MSc in Geosciences and Remote Sensing

MSc in Geographical Information Science

SESSION 2008/9

INVERSE THEORY

Timetable:

- Semester 1 Blocks 1 and 2.
- Time: 9:00am – 11:00am.
- Note: First session is in week 1 (Thursday 25 September)

Location:
Room 301 Crew Building, King's Buildings Campus.

Course details:

- 10 credit course.
- GIS and GRS option course.
- Organised teaching hours per week: 2.
- Course leader: Dr Hugh C. Pumphrey
- Other teaching staff: None

COURSE AIM

This course addresses a class of mathematical problems which occur in various branches of Earth science and elsewhere. The distinguishing feature of these problems is that they involve the estimation of an underlying continuous function from a finite number of measurements. This is a fundamentally difficult task as the measurements can never supply the infinite number of pieces of information which a continuous function could represent. The measurements do, however, supply some information on the underlying function, so what we can reasonably hope to do is to obtain an estimate of the function and an understanding of how good that estimate is.

By far the commonest application of these ideas is the estimation, from remote sensing measurements, of atmospheric properties which vary with height. A problem of this type is used as an example throughout this course. The concepts presented also have applications in seismology, geomagnetism and oceanography.

LEARNING OUTCOMES

On completion of this module, we expect students to be able to:

1. Explain the mathematical nature of the atmosphere remote-sensing problem.
2. Demonstrate competence in the mathematical techniques required to tackle the problem, specifically:
   a) Solve simultaneous equations (including under and over-determined examples)
   b) Calculate means, standard deviations and covariance matrices
   c) Find the eigenvalues and eigenvectors of symmetric matrices
3. Describe some of the methods used to solve inverse problems, set out their mathematical formulation and show clear understanding of their theoretical underpinnings. The methods to be covered are:
   a) naïve inversion, and why it usually doesn't work,
   b) the MAP formula, its derivation and the nature of the solution,
   c) the Twomey-Tikhonov formula, and the circumstances in which it is appropriate,
   d) The extra difficulties of a non-linear problem, and how one can solve it.

4. Write computer programs to implement these methods, applying them to an atmospheric sounding example
5. Understand the basic principles of data assimilation.

COURSE CONTENT

Week	Topics
1	Mathematics: matrices, simultaneous equations, eigenvalues. Lecture and class exercises.
2	Test covering week 1 (5%) Mathematics: Statistics. Lecture and class exercises.
3	Test covering week 2 (5%) The temperature sounding problem and how not to solve it (Lecture).
4	Representation Functions (Lecture). The MAP solution (Lecture)
5	How good is the MAP solution ?(Lecture)
6	Test covering weeks 3-5 (5%) A priori information. Where to get it ... (Lectures)
7	... and how to avoid using it. (Lecture) The non-linear problem (Lecture)
8	Test on Weeks 6-7 (5%) Data assimilation (lecture)
9	Data assimilation continued (lecture)
10	Test covering weeks 9-10 (5%)

ASSESSMENT OF OUTCOMES

- Learning outcomes 1 – 3 and 5 above will be assessed by five in-class tests and an end-of-semester examination. These will contribute 50% of the final mark: 5% for each test and 25% for the examination. Each in-class test will be 30 minutes long and will cover the material from the previous week or two. Testing is done in this progressive manner as material in the later weeks relies heavily on a good understanding of material in the earlier weeks.
- Learning outcome 4 (and to some extent the other learning outcomes) will be assessed by two practical exercises. The first (worth 30%) will be handed out in week 3 or 4 and will be due in week 7. The second (worth 20%) will be handed out in week 7 and will be due in week 10.