FACULTY OF
SCIENCE

SCHOOL OF MATHEMATICS
AND STATISTICS

MATH5835

Stochastic Processes

Semester 1, 2017

MATH5835 – Course Outline

1 Information about the course

Course Name: Stochastic Processes
Course Authority and Lecturer: Prof. Pierre Del Moral, email: p.del-moral@unsw.edu.au
Consultation: To be arranged via email.
UOC: 6
Prerequisites & Exclusions: Good knowledge of undergraduate mathematics and of undergraduate probability at the level of MATH2801/MATH2901 is required. This means familiarity with basic probability models, random variables and their probability distributions, independence, expectations and conditional probabilities, as well as the law of large numbers. If you need a thorough review of basics, the textbook Probability by Jim Pitman is recommended. Familiarity with linear algebra, and basic integration theory is also needed.
Lectures: Wednesday 5-8pm OMB G31, Thursday 5-8pm OMB G32, in **Weeks 7–13 only.**
Moodle: Further information and skeleton lecture notes, and other materials will be provided via Moodle. Please check the course homepage regularly for updates.

2 Course aims

MATH 5835 is a course on stochastic processes and their applications. Theoretical topics will include discrete and continuous stochastic processes. We will present Markov chain models, martingale theory, and some basic presentation of Brownian motion, as well as diffusion and jump processes. We will discuss the convergence stability analysis of (discrete generation) Markov chains. The course will also be illustrated with a variety of applications including statistical machine learning, operation research, mathematical biology, computational physics, as well as engineering sciences and financial mathematics.

Relation to other courses and relevant programs
This is a compulsory course for the Masters Program in Statistics. It builds on foundation knowledge of basic probability and will provide a solid background for courses offered in the Masters Program including Math5975, Math5816, Math5335, and Math5965.

3 Student Learning Outcomes

By the end of this course you should be able to:

1. State the defining properties of various stochastic process models.
2. Sample on a computer any type of continuous or discrete time stochastic process.
3. Identify appropriate stochastic process model(s) for a given research or applied problem.

4. Provide logical and coherent proofs of important theoretic results.
5. Apply the theory to model real phenomena and answer some questions in applied sciences.

Relation to graduate attributes
The above outcomes are related to the development of the Science Faculty Graduate Attributes, in particular: 1. **Research, inquiry and analytical thinking abilities**, 4. **Communication**, 5.**Teamwork, collaborative and management skills**, and 6. **Information literacy**.

4 Teaching strategies underpinning the course

New ideas and skills are first introduced and demonstrated in lectures, then students develop these skills by applying them to specific tasks in assessments.

Rationale for learning and teaching strategies
We believe that effective learning is best supported by a climate of inquiry, in which students are actively engaged in the learning process. To ensure effective learning, students should participate in all the lectures.

We believe that effective learning is achieved when students attend all classes, have prepared for classes by reading through previous lecture notes.

Furthermore, lectures should be viewed by the students as an opportunity to learn, rather than just to copy down lecture notes.

Effective learning is achieved when students have a genuine interest in the subject and make a serious effort to master the material.

The art of logically setting out mathematics is best learned by watching an expert and paying particular attention to detail. This skill can be learned by regularly attending classes.

5 Assessment

Assessment in this course will consist of 2 assignments ($2 \times 10\%$), a research project on a selected application domain (20%), and a final examination (60%).

Knowledge and abilities assessed: All assessment tasks will assess the learning outcomes outlined above, specifically, the ability to provide logical and coherent proofs of results and specific problems related to stochastic processes.

Assessment criteria: The main criteria for marking all assessment tasks will be clear and logical presentation of correct solutions.

5.1 Assignments

Rationale Assignments will give an opportunity for students to try their hand at more difficult problems which require more than one line of argument and also induce them to aspects of the subject which are not always explicitly covered in lectures.

Assignments one will be handed out in week 3 and will be collected in week 4. Assignment two will be handed out in week 5 and will be collected in week 6.

Assignments must be handed in by the due date and time. Late submission will not be accepted unless there is documentary evidence of mitigating circumstances.

Each assignment must include a signed declaration of the plagiarism coversheet which can be found on Moodle.

All work submitted for assessment (other than formal examination scripts) will be returned with comments where appropriate.

Assignments must be YOUR OWN WORK, or severe penalties will be incurred. Please refer to Section 9 for information on plagiarism.

Weighting: Each assignment weights 10% of your final mark. Students who miss an assigment will receive 0 marks unless they request special consideration in accordance with university guidelines. See
http://www.maths.unsw.edu.au/currentstudents/special-consideration-illness-misadventure

5.2 Research project

Rationale

Research projects offer the opportunity for students to apply the theory of stochastic processes to an application domain they will select among the ones discussed in the course:

Card shuffling, fractal images, ancestral evolutions, molecular dynamics, branching and interacting processes, genetic models, gambling betting systems, financial option pricing, advanced signal processing, stochastic optimization, Bayesian statistical inference, and many others.

The research project provides an opportunity to immerse the student in one of her/his favorite application area. To favor creativity, critical thinking, brainstorming, collaboration and organization, a given research project can be shared by two students.

