Faculty of Engineering, Architecture and Science

Department of Electrical Engineering

**Course Outline (Fall 2015)**

**ELE829: System Modeling and Identification**

**Instructor**
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**Prerequisites**
ELE639

**Course Type**
Elective

**Program Level**
ELE 07 (7th Semester)

**Website**
my.ryerson.ca (Blackboard)

**Compulsory Text**
1. ELE829 Notes, M.S. Zywno, © 1999-2015, are available from the course Blackboard site, at [http://courses.ryerson.ca](http://courses.ryerson.ca).
2. MATLAB System Identification Toolbox, available on the Departmental Network as Matlab help files.

**Reference Texts**
Texts in this area are highly specialized, therefore course lecture notes will be the main source of information. They are based on several references:


**Calendar Description**
Introduction to modern methods of linear system identification. Different types of models: mechanistic, empiric, parametric, non-parametric. Review of classic time- and frequency-based approach to empirical, 'black-box' system modeling. Non-parametric identification: impulse and step weights, spectral analysis. Parametric, discrete transfer function models from I/O data using Least Squares. Data-collection procedures and methods of obtaining non-parametric models (impulse, step, and frequency responses). Model structure selection based on analysis of the non-parametric models. An overview of stochastic processes and introduction of noise models. Combined deterministic-stochastic parametric models (Box-Jenkins models). Diagnostics and model validation through use of auto- and cross-correlation functions. Theory learned in the course is applied in a project identifying unknown systems using the Box-Jenkins approach, as well as to a real-life system, the servomotor positioning system first introduced in ELE639 lab.

Tutorial/Laboratory work consists of MATLAB simulations as well as real-time experiments with the servomotor, reinforcing analytical concepts and design procedures.
Learning Objectives

At the end of this course, the successful student will be able to:

1. Demonstrate competency in developing mathematical models for deterministic systems (dynamic processes) and for stochastic systems (noise), identify and carry out steps required in performing a successful model identification procedure (2a, 2b, 2c).

2. Design data collection experiments for diagnostics and identification of the model, select an appropriate model structure in form of a Box-Jenkins (BJ) process transfer function and noise filter function, an appropriate Least Squares Algorithm (4b, 4c), and then evaluate the quality of the derived combined system & noise model by validating it according to a set of criteria. (4f, 4h).

3. Demonstrate proficiency in the use of high-performance engineering modeling and analysis software (Matlab), including System Identification Toolbox, to perform system and noise model diagnostics, identification and verification, as appropriate in this course, and for subsequent engineering practice. (5c)

4. Apply the tools for system identification to a real-time control system (servomotor); this includes obtaining and verifying experimental data, selecting an appropriate analytical model, verifying the system model by comparing it to experimental results, assessing accuracy of the results and explaining sources of possible discrepancies. (3a, 3c)

5. Produce a technical report using appropriate format, grammar, and citation styles, with figures and tables carefully chosen to illustrate points made, with appropriate size, labels and references in the body of the report, and respond appropriately to verbal questions from instructors - lab interviews. (7a, 7d, 7b)

Note: Numbers in parentheses refer to the graduate attributes required by the Canadian Engineering Accreditation Board. For more information, see: http://ryerson.ca/feas/programs/qa/gradattributes.html

Assessment of Learning Objectives

1. Objectives (2a, 2b, 2c) - Engineering Science - will be assessed by:
   a. 80% of Lab 1, Lab 2, Lab 3 and 15% of Lab 4 (worth 25.6%)  
   b. 60% of Class Activities (worth 9%)  
   c. 50% of Final Project (worth 22.5%)  
   Total: 57.1%

2. Objectives (4b, 4c, 4f) - Engineering Design - will be assessed by:
   a. 25% of Lab 4 (worth 2.4%)  
   b. 40% of Class Activities (worth 6%)  
   c. 50% of Final Project (worth 22.5%)  
   Total: 30.9%

