ELEC2146
Electrical Engineering Modelling and Simulation

COURSE OUTLINE — Session 2, 2010

Course Staff
Course convenor: Dr Julien Epps, room EE337, j.epps@unsw.edu.au

Consultations: You are encouraged to ask questions on the course material before, during or after the regular class times in the first instance, rather than by email. Consultation times will be advised in lectures in the first couple of weeks. Note that the lecturer has a joint appointment as a Senior Researcher with National ICT Australia and can be expected to be off campus some days of the week (usually Monday and one of Thursday or Friday), during which only email contact will be available.

Course details
Credits: The course is a 6 UoC course; the expected workload is 9-10 hours per week throughout the 13 week session.

Contact hours: The course consists of 6 contact hours per week, comprising 2 hours of lectures, 1 hour of tutorial and 3 hours of laboratory:

Lectures: Wednesdays, 9-11am, room RedC M032
Tutorials: Tuesdays, 2-3pm, room Webster 256
Laboratories: Wednesdays, 3pm-6pm, room EE214
Lectures and Laboratory\(^1\) classes start in week 1, Tutorials start in Week 2.

Course Information
Background
This elective course is unique in its scope and emphasis, being the only course offered in Electrical Engineering and Telecommunications devoted specifically to simulation and modelling. It provides a solid grounding in modeling tools that can be applied not only to electrical engineering problems, but also to a variety of other problems addressed by engineering graduates in general. There is an emphasis on linear dynamic systems during the simulation topics, intended as a continuation from ELEC2134 and as a link to other courses in EE&T disciplines. During the modelling topics, the emphasis is on understanding the modelling process, exposure to some possible model structures, parameter estimation methods and measures of the efficacy of a model for a given practical situation/data set.

\(^{1}\) Week 1 laboratory is introductory (not assessed)
Context and aims

Modelling and simulation are a vital part of many areas of engineering, allowing engineers to reason about the expected behaviour of a system without having to physically implement it. Simulation pervades much of electrical engineering, for example models of individual electronic devices, circuit simulation, network modeling, compression of speech/audio/image/video signals, design of biomedical devices, and modeling of physical systems for control purposes. Modelling allows an abstract representation of a signal or system in a (mathematically) compact and/or simplified form that is extremely useful in many fields, including analysis, design, compression, classification, and control. The main high-level aim of the course is to provide a thorough grounding in aspects of constructing and applying models and their simulation using well-known simulation tools (MATLAB and C). In particular, the course looks at how continuous-time systems can be represented and simulated using (discrete-time) computers. This also provides an interesting insight into the relationship between physical systems and computing algorithms. The course is intentionally designed to have a strong practical focus, with extensive laboratory work serving to develop key skills in computing and applications of mathematics.

Aims: This course aims to:

a. Familiarise you with programming in MATLAB.

b. Convey the analytical and practical details of a range of modelling techniques.

C. Provide an understanding of finite difference approximation and numerical methods for differential equations, in the context of state-space representations of linear systems.

d. Familiarise you with the modeling of dynamical systems and stochastic systems, including the choice of model, choice of model order, parameter estimation and goodness of fit.

e. Provide a thorough grounding in parameter estimation techniques such as least squares (particularly) and maximum likelihood.

f. Give you practical experience with simulating physical systems and modeling typical experimental data, for example second-order circuits, non-linear circuits, electrical machines and power systems, control systems, biomedical systems, and introductory network simulation.

Relation to other courses

ELEC2146 Electrical Engineering Simulation and Modelling builds directly on students’ skills and knowledge in circuits, linear systems, differential equations and Laplace transforms gained during ELEC2134 Circuits and Signals. Knowledge gained in ELEC2134 will be extended using simulations, and the relationship between continuous and discrete systems will be explored through numerical integration. This course also

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2 Not all of these applications may be covered (each requires its own understanding of the context); also, in some cases synthetic problems or data may be used in place of more realistic problems or data.
builds on COMP1191, extending programming skills (including C programming) and providing an extensive introduction to MATLAB programming. Although ELEC2146 is an elective, it is closely related to other courses offered, in particular signal processing and control systems courses such as ELEC3114 Control Systems and ELEC3104 Digital Signal Processing, and also serves as very helpful background material to a range of final year thesis topics, many of which employ MATLAB simulation.

Pre-requisites: The minimum pre-requisite for the course is ELEC2134 Circuits and Signals (or equivalent) and COMP1191 Computing 1 (or equivalent). Knowledge from either 1st or 2nd year Maths courses is very helpful, perhaps essential.

Assumed knowledge: It is essential that you are familiar with basic principles of programming, circuit theory, transient analysis of 2nd order circuits, AC circuit analysis, and solution of differential equations. Familiarity with matrix operations is also assumed. Previous experience in deriving expressions for the expected value and 2nd order moments of probability density/mass functions would be helpful.