Some material will be given to the students, but the research project also requires to do a background study and a personal research. The final research project will be written in the format of a pedagogical report with 10 to 20 pages. It will include the following sections: introduction, a section on the theoretical aspects and another on the numerical aspects (including if possible some simulation codes), and a final conclusion.

Weighting: 20% of your final mark.

Research project must be delivered in week 6. Late submission will not be accepted unless there is documentary evidence of mitigating circumstances.

Each research project must include a signed declaration of the plagiarism coversheet which can be found on Moodle.

All work submitted for research projects will be returned with detailed comments.

Nevertheless each project must be YOUR OWN WORK, or severe penalties will be incurred. Please refer to Section 9 for information on plagiarism.

5.3 Examination

Duration: Two hours.

Rationale: The final examination will assess student mastery of the material covered in the lectures. It also allows students to individually demonstrate their achievement of the course outcomes under controlled conditions independent of assistance from others.

Students who miss an exam will receive 0 marks unless they request special consideration in accordance with university guidelines. See
http://www.maths.unsw.edu.au/currentstudents/special-consideration-illness-misadventure

Weighting: 60% of your final mark.

Further details about the final examination will be made available in class closer to the time and also on Moodle.

5.4 Additional resources and support

5.4.1 Lecture notes

A set of lecture notes will be provided on Moodle. Some of them will contain the full presentation of a topic and it will be sufficient to learn the required material. Others will be more brief and contain a list of the results that should be studied using recommended textbooks.

5.4.2 Textbooks

The content of the course will be defined by the lectures. Self contained and detailed lecture notes for the course will be provided. The following textbook is recommended

- Stochastic Processes From Applications to Theory by P. Del Moral and S. Penev.

Other textbooks which can be useful for supplemental reading are:

- G.R. Grimmett, D.R. Stirzaker, Probability and random processes, 2nd Ed, Oxford Science Publications, Oxford (1992).

- S.I. Resnick. Adventures in Stochastic Processes. Springer/ Birkhauser (1992).
- A. Shiryaev. Probability, Graduate Texts in Mathematics, Springer (2013).
- W. Feller. An Introduction to probability theory, vol. 1, Wiley (1971).
- S. Meyn, R. Tweedie. Markov chain and stochastic stability, Springer-Verlag (1993).
- R. Durrett. Probability: Theory and Examples. 4th Edition. Cambridge University Press (2010).
- C. Gardiner. `Handbook of Stochastic Methods: for Physics, Chemistry and the Natural Sciences`, 3rd ed., Springer (2004).

6 Course Schedule

The topics will be selected from the following:

PART 1: An illustrated guide

- Motivating examples : Counting, gambling, card shuffling, fractal, ancestral genetics.
- Selected topics : Reinforcement and population models, Google page rank, Web protocols.
- Computational and theoretical aspects : Monte Carlo methods, Doeblin-Itō differential calculus, speculation theory.

PART 2: Simulation toolbox

- Inversion technique, change of variables, acceptance-rejection methods.
- Illustrations : Computational physics and statistical machine learning.

PART 3: Markov chain models

- Different formulations : Tree of outcomes, transition matrices, transition diagrams
- Different classes of models : Finite state space models, general state space models.
- Non linear models : Self-interacting and mean field interacting processes.

PART 4: Analysis toolbox

- General mathematical tools : Matrix theory, spectral decompositions, functional analysis.
- Stochastic tools : Coupling, strong stationary times, martingale theory.
- Topological aspects : irreducibility and aperiodicity.

7 Course Evaluation and Development

The School of Mathematics and Statistics evaluates each course each time it is run. We carefully consider the student responses and their implications for course development. It is common practice to discuss informally with students how the course and their mastery of it are progressing.

8 Administrative matters

Expectations of Students, assessment policies	Important information for students (including rules and expectations for attendance, release of marks, additional assessment) is available from http://www.maths.unsw.edu.au/currentstudents/assessment-policies
Occupational Health and Safety	See http://www.gs.unsw.edu.au/policy/documents/ohspolicy.pdf for UNSW Occupational Health and Safety policies and expectations of students regarding health and safety.
Equity and Diversity	Those students who have a disability that requires some adjustment in their teaching or learning environment are encouraged to discuss their study needs with the course Convenor prior to, or at the commencement of, their course, or with the Equity Officer (Disability) in the Equity and Diversity Unit (9385 4734 or http://www.studentequity.unsw.edu.au/). Issues to be discussed may include access to materials, signers or note-takers, the provision of services and additional exam and assessment arrangements. Early notification is essential to enable any necessary adjustments to be made.
Grievance Policy	First, see your course authority! If resolution is not possible, then follow the procedures listed on the page https://my.unsw.edu.au/student/atoz/Complaints.html

9 Plagiarism and academic honesty

Plagiarism is the presentation of the thoughts or work of another as one's own. Issues you must be aware of regarding plagiarism and the university's policies on academic honesty and plagiarism can be found at http://www.lc.unsw.edu.au/plagiarism/.