RYERSON UNIVERSITY

Department of Electrical and Computer Engineering

Winter 2004

ELE829: SYSTEM MODELING AND IDENTIFICATION

COURSE DESCRIPTION:

This is a one semester course providing an introduction to modern methods of linear system identification. Different types of models will be discussed: mechanistic, empiric, parametric, non-parametric. Discrete transfer function models from input-output data are introduced, first using Impulse Weights. The effect of noise is discussed; next Least Squares models are introduced. Data-collection procedures and methods of obtaining non-parametric models (impulse, step, and frequency responses) are discussed. Model structure selection is then introduced, based on analysis of the non-parametric models. Next, an overview of stochastic processes is provided. Combined deterministic-stochastic parametric models are introduced, and use of auto- and cross-correlation functions for diagnostics and model validation are discussed. Theory learned in the course is applied in a project identifying unknown systems using a Box-Jenkins approach.

Please note that the course has a strong focus on collaborative learning, and stresses development of teamwork, oral and written communication skills, as well as critical evaluation skills. Students are required to collaborate on a series of tutorials, a system identification project, as well as on researching and presenting a project illustrating modern applications of control systems.

Pre-Requisites: ELE639 Controls

Teaching Mode: Lect/Tutorial 4 hr/Week. **Location:** SHE662 and T208

Course Professor:	Room	Tel. No.	Email
Malgorzata S. Zywno, Ph.D. Course Coordinator	T217	979-5000 ext 6105	gosha@ee.ryerson.ca

Resources:

1. ELE829 Notes, M.S. Zywno, © 1999-2004, are available from the course Blackboard site, at http://courses.ryerson.ca. Please note that in order to access the course website, you need an active Matrix account. If you don't have one activated, or don't know what Matrix account is, please contact the Computer Services (L71) immediately.
2. MATLAB *System Identification Toolbox*, available on the Departmental Network as Matlab help files.

References:

There isn't a single text in the Systems Identification area that could be used for a course on an undergraduate level. Most of the texts are highly specialized and a difficult read. Course lecture notes will be the main source of information. They are based on several references:

1. *System Identification - Theory for the User*, L. Ljung, Prentice Hall, 1999.
2. *System Identification Toolbox, User's Guide*, L. Ljung, the MathWorks, Inc., 1995-99.
3. *Modeling and Identification of Dynamic Systems*, N.K. Sinha, B. Kuszta, Van Nostrand, 1983.
4. *Time Series Analysis and Process Identification*, P.A. Taylor, McMaster University, 1992.

Instructor Course Evaluation (ICE) Survey: March 2004, exact date TBA

COURSE EVALUATION:

Course evaluation will be done through tutorial assignments, a report on design project, and an independent Internet Research project with an oral presentation and a written report.

Tutorial Assignments (best three)	group	30%
Identification Project Report	group	20%
Written Report on the Internet Research Project	group	15%
Records of Team Meetings	group	10%
		75% *
Presentation on the Internet Research Project	group	15%
Peer evaluation of your presentation:	group	10%
Instructor evaluation of your presentation:	group	5%
Your Review Mark	individual	10%**
Total:		**100%**

SPECIFIC RULES:

