

GEOP 697: Optimization Methods

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1 Prerequisite or Background

Students who have exposure in the undergraduate level with geophysics, hydrology, engineering, physics or applied mathematics will find this course useful. Undergraduate level courses in calculus, partial differential equation, integral equations, and background in linear algebra are sufficient to fulfill the prerequisite. For Geophysics students GEOP 605 is required. This is a general outline of syllabus. Depending on how we progress we will see how much can be covered.

2 Outline

1. Introduction to Inverse Problems:

- Data Space, Model Space, Forward Problem
- Ill-posed Problems
- Non-uniqueness
- Discussion on Noise, finite data

2. Mathematical Review of Linear Algebra and Properties of delta function:

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- Vector space, subspaces
- Hilbert Space, norms, inner product
- Decomposition theorem
- Matrix Norms, Condition Numbers

3. Singular Value Decomposition and its application:

- Singular value expansion
- SVD of matrices
- Truncated SVD solution
- Filter function

4. Unconstrained Optimization:

- Minimum norm solution with accurate and inaccurate data
- Minimum norm solution in finite-dimensional space
- Steepest Descent, Newton, Quasi-Newton, Gauss-Newton
- Search Strategy: Line Search and Trust Region
- Examples

5. Discussion on Iterative Methods:

- Basic of Iterative Methods
- Conjugate Gradients
- Lanczos Decomposition
- Methods for Rectangular systems: CGLS, LSQR
- Basics of Preconditioning: Jacobi, SOR, SSOR
- Practical Examples

6. Constrained Optimization

- General Idea
- Lagrange Multiplier, Augmented Method
- Brief discussion Linear Programming

- Introduction to Interior Point Method
- Global optimization (SA/GA)(time permitting)
- Practical Examples

7. Appraisal and Inference Analysis

- Backus-Gilbert Theory
- Deltaness Criteria
- Discussion on Averaging and Point Spread Function
- Bounded Functionals

3 Grading

The grade will be made of four parts:

- Assignments, Class participation and Quizzes (30%)
- Final Examination (open notes/books) (30%)
- Project (40%)

3.1 Assignments

Assignments will have theory part and also programming part. You are encouraged to use MATLAB for coding. If you are not familiar with MATLAB don't hesitate to ask for help. MATLAB is available on CGISS2 server. A part of the assignment will be seminar series on various topics.

3.2 Final Project

The final project can be your choice and something that will be useful to you for future research. It could be computational project or theoretical investigation related to using optimization methods. The project will be on going throughout the period of this course. You are highly encouraged to choose your topic early in the course so that you have sufficient time to work on it. If you have difficulty in choosing a topic please don't hesitate to come and discuss, I can help you define a project. The final project will be due

on **May 5th 2005**. You will present the final project to the class with a 25 min talk. You will submit the work in form of a written paper (like a peer-reviewed publication) with all relevant derivations and codes that you have used to solve the problem.

Just as a reminder: Please hand in your assignments and projects in time.

4 References

- Numerical Optimization: J. Nocedal and S. J. Wright, Springer
- Geophysical Inverse Theory, R. L. Parker, Princeton University Press
- Numerical Methods for unconstrained optimization and nonlinear problems, Dennis, Jr, and Schnabel, SIAM

5 Timings

- Lectures: E318, Tuesday and Thursday, 4.40-5.55 PM