THE UNIVERSITY OF NEW SOUTH WALES
SYDNEY · 2052 · AUSTRALIA

SCHOOL OF SURVEYING & SPATIAL INFORMATION SYSTEMS

GMAT 9161

Advanced Estimation Theory

Course Outline – Session 1, 2010

Version: 29/07/2009

This document, and other material, is available at the Course Website:
http://www.gmat.unsw.edu.au/gmat9161

(User name and password supplied in class)

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1. Staff involved in the Course and their Contact Details

1.1 Lecturer: Dr Samsung Lim

Office: EE406 (by appointment)
Email: s.lim@unsw.edu.au Phone: 9385 4505

1.2 Lab Supervisor: TBA

1.3 Staff absences during session:

None planned, however, in the circumstances of absences he can be contacted by email at the above email address. Also, on campus assistance with this course can be obtained from the lab supervisor during the period.

2. Educational Aspects of the Course

2.1 How this course relates to others in the program

This course is intended to introduce advanced-level estimation techniques to postgraduate students who have in need of data processing techniques for estimating the state of a non-linear dynamic system e.g. static and kinematic positioning from the Global Positioning Systems (GPS) carrier-phase observables, precise orbit determination (POD) of artificial satellites, statistical signal processing, etc. Estimation theory is a branch of statistics and applied mathematics that deals with time-varying measurements where uncertain noise is unavoidable due to the nature of data acquisition. Estimation theory is required in numerous areas including telecommunications, engineering mechanics (e.g. control theory for dynamic systems), network security, and satellite geodesy. Therefore this course is suited to students from not only Surveying and Spatial Information Systems but also Electrical Engineering and Telecommunications, Mechanical Engineering, and Computer Science/Engineering.

2.2 Aim of the Course

This course aims to provide estimation theory with practical exercises for POD and Global Navigation Satellite Systems (GNSS). Fundamentals of orbit determination in general engineering problems (e.g. a typical spring-mass problem) and positioning from GNSS carrier-phase measurements will be used to explain the linearization of the estimation process, the least squares solution, the minimum variance estimate, maximum likelihood and Bayesian estimation, the batch processor, the sequential estimation algorithm, the extended sequential estimation algorithm, state noise compensation algorithm (e.g. the Gauss-Markov process), smoothing techniques, covariance analysis and the probability ellipsoid.

2.3 Learning Outcomes

By the end of this semester students should be able to implement advanced estimation techniques such as the batch algorithm, the sequential algorithm, and the extended sequential algorithm into their own data processor in order to solve the problems of POD and GNSS, however, their applications are not limited to these specific areas. It is expected that students will have better understanding of the effect of error in measurements i.e. error propagation, data modelling, and statistical interpretation of the estimates.

2.4 Teaching Strategies

This course is based on a 2-hour lecture plus a 1-hour lab per week or a 3-hour lecture per week. Labs are designed to provide guidance for the term project that has to be completed by students with an extensive time.

2.5 Suggested Learning Methods

Either Matlab or C++ can be chosen by students for their assignments. Should other computer languages have to be used, a prior arrangement with the course lecturer is required.

2.6 UNSW Graduate Attributes

This course provides an environment that fosters in our students the following attributes is listed:

the skills involved in scholarly enquiry	Significant
an in-depth engagement with relevant disciplinary knowledge in its interdisciplinary context	Significant
the capacity for analytical and critical thinking and for creative problem solving	Significant
the ability to engage in independent and reflective learning	Significant
the skills to locate, evaluate and use relevant information (Information Literacy)	Significant
the capacity for enterprise, initiative and creativity	Significant
an appreciation of and respect for, diversity	Some
a capacity to contribute to, and work within, the international community	Minimal
the skills required for collaborative and multidisciplinary work	Significant
an appreciation of, and a responsiveness to, change	Significant
a respect for ethical practice and social responsibility	Some

3. Proposed Course Schedule (S1 2010)

Any changes will be notified in the class and at the course website. *Lab exercises for assessment.