- **All of the required course specific written reports will be assessed not only on their technical or academic merit, but also on the communication skills of the author(s), as exhibited through these reports.**
- *All written report marks are adjusted for individual group members based on the confidential "within the group" peer ratings of participation in team activities, filled out at the end of the course. In those assessments, team members will use Records of Team Meetings to justify the mark assignments.
- The Record of Team Meetings is a document filled out weekly by the team members, and signed by them all, describing the group meeting agenda, task distribution and individual contributions of team members in that week. It has to be handed in each week.
- **At the end of the semester each student submits documented assessments of all group presentations, including his or her own team. The instructor's evaluation is combined (at equal weights) with the class average to create a *class template*. Student's individual Review Mark is computed on a sliding scale, using Pearson's correlation coefficient between the template and the evaluation submitted by the student. A statistically significant correlation factor equal to or above the class median ensures a full Review Mark. Individual reviews convergent with perceptions of the class as a whole, and of the instructor, earn higher review marks. Unreasonable reviews result in the reduced marks.
- Five tutorials are to be completed by the teams, but only the best three will count toward the grade.
- Groups will engage in an independent research project on a control-related topic, will meet with the instructor regularly throughout the semester to discuss its progress, and will make a 20-minute multimedia presentation on it in the last two weeks of classes. An original demonstration of an experiment, or a software simulation, created specifically for the project is encouraged. A list of topics, some suggested sources and relevant publications, and other details will be available on the web site.
- The main goal of both the written report and the multimedia presentation on the researched topic is to educate the class on the wide extent of control systems and system identification in modern engineering applications. The write-up should have a form of an essay, include an Executive Summary, Bibliography and proper references to all sources of information, and concentrate on the accessibility of presented information. Because of the nature of the write-up, all teams will be required to submit it to Turnitin.com (http://www.turnitin.com) for verification that the work is original and properly referenced.
- All students are strongly encouraged to participate in the competition for a berth in the Ryerson 2004 Charette "Learning Environments that Work" – please see the enclosed flyer. The Information Night will take place on January 14, 2004. Successful applicants will participate in a three-day event, February 6-8, 2004, providing them with an extensive experience in cross-disciplinary team-building (urban planning, business, social work, and engineering), multidimensional thinking and presentation skills. The Charette presentations will be evaluated by a panel of judges from different department at Ryerson. Any ELE829 student participating in the Charette will have an option of using this experience and the mark received from the panel as a substitution for the Independent Research written report and presentation requirement in the course, worth a total of 30% of the course mark.

- Groups shall have maximum six members, with the maximum number of groups equal to 10. Team membership will be finalized in the first class on Tuesday, January 13, 2004.
- Only one report per group is required on all tutorials, and on both reports; group marks for tutorials, reports and presentations are released to all members of the group.
- All individual peer-assessments are confidential. An individual share of the group work is released only to the individual team member. Only cumulative mark is released.

EXPECTED GENERAL COURSE OUTCOMES

By the end of this semester the students will be able to:

- successfully perform a full identification of an unknown system, including specific tasks of:
    - designing a data collection experiment;
    - applying diagnostic tools to select an appropriate model structure;
    - verifying and presenting a robust model to effectively describe both the system dynamics and the system noise;
- write a comprehensive formal report with an executive summary, proper structure and references;
- improve their teamwork, communication and time management skills;
- improve their ability to research a technical subject, including:
    - identifying and evaluating sources of information, particularly on the WWW;
    - creating effective presentations on complex topics under strict time constraints;
- reflect on, and exercise judgment of performance and contributions of their peers, as well as their own, to accomplishing the team objectives;
- identify effective presentation skills and exercise judgment on the quality of oral presentations of their peers.

DETAILED COURSE SCHEDULE FOR WINTER 2004

Suggested Schedule for Lecture Topics and Reading Material Tuesdays, 9-11 am in SHE662	**Expected Weekly Learning Outcomes**	**Hands-On Activities Thursdays 2-4 pm and Mondays 9-11 am in T208**	**Course Deliverables**
Jan 13-19, 2004 Organizational meeting. Forming the teams. Goals for the course. Introduction to the course content: terminology, objectives, and system identification procedure. Types of empirical models: parametric, non-parametric, state-space, transfer function, continuous time, and discrete time.		**Tutorial # 1** Non-parametric models in frequency domain from PRBS signal: SPA, ETFE; Conversions between discrete and continuous domains. Conventional frequency response models.	
Jan 20-26, 2004 Review of discrete transfer function models, Z-transform. Conversion between continuous and discrete representations, sampling. Modern non-parametric estimation in time domain: step and impulse weights from deconvolution and correlation analysis. Modern non-parametric estimation in frequency domain: spectral analysis, discrete Fourier transforms.	By the end of this week, students will be able to: 1) list and classify different types of process models and modeling techniques; 2) choose an appropriate sampling rate to collect data and model it in discrete domain; 3) build a simple empirical model of a SISO system based on its frequency response.	**Tutorial # 1** Continuation.	List of presentation topics available on the web site. Sign-up for the presentation topics and the presentation slots begins. It is by email, on the first-come-first-serve basis.