3. Objective (3a,3c) - Investigation - will be assessed by:
   a. 40% of Lab 4 (worth 4%)  
   Total: 4%

4. Objective (5c) - Engineering Tools - will be assessed by:
   a. 30% of Lab 1, Lab 2, Lab 3 and Lab 4 (worth 9.6%)  
   b. 30% of Class Activities (worth 4.5%)  
   c. 30% of Final Project (worth 13.5%)  
   Total: 27.6%
5. Objectives (7a, 7d): Written Communication Skills - will be assessed by 30% of Lab 1, Lab2, Lab 3, Lab 4 (worth 9.6%); and Final Report -Executive Summaries and Discussions (worth 13.5%); Objectives (7b) - Oral Communication Skills - will be assessed by 20% of Lab 1, Lab2, Lab 3 and Lab 4 - Interviews with TAs (worth 8%)

NOTE:

- Assessment of Objectives (2a, 2b, 2c) Engineering Science, (4b, 4c, 4f) Design, (3a,3c) Investigation and (7b) Oral Communications add up to: 57.1% + 30.9% + 4% + 8% = 100%.
- There is an overlap in assessment of Objectives (5c) Engineering Tools and (7a, 7d) Written Communications, which add up to 50.7%. In the assessment of objectives for Engineering Science and Engineering Design, some of the same outcomes are used, because this course utilizes heavily the software for analysis and design, and written reports are used as a major assessment (no tests or final exams), combined with oral interviews.

Course Organization

<table>
<thead>
<tr>
<th>Course Organization</th>
<th>3 hours of lecture per week for 13 weeks, in 1 section</th>
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<tbody>
<tr>
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<td>1 hour of tutorial every week for 13 weeks</td>
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<td>3 Tutorial sections of maximum of 25 students</td>
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<td>2 Teaching Assistants</td>
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Course Evaluation

<table>
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<tr>
<th>Course Evaluation</th>
<th>Course Activities 15%</th>
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<td>Four Tutorial projects (in pairs) 40%</td>
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<td></td>
<td>Final report (individual) 45%</td>
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<td>Total 100%</td>
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NOTE: To earn a passing grade, a student must pass both the Individual (Report) and the Group (Tutorials) component of the course.

Examinations

Course evaluation is ongoing and semester-long, and includes both group work (tutorial reports) and individual effort (final project). Course activities include both individual effort, such as simple pop quizzes, and small group work on application of theory learned.
## Course Content

<table>
<thead>
<tr>
<th>Date</th>
<th>References</th>
<th>hours</th>
<th>Topic, description</th>
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<tbody>
<tr>
<td>WEEK 1</td>
<td>ELE829 Course Notes Part 1</td>
<td>2</td>
<td>Introductory meeting. Goals for the course and course logistics. Overview: terminology, objectives, introduction to modern identification procedures (diagnostics, identification, validation), types of models.</td>
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<tr>
<td>WEEK 3</td>
<td>ELE829 Course Notes Part 2, 3</td>
<td>3</td>
<td>Review: Transfer function models, conversion between continuous and discrete representations, sampling. Modeling - simple Box-Jenkins model structures: OE Model.</td>
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<tr>
<td>WEEK 8 &amp; 9</td>
<td>ELE829 Course Notes Part 5</td>
<td>6</td>
<td>Least Squares method. Robustness of parametric models, the effect of noise. Introduction to combined dynamic-stochastic models - Box-Jenkins structures.</td>
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<tr>
<td>WEEK 12</td>
<td>ELE829 Course Notes Part 7</td>
<td>3</td>
<td>Stochastic models for noise: AR, MA, ARMA, and “Random Walk” processes. Validation for all BJ Models: Residue whiteness testing - Chi-Square tests, Confidence Intervals.</td>
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<tr>
<td>WEEK 13</td>
<td>ELE829 Course Notes Part 6, 8</td>
<td>4</td>
<td>Review - designing data collection experiment, model structure selection, diagnostics and model validation. Examples of a full system identification procedure. Questions and answers regarding the final project.</td>
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### Course Deliverables: Tutorials and Final Project