Learning outcomes

On successful completion you should be able to:

1. Express a linear system in terms of its differential equation, transfer function, magnitude response, impulse response and step response, be able to convert between the different forms and explain the advantages of each;
2. Derive expressions that can be used to estimate parameters from different types of data, for different types of model structures;
3. Explain analytically how to simulate a continuous-time system by means of numerical integration;
4. Synthesise MATLAB code to simulate a given system or model;
5. Implement a suitable model for a given problem, making informed choices about the model type and model order, and calculate the model error.
6. Deduce the behaviour of previously unseen models or parameterisations and hypothesise about their merits.

The course delivery methods and course content address a number of core UNSW graduate attributes; these include:

a. The capacity for analytical and critical thinking and for creative problem-solving, which is addressed by the tutorial exercises, laboratory work and the project.
b. The ability to engage in independent and reflective learning, which is addressed by tutorial exercises and the assignment, together with self-directed study.
c. The skills of effective communication, which are addressed by the viva-style verbal assessment in the laboratory.

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3 i.e. essentially the content of ELEC2134. If you don’t feel confidence with this material, you are strongly advised to spend some time with a text like Alexander and Sadiku (details shown below), which is clearly written, has many worked examples and has many problems (with solutions) to attempt.
d. Information literacy, which is addressed by the homework and project. Please refer to http://www.ltu.unsw.edu.au/content/userDocs/GradAttrEng.pdf for more information about graduate attributes.

Teaching strategies
The course consists of the following elements: lectures, tutorials, laboratory work, project work, and homework comprising self-guided study and a problem sheet. These strategies are traditional, however efforts will be made to keep lectures and particularly tutorials interactive (your suggestions on the teaching strategies for this course are welcome). The course has a strong practical focus, with 45% or more of the assessment based on laboratory work, acknowledging both the importance of practical modeling, simulation and programming skills and the importance of the laboratory context in learning theoretical and analytical concepts.

Availability of Course Materials
Course materials will be made available progressively via Blackboard. Typically lecture notes, tutorial problem sheets and lab sheets will be made available ahead of time, and lectures slides will be posted after lectures. Occasionally posted course materials may be updated (indicated by the version number in the file name); as a precaution please check that you have the latest version of lecture notes, tutorial problems and lab sheets.

Lectures
During the lectures, techniques for developing models and simulations will be presented. The lectures provide you with a focus on the core analytical material in the course, together with qualitative, alternative explanations to aid your understanding. Once theory has been presented, attempts will be made to reduce the cognitive load of the learning: worked examples will be presented in a step-by-step manner (with class input where time permits) using consistent notation and with efforts made to link to existing knowledge. The worked examples may not always be contained in the lecture notes or slides, so attendance at lectures is strongly advised. The lecture materials distributed in class (or via the course web site) will give a good guide to the course syllabus, but you will need to supplement them with additional reading, from the recommended text book(s) and/or other materials recommended by the teaching staff. In particular, you should not assume that attendance at all lectures (even with a glance or two through the notes), on its own, is sufficient to pass the course.

Tutorials
A number of suggested tutorial problems will be distributed ahead of each class, and brief answers to these will be given at a later date. In general, however, once specific questions have been addressed during the tutorial, different problems (to the tutorial problem sheet) will be discussed and worked through, so that you have a wider range of study materials. The tutor may give example solutions to selected problems, or request you to attempt one or more problems in the class, or a combination of the two. If you would like assistance on a particular aspect of the lectures or tutorials (e.g. going over a particular concept, example or tutorial exercise), please indicate this to the lecturer ahead of the tutorial
(preferably a couple of days beforehand). This way, the benefit of the tutorial time can be maximized.

**Laboratory work**
The laboratory schedule is deliberately designed to gain practical, hands-on exposure to the concepts conveyed in lectures soon after they are covered in class. This course should be a great opportunity to developing your programming and debugging skills in relevant languages (MATLAB and C are listed in quite a few job advertisements) with a strong electrical engineering flavour throughout. Generally there will be around one week between the introduction of a topic in lectures and a laboratory exercise on the same topic, sufficient time in which to revise the lecture, attempt related problems and prepare for the laboratory. The laboratory work provides you with hands-on experience with simulation tools and algorithms used widely in electrical engineering. *You must be prepared for the laboratory sessions:* the laboratory sessions often require comparison with analytical results from the preparation, so this is only possible way to complete the given tasks in the allocated time.