Jan 27-Feb 2, 2004 Identification of simple parametric discrete models from impulse response. The effect of noise on the robustness of the solution. Hankel Test of system order. Other diagnostic tests – step, impulse and frequency responses. Vector and matrix norms. Least Squares method. Least Squares estimation of parametric models with and without noise.	By the end of this week, students will be able to: 1) build a non-robust parametric discrete model from impulse weights; 2) select the model order based on the Hankel Test; 3) estimate the system order based on its frequency response; 4) estimate the system delays from impulse weights; 5) define different matrix norms and assess whether data is ill-conditioned.	**Tutorial # 2** Non-parametric models in time domain – impulse and step weights from PRBS signal. Conversions between discrete and continuous domains. Conventional models in time domain.	Tutorial # 1 handed in by the end of the lecture on January 27, 2004.
Feb 3-9, 2004 Least Squares estimation of parametric models continued. Plant tests to obtain I/O data. Introduction to MATLAB System Identification Toolbox. Simple combined stochastic-dynamic model - Output Error (OE).	By the end of this week, students will be able to: 1) explain how numerical methods can be used for modern system identification; 2) design a data collection experiment with an appropriate PRBS signal; 3) build a robust parametric discrete model using Least Squares algorithm; 4) compare the effect of system noise on impulse weights vs. LSQ models.	**Tutorial # 2** Continuation.	Final deadline for picking up the presentation topic – **Monday, February 9, 4pm, by email**.
Feb 10-16, 2004 Combined stochastic-dynamic models (Box-Jenkins structures): BJ, PEM models. Review of different parameter estimation algorithms.	By the end of this week, students will be able to: 1) model system noise using OE structure; 2) explain advantages and disadvantages of different stochastic-dynamic models; 3) select a model structure and apply an appropriate estimation algorithm; 4) evaluate the quality of identification through Loss Function and Akaike Index.	**Tutorial # 3** Least Squares warm-up exercise. Simple parametric model: LSQ Model.	Tutorial # 2 handed in by the end of the lecture, on February 10, 2004.
Feb 17-20, and March 1, 2004 Review of stochastic processes. Auto-, Partial Auto- and Cross-Correlation Functions. Stochastic models for noise: AR, MA, ARMA, and “Random Walk” processes.	By the end of this week, students will be able to: 1) recognise patterns in correlation functions corresponding to different sources of noise and to presence of feedback; 2) select a noise model appropriate for the collected data.	**Tutorial # 3** Continuation.	
Feb 23 – Feb 27, 2003 Study Week: no lectures, no hands-on activities, no counseling			

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March 2-8, 2004 Scheduled group consultations on the multimedia presentations.			Tutorial # 3 handed in by the end of the lecture, on March 2, 2004.
March 9-15, 2004 Residue whiteness testing - Chi-Square tests, Confidence Intervals. Model structure selection, diagnostics and model validation. Examples of a full system identification procedure.	By the end of this week, students will be able to: 1) select appropriate diagnostic tests for the system; 2) test for and justify the choice of the model order and its delays and select the model structure; 3) perform various validation tests; 4) compare and contrast different valid models for the system, and justify the final model choice. 5) apply the complete procedure to identify a simulated unknown industrial SISO process with noise.	**Tutorial # 4** Parametric Models in time domain: OE Model.	
March 16-22, 2004 **Multimedia Presentations** Where: in SHE662. When: **Tuesday March 16, 2003.** How: five presentation slots, each is 20 minutes + 5 minutes for questions.		**Tutorial # 5** Stochastic processes.	Tutorial # 4 handed in by the end of the lecture, on March 16, 2004.
March 23-29, 2004 **Multimedia Presentations** Where: in SHE662. When: **Tuesday March 23, 2003.** How: five presentation slots, each is 20 minutes + 5 minutes for questions.		**Tutorial # 5** Continuation.	All individual presentation evaluations handed in by **Monday, March 29, 4pm***.
March 30-April 5, 2004 Hints on effective writing of technical reports, proper referencing techniques, code of student ethics vis. a vis. plagiarism.	By the end of this week, students will improve their ability to: 1) outline the structure of a formal technical report; 2) properly reference sources in written submissions; 3) define and choose contents of an executive summary.	No scheduled activities – work on final reports.	Written report on Research Project handed in by **Monday, April 5, 4 pm*.**
April 6-12, 2004 No scheduled activities: project wrap-up. Counseling during lecture time. Tutorial # 5 handed in by the end of the lecture, on April 6, 2004. Identification Project and all individual “within-the-group” peer evaluations handed in by Monday, **April 12, 4pm***.			

*Ask to have your submission date & time-stamped at the main desk and drop it off in my mailbox.