- Lecture – Introduction to inverse methods, Newton and Gradient methods
  - Computer exercises: Initial inversion examples
- Lab – lecture on fast calculation of gradient
  - Discussion of homework solutions

Reading week

Week 6 (Feb 24th)
- Due: Section 4.5 exercises (1, 2, 3)
- Lecture – Fast calculation of the gradient, illustration of the gradient
- Lab – Computer exercise: Inverting for 2D velocity and attenuation models

Week 7 (March 3rd)

Due: Section 4.5 exercises (4, 5)
Lecture – source signature inversion (including computer exercise)
– how to choose parameters for frequency domain inversion
Lab – Computer exercise: Inverting for 2D velocity and attenuation models

Week 8 (March 10th)

Due: Section 5.6 (all questions)
Lecture – Problems of non-linearity
Lab – lecture on detailed case studies
– discussion of homework solutions

Week 9 (March 17th)

Due: Section 6.6 (all questions)
Lecture – discussion of homework solutions
– further case studies lecture
Lab – Introduction to CCSS case study data
– Initial work on CCSS case study data

Week 10 (March 24th)

Due: Initial processing of CCSS case study data (to 0.8 Hz only)
Lecture/Lab – discussion and work on CCSS case study data

Week 11 (March 31st)

Due: Final processing of CCSS case study data (to 4 Hz)
Lecture/Lab – discussion and work on CCSS case study data

Week 12 (April 7th)

Due: Either: Section 7.4 (choose one question to examine in detail).
Or: separate processing of a dataset of your choice
Lecture/Lab – discussion of homework

Course evaluation

50% Weekly exercises (Sections 2.5, 3.5, 4.5, 5.6, 6.6)

20% Participation

30% Final project (either a full report on the CCSS dataset including at least two questions from section 7.4, or a full report on processing a dataset of your choice)

Student's responsibilities in the event of a medical issue: If you are unable to meet a course requirement due to illness or other serious circumstances, you must provide valid medical or other supporting documentation to the Dean's office as soon as possible and contact your instructor immediately. It is the student's responsibility to make alternative arrangements with their instructor once the accommodation has been approved and the instructor has been informed. In the event of a missed final exam, a "Recommendation of Special Examination" form must be obtained from the Dean's Office immediately. For further information please see:
http://www.uwo.ca/univsec/handbook/appeals/medical.pdf

A student requiring academic accommodation due to illness, should use the Student Medical Certificate when visiting an off-campus medical facility or request a Records Release Form (located in the Dean's Office) for visits to Student Health Services. The form can be found here:
https://studentservices.uwo.ca/secure/medical_document.pdf

Statement on Academic Offenses:
Academic offenses are taken seriously. Students are directed to read the appropriate policy on academic offenses at:
www.uwo.ca/univsec/handbook/appeals/scholoff.pdf

Students must write their essays and assignments in their own words. Proper referencing or quotations must be used when taking an idea or passage from another author.

Accessibility Statement

Please contact the course instructor if you require material in an alternate format or if you require any other arrangements to make this course more accessible to you. You may also wish to contact Services for Students with Disabilities (SSD) at 661-2111 x.82147 for any specific question regarding an accommodation.