# Course Outline (F2018)

### ELE829: System Models and Identification

| Instructor(s) | Saba Sedghizadeh (Coordinator)  
|              | Office: ENG328  
|              | Phone: TBA  
|              | Email: ssedghiz@ryerson.ca  
|              | Office Hours: Tuesdays 11:30AM - 1:30PM |

### Calendar Description


### Prerequisites

ELE 639

### Antirequisites

None

### Corequisites

None

### Compulsory Text(s):

1. ELE829: Course Notes, The notes are available from the secure course website, (login at https://my.ryerson.ca) as PDF downloadable files.


### Reference Text(s):


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

1. Demonstrates competency in developing mathematical models for deterministic systems (dynamic processes) and for stochastic systems (noise). Uses relevant computer simulation software - MATLAB System Identification Toolbox. Identifies and carries out steps required in performing a successful model identification procedure. Evaluates the effect of uncertainty in model parameters. (2b)

2. Applies the tools for system identification to a real-time servomotor system, including obtaining experimental data. Selects appropriate analytical model for the real-time servomotor system, and verifies the model by comparing to experimental results. (3a)

3. Selects appropriate analytical model for the real-time servomotor system, and verifies the model by comparing to experimental results. Assesses accuracy of the results obtained from the real-time servomotor system, verifying experimental data and explaining sources of possible discrepancies (non-linearity), (3b)

4. Designs data collection experiments for diagnostics and identification of the model, selects appropriate model structure (BJ model) and noise filter function, and appropriate Least Squares Algorithm. (4b), (4a)

5. Evaluates the quality of the derived system and noise models by validating against a set criteria, then improves the design until the model is validated. (4c)

6. Demonstrates proficiency in the use of high-performance engineering modeling and analysis software, including System Identification Toolbox, in this course, and for subsequent engineering practice â€” by completing and demonstrating to the professor the required simulation and analyses to perform system and noise model diagnostics, identification and verification. (5a)

7. Produces a professionally prepared technical report using appropriate format, grammar, and citation styles, with figures and tables chosen to illustrate points made, with appropriate size, labels and references in the body of the report. Reports are graded on correctness, completeness, grammar, quality of graphics and layout. (7a)

8. Responds appropriately to verbal questions from instructors, formulating and expressing ideas, using appropriate technical terminology â€” this is assessed through comprehensive lab interviews by instructors. (7b)

NOTE: Numbers in parentheses refer to the graduate attributes required by the Canadian Engineering Accreditation Board (CEAB).

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### Course Organization

- 3.0 hours of lecture per week for 13 weeks
- 1.0 hours of lab/tutorial per week for 12 weeks

### Teaching Assistants

1. Somayeh Norouzi Ghazbi
2. Brandon Mac

### Course Evaluation

<table>
<thead>
<tr>
<th>Component</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quizzes (3 x 10%)</td>
<td>30 %</td>
</tr>
<tr>
<td>Lab/Tutorial Project (Group) #1</td>
<td>8 %</td>
</tr>
<tr>
<td>Lab/Tutorial Project (Group) #2</td>
<td>8 %</td>
</tr>
<tr>
<td>Lab/Tutorial Project (Group) #3</td>
<td>8 %</td>
</tr>
<tr>
<td>Lab/Tutorial Project (Group) #4</td>
<td>6 %</td>
</tr>
<tr>
<td>Final Project Report (Individual)</td>
<td>40 %</td>
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<tr>
<td>TOTAL:</td>
<td>100 %</td>
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</tbody>
</table>

### Examinations

Course evaluation is ongoing and semester-long and includes both group work (lab/tutorial reports) and individual effort (quizzes and final project). All reports include simulations – Matlab codes are submitted and parsed for originality and efficacy. The course professor personally verifies all individual codes submitted with the final report. If the execution of the code does not support claims in the report, the project will automatically receive an automatic deduction in the grade.

