Department of Electrical, Computer, & Biomedical Engineering
Faculty of Engineering & Architectural Science

Course Outline (F2023)

ELE829: System Models and Identification

Instructor(s)	Md Waselul Haque Sadid [Coordinator] Office: TBA Phone: TBA Email: whsadid@torontomu.ca Office Hours: Wednesday 10:00 - 11:00
Calendar Description	Introduction to modern methods of linear system identification. Different types of models. 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, model structure selection, use of auto- and cross-correlation functions for diagnostics and model validation, overview of different estimation algorithms.
Prerequisites	ELE 639
Antirequisites	None
Corerequisites	None
Compulsory Text(s):	1. ELE829: Course Notes, available from the secure course website (login at https://my.ryerson.ca) as PDF downloadable files. 2. MATLAB System Identification Toolbox (Matlab R2020) and System Identification Toolbox, User Guide, L. Ljung, the MathWorks, Inc., Copyright 1995-2020, available on the Departmental Network as Matlab help files.
Reference Text(s):	1. System Identification - Theory for the User, L. Ljung, Prentice Hall, 11th Edition, 2009. 2. System Identification, T. Soderstrom, P. Stoica, Prentice Hall, 1994.
Learning Objectives (Indicators)	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 by completing and demonstrating to the professor the required simulation and analyses to perform system and noise model diagnostics, identification and verification. (**5a**)
7. Helps other team members, and accepts help, on technical and team issues. Demonstrates capacity for team leadership while respecting others roles. Evaluates team effectiveness and plans for improvements. (**6b**)
8. 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**)
9. Responds appropriately to verbal questions from instructors, formulating and expressing ideas, using appropriate technical terminology this is assessed through comprehensive lab interviews by instructors. (**7b**)
10. Demonstrates an understanding of project management principles, applying them both to the individual final project and to group tutorials. These include: negotiating the project scope, managing the deadlines, decomposing projects into key tasks and allocating responsibilities and resources according to deadlines. (**11b**)

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

Course Organization

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

Teaching Assistants

Shayan Sepahvand, shayan.sepahvand@torontomu.ca

Course Evaluation

Theory	
Course Activities (Individual/Group)	20 %
Final Project Report (Individual)	40 %
Laboratory	
Lab/Tutorial Project (Group) #1	9 %
Lab/Tutorial Project (Group) #2	9 %
Lab/Tutorial Project (Group) #3	9 %
Lab/Tutorial Project (Group) #4	13 %
TOTAL:	100 %

Note: In order for a student to pass a course, a minimum overall course mark of 50% must be obtained. In addition, for courses that have both **"Theory and Laboratory"** components, the student must pass the Laboratory and Theory portions separately by achieving a minimum of 50% in the combined Laboratory components and 50% in the combined Theory components. Please refer to the **"Course Evaluation"** section above for details on the Theory and Laboratory components (if applicable).

Examinations	Course evaluation is ongoing and semester-long, and includes both group work (lab/tutorial reports) and individual effort (final project). All reports include simulations. The course professor 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 receive a non-negotiable and significant reduction in the grade.
Other Evaluation Information	Course activities are part of the ongoing and semester-long evaluation: there are graded activities in every week of classes (on top of scheduled tutorial/lab reports). The graded activities include both individual assessments (D2L quizzes), homework assignments and computer simulations on the application of theory learned, which are then demonstrated to the professor in class.
Teaching Methods	Lectures and Tutorials will be conducted in person. Students will have access to course materials on D2L. Students will be required to complete D2L Quizzes and Homework Assignments using upload features of D2L. All tutorials and final project reports have to be uploaded to D2L. Zoom teleconferencing software will be used for individual consultation, office hours, and individual student simulation presentations.
Other Information	Students will learn to work MATLAB System Identification Toolbox in the tutorial session with the help of course TA.

