SCHOOL OF ELECTRICAL ENGINEERING
ELEC9733 Real Time Computing and Control

Session 1, 2009

Contents

1 Course Outline

This course is one of the courses which leads to the award of postgraduate coursework degrees, in particular the Master of Engineering Science. The course may be selected as an elective contributing to a number of coursework plans, but is offered primarily as one of the electives within the *Systems and Control* plan. It builds on undergraduate courses which address introduction to control systems (such a course is remarkably similar all over the world), and real-time computing (available as an elective in the UNSW EET Undergraduate program).

No assumptions will be made about prior knowledge of real time systems. Some appreciation of basic control would be of assistance, but sufficient coverage will be provided to introduce a particular view of this topic which is relevant and important for real time controller implementation. This view would not normally be covered at an undergraduate level.

The Handbook entry states:

Examines the implementation of modern control techniques and associated instrumentation,

using distributed computers. Practical hardware aspects, including measurement and actuation, data conditioning, acquisition and transmission, microprocessor devices and other distributed computing components. Commercial realisations ranging from PLCs to full process control computing systems. Software: executive operating systems, concurrency, control algorithms, numerical problems, languages and development tools in the real-time context. Design of the man-machine interface using interactive computer display systems. The role of simulation and other CAD tools. Steps of engineering development from concept to commissioning. The viewpoint of industrial design is maintained throughout.

The course outline defines material that would fill several subjects. We shall aim to develop certain fundamental concepts which underpin all of the above topics. The course content may be divided into three main areas: Modelling; Controller Design and Computer Implementation.

1.1 Modelling

- A review of linear models: transfer functions and bock diagrams; state space models; discrete state space; discrete transfer functions.
- Linear discrete models suitable for real-time application (Input/Output State Models)
- Limitations of such models
- Parameter identification of linear systems

1.2 Controller Design

- State Feedback and consequences of Input/Output State Models
- Linear quadratic control
- Output feedback and feedforward

1.3 Computer Implementation

- Numerical implementation of controller algorithms
- Real time requirements
- A real time operating system (Linux + RTAI)
- Commercial controller implementations and embedded systems
- Scaling

1.4 Student Learning Outcomes

The primary objective of this course is to provide you with the knowledge, skills and ability to implement a computer-based control system.

- Mastery of design and implementation of real time controllers based on the above topics.
- An appreciation of the theoretical issues which underpin the designs.
- In practical terms, this will mean the capacity to develop and identify linear models for industrial processes, to manipulate the models into forms suitable for controller design, to perform the optimisation necessary for realising the controller, to implement the controller in a high level language or block diagram form, to translate the controller into code suitable for real-time operation, to understand the functions performed by a real-time operating system, and to prepare real-time tasks suitable for implementation in an embedded system.
- While this course will concentrate on SISO plants, extensions to MIMO plants are readily undertaken.

More information about student learning outcomes is available at: www.ltu.unsw.edu.au/ref4-2-1_outcomes.cfm

Graduate attributes are the skills, qualities, understandings and attitudes a university agrees its students will develop during their program of study. The UNSW Graduate Attributes are available at: www.ltu.unsw.edu.au/ref4-4-1-1_unsw_grad_atts.cfm

Some Faculties have contextualised the UNSW Graduate Attributes according to their disciplines and professional areas. Faculty-based graduate attributes are available at: www.ltu.unsw.edu.au/ref4-4-1-2_faculty_grad_atts.cfm

1.5 The Rationale behind this Course's Approach to Learning

- You will be provided with material which describes the basic concepts and theory behind the modelling and design approaches. This will take the form of a paper on each topic.
- Additionally, you may be provided with DVD-based material to supplement normal lectures.
- You should supplement this material with additional readings, as appropriate to a post-graduate course.
- We will spend most of our time describing how to solve problems.
- Given the provision of materials, there may not be a "lecture" every week. However, you will be encouraged to undertake work in laboratories to enhance understanding of the formal material and problem solving. Assistance may be available at some of these informal sessions, by arrangement.
- All assessment will stress problem solving. It is important that you recognise this.