### Other Evaluation Information

None

### Other Information

Students will learn to work MATLAB System Identification Toolbox in the tutorial class with the help of course TAs.
<table>
<thead>
<tr>
<th>Week</th>
<th>Hours</th>
<th>Chapters / Section</th>
<th>Topic, description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1</td>
<td>3</td>
<td></td>
<td>Introduction: General introduction to system identification and modeling Purpose of modeling Parametric models and Non-parametric models System identification procedure (Experiment design and data examination Model structure selection Model estimation Model validation) Choice of input signal Data collection and examination (Outliers Aliasing effect Trends Noise filtering Persistent excitation) (References: Course Notes Week 1)</td>
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<tr>
<td>Week 2</td>
<td>3</td>
<td></td>
<td>Non-parametric Models in Frequency-Domain: Frequency-response analysis Modeling via Bode plots Empirical transfer function estimate method (ETFE) Statistical properties of ETFE Smoothing the ETFE Spectral analysis method (SPA) Smoothing the SPA. (References: Course Notes Week 2)</td>
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<tr>
<td>Week 3</td>
<td>3</td>
<td></td>
<td>Parametric Models Structures: General parametric model structure Classification of parametric models Transfer function models (ARMAX ARX BJ and OE models) Time Series Models (AR MA and ARMA models) Conversion between continuous-time and discrete-time representations Poles/Zeros transformation rules from s-plane to z-plane Output-Error (OE) Model Estimation Introduction to model validation tools. (References: Course Notes Week 3)</td>
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<tr>
<td>Week 4</td>
<td>3</td>
<td></td>
<td>Non-parametric Models in Time-Domain: Transient-response analysis Simple model identification from step response Deconvolution method Impulse response reconstruction Step response recovery Effect of noisy data and robustness Correlation Analysis Impulse response estimation Statistical properties of the correlation function (References: Course Notes Week 4)</td>
</tr>
<tr>
<td>Week 5</td>
<td>3</td>
<td></td>
<td>Parametric Models Identification: Review of matrix algebra Singular value decomposition (SVD) Parametric model identification from the impulse response Model order estimation via Hankel matrix MATLAB function for Hankel matrix test Model order estimation via singular values Effect of noisy data on order selection and parametric model identification and robustness (References: Course Notes Week 5)</td>
</tr>
<tr>
<td>Week 6</td>
<td>3</td>
<td></td>
<td>Parameter Estimation Methods: General Least Squares Problem Regression models Least Squares estimation of static systems Least Squares solution via Normal equation Least Squares solution via SVD Geometric interpretation (References: Course Notes Week 6)</td>
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<tr>
<td>Week 7</td>
<td>3</td>
<td></td>
<td>Parameter Estimation Methods: Least Squares estimation in dynamic systems Parameters estimation for deterministic transfer function models Effect of noise on Least squares estimation (References: Course Notes Week 7)</td>
</tr>
<tr>
<td>Week 8</td>
<td>3</td>
<td></td>
<td>Model Validation Techniques: Model validity criterion Loss function Akaike's Final Prediction Error (FPE) Pole-Zero plots Bode diagram Residual analysis Confidence intervals Auto-correlation test Cross-correlation test Whiteness test Chi-squared test Simulation and Cross-validation (References: Course Notes Week 8)</td>
</tr>
<tr>
<td>Week 9</td>
<td>3</td>
<td></td>
<td>Noise Model Identification: Review of basic definitions of stochastic processes Time series models (AR MA and ARMA models) General AR process Markov process Yule process Yule-Walker Equation Partial auto-covariance function General MA process General ARMA process (References: Course Notes Week 9)</td>
</tr>
</tbody>
</table>
Combined Deterministic and Stochastic Models: Box-Jenkins (BJ) structure Complete identification and validation for BJ Model
(References: Course Notes Week 10)

Advanced Topics in System Identification: Closed-loop system identification Direct Approach
Indirect Approach Joint Input-Output Approach
(References: Course Notes Week 11)

Overview of Final Project: Part 1: Least squares curve fitting from noisy data Part 2: "Black Box" System Identification of a BJ/PEM model Questions and answers regarding the final project
(References: Course Notes Week 12)

Course Review: Review of the course materials Questions and answers regarding the final project Course wrap up.

Laboratory/Tutorials/Activity Schedule

| Week 10 | 3 | Combined Deterministic and Stochastic Models: Box-Jenkins (BJ) structure Complete identification and validation for BJ Model (References: Course Notes Week 10) |
| Week 11 | 3 | Advanced Topics in System Identification: Closed-loop system identification Direct Approach Indirect Approach Joint Input-Output Approach (References: Course Notes Week 11) |
| Week 12 | 3 | Overview of Final Project: Part 1: Least squares curve fitting from noisy data Part 2: "Black Box" System Identification of a BJ/PEM model Questions and answers regarding the final project (References: Course Notes Week 12) |
| Week 13 | 3 | Course Review: Review of the course materials Questions and answers regarding the final project Course wrap up. |

<table>
<thead>
<tr>
<th>Week</th>
<th>Lab</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>ENG413</td>
<td>Tutorial 4: Stochastic Noise Models - Identify the structure of different noise models (AR, MA, and ARMA)</td>
</tr>
<tr>
<td>11, 12, 13</td>
<td>ENG413</td>
<td>Final Project: Students use the tutorial time to work on their final projects. - Part 1: Noise reduction and curve fitting an unknown function (Noise reduction via SVD and Curve fitting by Least-squares) - Part 2: &quot;Black Box&quot; System Identification of an unknown BJ/PEM-type system (Diagnostics, Identification, and Validation)</td>
</tr>
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Policies & Important Information:

1. Students are required to obtain and maintain a Ryerson e-mail account for timely communications between the instructor and the students;
2. Any changes in the course outline, test dates, marking or evaluation will be discussed in class prior to being implemented;
3. Assignments, projects, reports and other deadline-bound course assessment components handed in past the due date will receive a mark of ZERO, unless otherwise stated. Marking information will be made available at the time when such course assessment components are announced.
4. If you have taken the course previously and are currently looking to get a laboratory exemption, then you must fill out this form:
Important Resources Available at Ryerson

Academic Integrity

If a student needs accommodation because of religious, Aboriginal or spiritual observance, they must submit a Request for Accommodation of Student Religious, Aboriginal and Spiritual Observance AND an Academic Consideration Request form within the first 2 weeks of the class or, for a final examination, within 2 weeks of the posting of the examination schedule. If the requested absence occurs within the first 2 weeks of classes, or the dates are not known well in advance as they are linked to other conditions, these forms should be submitted with as much lead time as possible in advance of the absence. Both documents are available at www.ryerson.ca/senate/forms/relobservforminstr.pdf. If you are a full-time or part-time degree student, then you submit your forms to your own program department or school.

Missed Classes and/or Evaluations

When possible, students are required to inform their instructors of any situation which arises during the semester which may have an adverse effect upon their academic performance, and must request any consideration and accommodation according to the relevant policies as far in advance as possible. Failure to do so may jeopardize any academic appeals.

1. **Health certificates** - If a student misses the deadline for submitting an assignment, or the date of an exam or other evaluation component for health reasons, they should notify their instructor as soon as possible, and submit a Ryerson Student Health Certificate AND an Academic Consideration Request form within 3 working days of the missed date. Both documents are available at https://www.ryerson.ca/senate/forms/medical.pdf. If you are a full-time or part-time degree student, then you submit your forms to your own program department or school.

2. **Religious, Aboriginal and Spiritual observance** - If a student needs accommodation because of religious, Aboriginal or spiritual observance, they must submit a Request for Accommodation of Student Religious, Aboriginal and Spiritual Observance AND an Academic Consideration Request form within the first 2 weeks of the class or, for a final examination, within 2 weeks of the posting of the examination schedule. If the requested absence occurs within the first 2 weeks of classes, or the dates are not known well in advance as they are linked to other conditions, these forms should be submitted with as much lead time as possible in advance of the absence. Both documents are available at www.ryerson.ca/senate/forms/relobservforminstr.pdf. If you are a full-time or part-time degree student, then you submit your forms to your own program department or school.

3. **Academic Accommodation Support** - Before the first graded work is due, students registered with the Academic Accommodation Support office (AAS - www.ryerson.ca/studentlearningsupport/academic-accommodation-support) should provide their instructors with an Academic Accommodation Support letter that describes their academic accommodation plan.

Academic Integrity

Ryerson's Policy 60 (the Academic Integrity policy) applies to all students at the University. Forms of academic misconduct include plagiarism, cheating, supplying false information to the University, and other acts. The most common form of academic misconduct is plagiarism - a serious academic offence, with potentially severe penalties and other consequences. It is expected, therefore, that all examinations and work submitted for evaluation and course credit will be the product of each student's individual effort (or an authorized group of students). Submitting the same work for credit to more than one course, without instructor approval, can also be considered a form of plagiarism. Suspicions of academic misconduct may be referred to the Academic Integrity Office (AIO). Students who are found to have committed academic misconduct will have a Disciplinary Notation (DN) placed on their academic record (not on their transcript) and will normally be assigned one or more of the following penalties:

1. A grade reduction for the work, ranging up to an including a zero on the work (minimum penalty for graduate work is a zero on the work);
2. A grade reduction in the course greater than a zero on the work. (Note that this penalty can only be applied to course components worth 10% or less, and any additional penalty cannot exceed 10% of the final course grade. Students must be given prior notice that such a penalty will be assigned (e.g. in the course outline or on the assignment handout);
3. An F in the course;
4. More serious penalties up to and including expulsion from the University.

The unauthorized use of intellectual property of others, including your professor, for distribution, sale, or profit is expressly prohibited, in accordance with Policy 60 (Sections 2.8 and 2.10). Intellectual property includes, but is not limited to:

1. Slides
2. Lecture notes
3. Presentation materials used in and outside of class
4. Lab manuals
5. Course packs
6. Exams

For more detailed information on these issues, please refer to the Academic Integrity policy (https://www.ryerson.ca/senate/policies/pol60.pdf) and to the Academic Integrity Office website (https://www.ryerson.ca/academicintegrity/).

Important Resources Available at Ryerson

1. The Library (https://library.ryerson.ca/) provides research workshops and individual assistance. Inquire at the Reference Desk on the second floor of the library, or go to library.ryerson.ca/guides/workshops
2. Student Learning Support (https://www.ryerson.ca/studentlearningsupport) offers group-based and individual help with writing, math, study skills and transition support, and other issues.

Approved by: _______________________________                Date ________________________________

Course Instructor