*Laboratory classes will start in week 1 of session,* with the strongly recommended Introductory MATLAB laboratory. Regular laboratory classes will start in week 2. You will need to bring to the laboratories:
- A USB drive for storing MATLAB script files
- A laboratory notebook for recording your work
- Your lecture notes, laboratory preparation and/or any other relevant course materials

**Homework and Problem sheets**
The lectures can only cover the course material to a certain depth; you must read the textbook(s) and reflect on their content as preparation for or follow-up after the lectures to fully appreciate the course material. Home preparation for laboratory work provides you with the background knowledge you will need. The problem sheets aim to provide in-depth quantitative and qualitative understanding of theory and methods. Together with your attendance at classes, your self-directed reading, completion of problems from the problem sheet and reflection on course materials will form the basis of your understanding of this course.

**Assessment**
- Laboratory work: 35%
- Assignment: 10%
- Mid-session exam: 10%
- Final examination: 45%

Marks for the various assessments will be posted to Blackboard once they are available.

**Laboratory work:** From week 2, the laboratory work will be assessed in order to ensure that you are studying and that you understand the course material. The laboratory assessment is conducted live at the end of each lab exercise – specifically, the labs will be
marked at the next lab after the time allocated for each exercise is complete (in which labs all students must be moving on with the next lab exercise). Late marking of labs will attract a penalty of 20% per week. It is essential that you arrive at each lab having revised lecture materials (and attempted problems from the problem sheet) in advance of each laboratory, and having completed any requested preparation for the labs. Without preparation, marks above 50% may be difficult to obtain. No lab reports are required in this course. During the laboratory, you may consult with others in the class, but you must keep your own notes of the laboratory. In particular, note that laboratory assessment will be conducted individually, not on a per-group basis. Please also note that you must pass the laboratory component in order to pass the course.

Assessment marks will be awarded according to your preparation (completing set preparation exercises and correctness of these or readiness for the lab in terms of pre-reading), how much of the lab you were able to complete, your understanding of the experiments conducted during the lab, the quality of the code you write during your lab work (according to the guidelines given in lectures), and your understanding of the topic covered by the lab. There are no lab reports; all lab assessment is live. Student feedback in 2009 indicated the lab requirements were quite challenging, so the weighting for this assessment component has been increased to reflect this.

**Assignment:** The assignment allows self-directed study leading to the solution of partly structured problems in MATLAB. This will be written up as a formal report, and marks will be assigned according to how completely and correctly the problems have been addressed, the quality of the code written for the assignment (must be attached to the report), and the understanding of the course material demonstrated by the report.

The assignment report will be due at the Wednesday lecture in Week 10. Late reports will attract a penalty of 10% per day (including weekends).

**Mid-session examination:** The mid-session examination tests your general understanding of the course material, is designed to give you feedback on your progress through the analytical components of the course. Questions may be drawn from any course material up to the end of week 6. Note that although some revision material is covered in the first three weeks, the mid-session may not contain many questions drawing from this revision material, relative to the new material covered. It may contain questions requiring some (not extensive) knowledge of MATLAB programming, and will definitely contain numerical and analytical questions. Marks will be assigned according to the correctness of the responses.

**Final examination:** The exam in this course is a standard closed-book 3 hours written examination, comprising five compulsory questions. University approved calculators are allowed. The examination tests analytical and critical thinking and general understanding of the course material in a controlled fashion. Questions may be drawn from any aspect of the course (including MATLAB programming), unless specifically indicated otherwise.

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4 Unless suitable justification (preferably in advance) is given. Note however that it is always better to submit your work late than not at all.
by the lecture staff. Marks will be assigned according to the correctness of the responses. Please note that you must pass the final exam in order to pass the course.

Course Schedule

This schedule is approximate; some variation to the timing below can be expected.