Course Content

Week	Hours	Chapters / Section	Topic, description
Week 1	3		Goals for the course and course logistics. Overview: terminology, objectives, introduction to modern identification procedures (diagnostics, identification, validation), types of models. Data Collection - PRBS signal. Introduction to Matlab System Identification Toolbox. Introduction to Tutorial # 1. Review - frequency response, Bode plots for conventional modeling.
Week 2	3		Modeling: Non-parametric models in frequency domain: SPA, ETFE. Review: Transfer function models, conversion between continuous and discrete representations, sampling. Modeling - simple Box-Jenkins model structures: OE Model (deterministic process, white noise). Diagnostic tools in frequency domain - summary. Activity # 1 due.
Week 3	3		Introduction to Tutorial # 2: Non-parametric models in time domain. Review - time domain response for conventional modeling (Step and Impulse response plots). Review of basic definitions of stochastic processes. Non-parametric models in time domain: impulse and step weights from de-convolution and from correlation analysis. The effect of noise on non-parametric models in time domain. Simple parametric, non-robust, discrete transfer function models from impulse weights. Hankel Test of system order. Activity # 2 due.
Week 4	3		Diagnostic tools in time domain summary. Review of matrix algebra. Introduction to Least Squares methods. Robustness of parametric models, The effect of noise on conventional parametric models (non-robust and robust).

Week 5	3		Introduction to time-series modeling. Combined dynamic-stochastic models - Box-Jenkins structures. Overview of different parameter estimation algorithms. Figures of Merit for Model selection: Akaike Index, Loss Function. Refining OE model: ACF, PACF and CCF checks. Activity # 3 (D2L Quiz) due.
Week 6	3		Validation for OE Model: Residue whiteness testing - Chi-Square tests, Confidence Intervals. Full examples of OE Model Identification and Validation. Hands-on simulations and group work.
Week 7	3		Hands-on simulations and group work - Activity # 4 due. Introduction to Tutorial # 3: Stochastic noise models. Noise models: AR, MA, ARMA, processes. Auto- and Partial Auto-Correlation Functions as diagnostic tools for stochastic noise models.
Week 8	3		Hands-on simulations and group work - Activity # 6 due. Summary of all diagnostic tools for all Box-Jenkins models: non-parametric time and frequency domain models, Auto- and Partial Auto-Correlation functions.
Week 9	3		Hands-on simulations and group work- Activity # 7 due. Refining BJ model: ACF, PACF and CCF checks. Complete Validation for BJ Model: Residue whiteness testing - Chi-Square tests, Confidence Intervals. Activity # 8 (D2L Quiz) due.
Week 10	3		Hands-on simulations and group work - Activity # 9 due. Review - designing data collection experiment, model structure selection, complete diagnostics, structure revisions and final model validation. Examples of a full system identification procedure.
Week 11	3		Hands-on simulations and group work - Activity # 10 due. Overview of the Final Project (individual): "Black Box" System Identification of two systems (OE and PEM structures). Questions and answers regarding the project.
Week 12	3		Hands-on simulations and group work. Questions and answers regarding the final project, active consultation on final project computer simulations. Activity # 11 (D2L Quiz) due.
Week 13	3		Questions and answers regarding the final project, active consultation on final project computer simulations. Final Project due on December 6.

Laboratory(L)/Tutorials(T)/Activity(A) Schedule

Week	L/T/A	Description
2-3	2	Tutorial 1: Diagnostic Tools in Frequency Domain and Simple Model identification - OE Model (2 sessions) Part 1 - Non-Parametric Models in Frequency Domain as Diagnostic Tools. Part 2 - Simple Model Identification using OE Model. Part 3 - Conventional Parametric Model from Frequency Response Data.
4-5	2	Tutorial 2: Diagnostic Tools in Time Domain and Simple Model identification - OE Model (2 sessions) Part 1 - Non-Parametric Models in Time Domain as Diagnostic Part 2 - Simple Model Identification using OE Model. Part 3 - Conventional Parametric Model from Frequency Response Data. Week 4: Tutorial 1 Report due/Tutorial 1 Quiz online.
6-7	2	Tutorial 3 - Stochastic Noise Models - Identify structure of four different noise models (2 sessions) Week 6: Tutorial 2 Report due/Tutorial 2 Quiz online.
8-10	3	Tutorial 4 - Simple System Identification of a Real-Life System â€“ Servomotor (3 sessions) Part 1: Obtaining Experimental Frequency and Time Domain Responses from the Servo-motor. Part 2: Model Identification and Comparisons with Nominal Values Model. Week 8: Tutorial 3 Report due/Tutorial 3 Quiz online. Week 11: Tutorial 4 Report due/Tutorial 4 Quiz online.