- You will only learn by doing. At some stage, you must close your notes and solve problems. Reading the notes will not by itself equip you to pass this course.
- It is essential that you form your own *schema*, i.e. your own mental models for how things work and fit together.
- Most evening classes will take the form of:
  - A lecture
  - Group problem solving activities
  - Commencement of an assignment which should be completed in your own time, some of which will be handed in for assessment.

Consult the Guidelines on Learning that Inform Teaching at UNSW. The Guidelines are available at: www.guidelinesonlearning.unsw.edu.au

2 Staff

A/Prof.	Tim Hesketh	Phone	9385 4009
Room	G08	Fax	9385 6743
	Ground Floor	E-Mail	T.Hesketh@unsw.edu.au
	EE Building		
Ms.	Z. Xi	E-Mail	zhiyu.xi@unsw.edu.au

My room and telephone number will change, but I can be contacted as nominated above. We can discuss how you can equip your own computer to support the work of this course.

3 Lectures and Course Material

Formal lecture time is 6.00 - 9.00 pm on Monday evenings during session. Lectures are scheduled for Room G25 in Electrical Engineering. At time s we will use Room 214, which is equipped with computers for interactive work.

A web page for the course will be developed, from which all material may be downloaded. You will be encouraged to study in your own time. The web page is: http://subjects.ee.unsw.edu.au/elec9733

3.1 Recommended Reading

Papers and notes will be handed out during the lectures and placed on the web page. The following texts will supplement the material, but are not essential:

1. Astrom, K. and B. Wittenmark, *Computer Controlled Systems*, Prentice Hall International, 1997. (An excellent book, though now a little dated).

2. Bennet, S., *Real Time Computer Control - An Introduction*, Prentice Hall International, 1994. (Not many books cover this topic as we require).

3. Bitmead, R., M. Gevers and V. Wertz, *Adaptive Optimal Control: The Thinking Man's GPC*, Prentice Hall International, 1990. (Another excellent book, dated, but worth having on one's bookshelf).

3.2 Software

We will be using Linux during the course, with RTAI for real-time extensions. The real time kernel is built on top of a Linux installation. We will make the software available for anyone who wishes to install it on their own machines. Otherwise, we will use machines in the laboratory. If you seriously want to install Linux at home, we will provide access to CD-ROMs. The School of Computer Science and Engineering mirrors software distributions.

Simulations and controller design will be undertaken with a suitable matrix manipulation package such as MATLAB; SCILAB will be used in the course. The SCILAB software is freely available on the web for both LINUX and WINDOWS. It can be downloaded from www.scilab.org

4 Assessment

There will be four assessment tasks.

Control Assignments The control assignments will enable demonstration of competence in performing modelling of a process, followed by controller design and simulation. The end result of this design is a controller suitable for real time implementation. Assignments are due in Week 6, Week 10 and Week 12; each is worth 10%.

Examination There will be a formal examination, scheduled as part of the University Examination process by the relevant offices reporting to the Registrar. The exam will contribute 70% to the final mark.

5 Plagiarism

Plagiarism is the presentation of the thoughts or work of another as one's own. [1] Examples include:

- direct duplication of the thoughts or work of another, including by copying work, or knowingly permitting it to be copied. This includes 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;

[1] Based on that proposed to the University of Newcastle by the St James Ethics Centre. Used with kind permission from the University of Newcastle

- 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. [2]
- Submitting an assessment item that has already been submitted for academic credit elsewhere may also be considered plagiarism.
- 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 and the Library also provide 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.

[2] Adapted with kind permission from the University of Melbourne.

6 Lecture Topics

Week	Topic
1	Linear systems revision
	Transfer functions, continuous/discrete state space, difference equations
2	Parameter estimation and model identification
3	Recursive parameter identification
4	Non-minimal state space models
5	Linear quadratic control
6	Controller design
7	Simulation methods
8	Software implementation of controllers
9	RTAI and real-time operating systems
10	Controller implementation in a real-time operating system
11	National Instruments and Labview
12	Design exercise and case studies