Week No.	Lecture (2 hours)	Lab (1 hour)	Assignment
1	**Introduction to Estimation Theory**	No Lab	
2	**The Uniform Gravity Field Problem** * Formulation of the problem * The equation of the orbit * Linearisation procedure * State transition matrix	*Programming for the uniform gravity filed problem	
3	**The Orbit Problem** * Problem of two bodies * Perturbed motion * Coordinate systems and time * Orbit accuracy	*Numerical integration of motion for one day for a GLONASS-like satellite	
4	**Observations** * Conceptual measurement systems * Realisation of measurements * Differenced measurements * Satellite positions * Angles	*Orbit determination for ICESat using GPS measurements	
5	**Fundamentals of Estimation Techniques** * The least squares solution * The minimum variance estimate * Maximum likelihood and Bayesian estimation	*The spring-mass system	
6	**The Batch Processor** * Computational algorithm * Integer ambiguity resolution * LAMBDA	*Batch processing	Term Project: Developing a data processing program by implementing the batch-, the sequential-, and the extended sequential algorithms. Due: Week 13
7	**The Sequential Estimation Algorithm** * Kalman Filter * Computational algorithm * Prediction residual	*Sequential processing	
8	**The Extended Sequential Estimation Algorithm** * Extended Kalman Filter	*Extended sequential processing	

	* Computational algorithm * Prediction residual		
9	**State Noise Compensation Algorithm** * Gauss-Markov process * Information filter * Error sources	*State noise compensation	
10	**Smoothing** * Computational algorithm	*Smoothing	
11	**The Probability Ellipsoid** * Covariance matrix * Transformation of the covariance matrix	Term project	
12	**Square Root Solution Methods** * Givens transformations * Householder transformations * Square root filter algorithms	Term project	
13	**Course Summary** * Sample final exams	Term project	

4. Assessment in the Course

• Lab assessment (3% each x 9)	27%	Each Week except Weeks 1 & 11-13
• Term Project: Data Processor	40%	Due Week 13
• Final Exam	33%	Will be formally arranged by Exam Section

4.1 Term Project

This project aims to develop a prototype data processing program by implementing the batch-, the sequential-, and the extended sequential algorithms. In this project, data refers to any measurements that include uncertain errors to which estimation theory is applicable. A typical example is GPS carrier-phase measurements. The project is designed for individual work. For those who have to choose C++ as their programming language, a math library developed by the course lecturer will be given to them in order to minimise the time and effort on programming vector/matrix functions (e.g. matrix inversions, Choleski decomposition and singular value decomposition, etc.)

All assignments and assessment items should be submitted with a signed Assessment Cover Sheet:

I declare that this assessment item is my own work, except where acknowledged, and has not been submitted for academic credit elsewhere, and acknowledge that the assessor of this item may, for the purpose of assessing this item:

Reproduce this assessment item and provide a copy to another member of the University; and/or,

Communicate a copy of this assessment item to a plagiarism checking service (which may then retain a copy of the assessment item on its database for the purpose of future plagiarism checking).

I certify that I have read and understood the University Rules in respect of Student Academic Misconduct.

Signed: .....date: ☐☐ ☐☐ ☐☐

5. Course Resources

5.1 Lecture Material (check the course website):

http://www.gmat.unsw.edu.au/gmat9161

5.2 Text and Reference Books

Byron D. Tapley, Bob E. Schutz, and George H. Born, (2004) Statistical Orbit Determination, Elsevier Academic Press

5.3 Computational Aids

Computer software relevant to this course and available in the School's computer lab EE401A, includes: Matlab and Visual Studio (C++).

6. Administrative Matters

6.1 Expected work load

At UNSW, the normal workload expectations of a student are 25-30 hours per session for each unit of credit, including class contact hours, preparation and time spent on all assessable work.

To assist students with the organisation of their studies, the expected workloads of the various components of the course are listed below. It is strongly suggested that students use the listed hours to plan their work during session.