University Policies

Students are reminded that they are required to adhere to all relevant university policies found in their online course shell in D2L and/or on the Senate website

Important Resources Available at Toronto Metropolitan University

- The Library provides research workshops and individual assistance. If the University is open, there is a Research Help desk on the second floor of the library, or students can use the Library's virtual research help service to speak with a librarian.
- Student Life and Learning Support offers group-based and individual help with writing, math, study skills, and transition support, as well as resources and checklists to support students as online learners.
- You can submit an Academic Consideration Request when an extenuating circumstance has occurred that has significantly impacted your ability to fulfill an academic requirement. You may always visit the Senate website and select the blue radio button on the top right hand side entitled: Academic Consideration Request (ACR) to submit this request.

For Extenuating Circumstances, Policy 167: Academic Consideration allows for a once per semester ACR request without supporting documentation if the absence is less than 3 days in duration and is not for a final exam/final assessment. Absences more than 3 days in duration and those that involve a final exam/final assessment, require documentation. Students must notify their instructor once a request for academic consideration is submitted. See Senate Policy 167: Academic Consideration.

- If taking a remote course, familiarize yourself with the tools you will need to use for remote learning. The Remote Learning Guide for students includes guides to completing quizzes or exams in D2L Brightspace, with or without Respondus LockDown Browser and Monitor, using D2L Brightspace, joining online meetings or lectures, and collaborating with the Google Suite.
- Information on Copyright for Faculty and students.

Accessibility

- Similar to an accessibility statement, use this section to describe your commitment to making this course accessible to students with disabilities. Improving the accessibility of your course helps minimize the need for accommodation.
- Outline any technologies used in this course and any known accessibility features or barriers (if applicable).
- Describe how a student should contact you if they discover an accessibility barrier with any course materials or technologies.

Academic Accommodation Support

Academic Accommodation Support (AAS) is the university's disability services office. AAS works directly with incoming and returning students looking for help with their academic accommodations. AAS works with any student who requires academic accommodation regardless of program or course load.

- Learn more about Academic Accommodation Support.
- Learn how to register with AAS.

Academic Accommodations (for students with disabilities) and Academic Consideration (for students faced with extenuating circumstances that can include short-term health issues) are governed by two different university policies. Learn more about Academic Accommodations versus Academic Consideration and how to access each.

Wellbeing Support

At Toronto Metropolitan University, we recognize that things can come up throughout the term that may interfere with a student's ability to succeed in their coursework. These circumstances are outside of one's control and can have a serious impact on physical and mental well-being. Seeking help can be a challenge, especially in those times of crisis.

If you are experiencing a mental health crisis, please call 911 and go to the nearest hospital emergency room. You can also access these outside resources at anytime:

- **Distress Line:**24/7 line for if you are in crisis, feeling suicidal or in need of emotional support (phone: 416-408-4357)
- **Good2Talk:**24/7-hour line for postsecondary students (phone: 1-866-925-5454)
- **Keep.meSAFE:** 24/7 access to confidential support through counsellors via My SSP app or 1-844-451-9700

If non-crisis support is needed, you can access these campus resources:

- **Centre for Student Development and Counselling:** 416-979-5195 or email csdc@torontomu.ca
- **Consent Comes First - Office of Sexual Violence Support and Education:** 416-919-5000 ext 3596 or email osvse@torontomu.ca
- **Medical Centre:** call (416) 979-5070 to book an appointment

We encourage all Toronto Metropolitan University community members to access available resources to ensure support is reachable. You can find more resources available through the Toronto Metropolitan University Mental Health and Wellbeing website.