<table>
<thead>
<tr>
<th>Week</th>
<th>Lecture 1st hour</th>
<th>Lecture 2nd hour</th>
<th>Ref</th>
<th>Laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction to modeling and simulation</td>
<td>Simulation programming</td>
<td>[1,2,7]</td>
<td>Introductory MATLAB</td>
</tr>
<tr>
<td>2</td>
<td>Simulation prog (cont’d)</td>
<td>Circuits as dynamic systems</td>
<td>[1,2,3, 4,10,13]</td>
<td>Lab 1: Circuit simulation</td>
</tr>
<tr>
<td>3</td>
<td>State space</td>
<td>Linearisation</td>
<td>[1,2,3, 4,10,13]</td>
<td>Lab 2: Linear system simulation</td>
</tr>
<tr>
<td>4</td>
<td>Numerical methods for differential equations</td>
<td>Numerical methods for differential equations</td>
<td>[1,2,6, 12]</td>
<td>Lab 2: Linear system simulation</td>
</tr>
<tr>
<td>5</td>
<td>Runge-Kutta</td>
<td>Runge-Kutta Discretization</td>
<td>[1,2,12]</td>
<td>Lab 3: Numerical DEs</td>
</tr>
<tr>
<td>6</td>
<td>Least squares</td>
<td>Least squares</td>
<td>[5,6,9, 12]</td>
<td>Lab 3: Numerical DEs</td>
</tr>
<tr>
<td>7</td>
<td>Mid-session examination, duration 50 min</td>
<td>Introduction to system identification</td>
<td>[5,11]</td>
<td>Lab 4: Runge-Kutta</td>
</tr>
<tr>
<td></td>
<td>Sep 7th</td>
<td>Break</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Introduction to system identification</td>
<td>Stochastic models</td>
<td>[1,8]</td>
<td>Lab 5: Least squares</td>
</tr>
<tr>
<td>9</td>
<td>Stochastic models</td>
<td>Parameter estimation</td>
<td>[6,8,9]</td>
<td>Lab 6: System identification</td>
</tr>
<tr>
<td>10</td>
<td>Parameter estimation</td>
<td>Goodness of fit</td>
<td>[6,8]</td>
<td>Lab 7: Stochastic models</td>
</tr>
<tr>
<td>11</td>
<td>Goodness of fit</td>
<td>Model Types</td>
<td>[6]</td>
<td>Lab 8: Parameter Estimation</td>
</tr>
<tr>
<td>12</td>
<td>Model Types</td>
<td>Summary and research</td>
<td>[6]</td>
<td>Lab 9: Goodness of fit</td>
</tr>
<tr>
<td>13</td>
<td>No lectures</td>
<td></td>
<td></td>
<td>Lab: Catch-up</td>
</tr>
</tbody>
</table>

Resources

Textbooks

Prescribed textbook

The following textbooks are suggested, rather than prescribed, for the course:

aimed slightly above the level of this course. For anyone with longer-term interests in dynamic systems, this text is highly recommended.

[2] Woods, R. L., and Lawrence, K. L. (1997), *Modeling and simulation of dynamic systems*, Prentice-Hall, Upper Saddle River, NJ. – This is a more introductory level text that also deals with dynamic systems, across all areas of engineering. The coverage of the course is not very complete, but the style is fairly straightforward and there are many problems (with answers) given.

You may want to check the availability and coverage of the texts before purchasing, as some topics in the syllabus are not featured. Unfortunately there is no single text that covers all topics in a satisfactory depth. Additional references, listed below and at the end of some lecture note sets, will in combination provide complete coverage of the course. Please contact the lecturer for further text recommendations where needed. Lecture notes will be provided, however these do not treat each topic exhaustively and additional reading is required.

**Reference books**
The following books are good additional resources for various topics, and many should be available in the library:


[5] van den Bosch, P. P. J., and van der Klauw, A. C., *Modeling, Identification and Simulation of Dynamical Systems*, CRC Press, Boca Raton, FL, 1994. – Good coverage of many parts of the course, including modeling ideas and system identification, but some parts of the course are covered only briefly. Not available in the UNSW Library.


**On-line resources**

Some additional on-line resources relevant to the course:


http://sting.deis.unibo.it/virtue/DemoVirtue/Sid.html

**Other Matters**

**Academic Honesty and Plagiarism**

Plagiarism is the unacknowledged use of other people’s work, including the copying of assignment work and laboratory results from other students. Plagiarism is considered a serious offence by the University and severe penalties may apply. For more information about plagiarism, please refer to [http://www.lc.unsw.edu.au/plagiarism](http://www.lc.unsw.edu.au/plagiarism), or discuss any questions you have with the lecture staff.

**Continual Course Improvement**

ELEC2146 is under constant revision in order to improve the learning outcomes of its students. Please forward any feedback (positive or negative) on the course to the course convener or via the Course and Teaching Evaluation and Improvement Process (surveys at the end of the course).

In 2010, ELEC2146 will be modified from the 2009 version in the following ways: some C programming will be introduced into labs (following input from the school’s Academic Executive Committee) (note that the only assessment of this in 2010 will be in the lab component of the course), to help improve C programming skills/debugging/confidence; lectures will be made more interactive (as a result of peer assessment of teaching in 2009); labs have been revised to make them more consistent in length and less repetitive (student feedback in 2009); and some topics have been slightly expanded (student feedback in 2009).
As a final note, it is hoped that you will be satisfied with this course not only while studying it and on completion, but also with how it contributes to your understanding of future courses and thesis within Elec Eng, Telecomms, Photonics, Biomed, Physics and maybe even CompSci programs. In particular, the lecturer welcomes your comments 6, 12, 18 months later, on what parts you found helpful in subsequent courses and/or what changes to this course could provide better preparation for those courses. Use of modeling and simulation techniques and fundamental ideas in subsequent coursework and especially in future employment is after all one ultimate objective of this course.

**Administrative Matters**

On issues and procedures regarding such matters as special needs, equity and diversity, occupational health and safety, enrolment, rights, and general expectations of students, please refer to the School policies, see [http://scoff.ee.unsw.edu.au/](http://scoff.ee.unsw.edu.au/).