Lectures (12 x 2hr)	24hr
Labs & tutorials (12 x 1hr)	12hr
Assignments (1 x 10hr x 8wk)	80hr
Quiz	0hr
Field exercises & demos	0hr
Revision of Lectures, preparation of practical/tutorial reports, background reading (approximately 4hr x 12wk)	48hr
Total	164hr

6.2 Rules

Students should read the University Calendar or Student Guide for details of University Rules and special considerations.

Students are reminded that the University regards academic misconduct as a very serious matter. Unauthorised material must not be taken into a test or examination. The penalty for any suspected academic misconduct ranges from zero mark for the assignment or exam involved, through failure of the subject, to expulsion from the University. If absent from an examination, class test or practical, students must submit written documentation to the University, via the Student Centre in the Chancellery.

All lab/tutorial assignments are compulsory parts of the course and must be handed in by the due date. A mark of zero will be given for any submission which violates this rule.

If a student is unable to submit on time due to illness or other legitimate reason, then a brief written explanation must be given to the lecturer for consideration as soon as is feasible. In some cases

the lecturer may grant an extension to the submission date provided he has been contacted before the due date.

Further assessment may be granted in this course at the lecturer's discretion. If further assessment is granted then performance in tutorials may be considered as well as an oral exam including use of a computer.

If students attend less than 80% of their possible classes they may be refused final assessment.

6.3 Plagiarism

Plagiarism is the presentation of the thoughts or work of another as one's own.*

Examples include:

- direct duplication of the thoughts or work of another, including by copying material, ideas or concepts from a book, article, report or other written document (whether published or unpublished), composition, artwork, design, drawing, circuitry, computer program or software, web site, Internet, other electronic resource, or another person's assignment without appropriate acknowledgement;
- paraphrasing another person's work with very minor changes keeping the meaning, form and/or progression of ideas of the original;
- piecing together sections of the work of others into a new whole;
- presenting an assessment item as independent work when it has been produced in whole or part in collusion with other people, for example, another student or a tutor; and,
- claiming credit for a proportion a work contributed to a group assessment item that is greater than that actually contributed.†

Submitting an assessment item that has already been submitted for academic credit elsewhere may also be considered plagiarism. Knowingly permitting your work to be copied by another student may also be considered to be plagiarism. An assessment item produced in oral, not written form, or involving live presentation, may similarly contain plagiarised material.

The inclusion of the thoughts or work of another with attribution appropriate to the academic discipline does *not* amount to plagiarism.

Students are reminded of their Rights and Responsibilities in respect of plagiarism, as set out in the University Undergraduate and Postgraduate Handbooks, and are encouraged to seek advice from academic staff whenever necessary to ensure they avoid plagiarism in all its forms.

The Learning Centre website is the central University online resource for staff and student information on plagiarism and academic honesty. It can be located at:

www.lc.unsw.edu.au/plagiarism

The Learning Centre also provides substantial educational written materials, workshops, and tutorials to aid students, for example, in:

- correct referencing practices;
- paraphrasing, summarising, essay writing, and time management;
- appropriate use of, and attribution for, a range of materials including text, images, formulae and concepts.

Individual assistance is available on request from The Learning Centre.
Students are also reminded that careful time management is an important part of study and one of the identified causes of plagiarism is poor time management. Students should allow sufficient time for research, drafting, and the proper referencing of sources in preparing all assessment items.

* Based on that proposed to the University of Newcastle by the St James Ethics Centre. Used with kind permission from the University of Newcastle.
† Adapted with kind permission from the University of Melbourne.

Please visit the School's Plagiarism Statement:
http://www.gmat.unsw.edu.au/currentstudents/general/plagiarism.htm for the key information on the new plagiarism policy. From the page the students can download the policy document (as a PDF), and the assessment cover sheets (as DOC or PDF).

6.4 Grievances

In the first instance all grievances should be discussed with the lecturer involved. If the problem cannot be resolved, students should contact the School's Grievance Officer in writing.