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<thead>
<tr>
<th>Week</th>
<th>Title</th>
<th>Room</th>
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<tbody>
<tr>
<td>Weeks 2, 3 &amp; 4</td>
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### Tutorial # 3

**Week 8**

Stochastic Noise Models  
(1 session)  

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### Tutorial # 4

**Weeks 9 & 10**

Simple System Identification of a Real-Life System (Servomotor)  
(2 sessions)  
Part 1: Obtaining Experimental Frequency and Time Domain Responses from a the Servomotor  
Part 2: Simple Model identification using OE Model, and Comparisons with Nominal Values Model

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### Individual Final Project

**Weeks 11 -13**

Final System Identification Project  
(3 sessions)  
“Black Box” System Identification of two systems ("Easy" and "Difficult").  
Part 1: Diagnostics for both G(q) and H(q) models  
Part 2: Identification  
Part 3: Validation

**ENGR413**

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### Important Notes

1. All of the required course-specific written reports will be assessed not only on their technical/academic merit, but also on the communication skills exhibited through these reports.

2. All tutorial and project reports must have the standard cover page which can be completed and printed from the course Blackboard website. The cover page must be signed by the student(s) prior to submission of the work. Submissions without the cover pages **will not** be accepted.

3. Medical or Compassionate documents for the missed submission deadline for a tutorial or the project report must be submitted within 3 working days of the deadline.

4. Requests for accommodation of specific religious or spiritual observance must be presented to the instructor no later than two weeks prior to the conflict in question. If the dates are not known well in advance because they are linked to other conditions, requests should be submitted as soon as possible in advance of the required observance. Given that timely requests will prevent difficulties with arranging constructive accommodations, students are strongly encouraged to notify the instructor of an observance accommodation issue within the first two weeks of classes.

5. The results of the first evaluation will be returned to students before the deadline to drop an undergraduate course in good Academic Standing.

6. Students are required to adhere to all relevant University policies including:
   - Undergraduate Grading, Promotion and Academic Standing, [http://www.ryerson.ca/senate/policies/pol46.pdf](http://www.ryerson.ca/senate/policies/pol46.pdf)
   - Student Code of Academic Conduct, [http://www.ryerson.ca/senate/policies/pol60.pdf](http://www.ryerson.ca/senate/policies/pol60.pdf)
   - Undergraduate Academic Consideration and Appeals, [http://www.ryerson.ca/senate/policies/pol134.pdf](http://www.ryerson.ca/senate/policies/pol134.pdf)
7. All students are required to activate and maintain a Ryerson University central Matrix e-mail account which shall be the official means by which they will receive University communications. These communications will be via Blackboard course website at https://my.ryerson.ca/. Emails from other sources (such as yahoo, hotmail, gmail, etc.) will be ignored.

8. There are four tutorials, combining computer simulations with real-time control experiments on a servomotor. The tutorials are to be completed in pairs. Both partners shall contribute equally to the tutorial report. All students will be interviewed by their lab instructor and will be asked to describe their contributions to the report. Any student found not to have contributed to the tutorial report will be asked to re-do it on their own and will no longer be eligible to work with a partner.

9. In all tutorials and in the final project students will work with distinct, non-repeating data sets that are frequently updated.

10. 15% of the grade is assigned to Course Activities - all students registered in ELE829 are expected to participate throughout the course in activities, either individual or group, in-class or take-home, that will support their understanding of the course material, such as: answering questions using iClickers, pop-quizzes, take-home assignments, computer simulations, etc. All students are expected to either purchase iClickers, or download an equivalent app for a tablet/mobile, and to use them during classes.

11. Any changes in the course outline, test dates, marking or evaluation will be discussed in class prior to being implemented.

Course Developer: Professor Malgorzata S. Zywno, Ph.D., P.Eng. F.E.C. Date: December 3, 2014

Program Director of Electrical Engineering: _______________________________ Date: _______________