Western Engineering

Western University
Faculty of Engineering
Ar6ficial Intelligence Systems Engineering Program

AISE 4450A – Data Driven Control of Cyber-Physical Systems

Course Outline Fall/Winter 2025

COURSE DESCRIPTION: In this course, modern control methods for cyber-physical systems with an emphasis on data-driven approaches are introduced. Topics include continuous- and discrete-time linear and nonlinear systems, state-space modeling, control and estimation, system identification, and adaptive control. Advanced data-driven methods such as model predictive control with machine learning, neural network control, and extremum seeking control are also covered. Laboratories focus on practical applications, including inverted pendulum simulations and experiments, controllability and observability analysis, state feedback and observer design, system identification, adaptive control, neural network-based control, model predictive control, and extremum seeking.

ACADEMIC CALENDAR:
https://www.westerncalendar.uwo.ca/Courses.cfm?CourseAcadCalendarID=MAIN_030978_1&SelectedCalendar=Live&ArchiveID=

The course covers: 1) State-space control of systems using data processing algorithms. Adaptive algorithms. Implementation of Kalman filtering; 2) Use of ML in control of real-world Physical systems and Cyber systems.

PRE OR COREQUISITES: AISE 3010A/B, AISE 3351A/B (or the former ECE 3351A/B), Data Science 3000A/B

ANTIREQUISITES: the former ECE 4450A/B

CEAB ACADEMIC UNITS:

CONTACT HOURS:

Lectures: 3 hours weekly. Laboratory sessions: 2 hours weekly.

RECOMMENDED REFERENCE: Brunton, S. L., & Kutz, J. N. (2022). *Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Control* (2nd ed.). Cambridge: Cambridge University Press

RECOMMENDED/ REQUIRED SOFTWARE: MATLAB/Simulink and/or Python

GENERAL LEARNING OBJECTIVES (CEAB GRADUATE ATTRIBUTES)

Knowledge Base		Engineering Tools		Impact on Society	
Problem Analysis		Individual & Teamwork		Ethics and Equity	
Invesfgafon		Communicafon		Economics and Project Mgmt.	
Design		Professionalism		Life-Long Learning	

Nota%on: x represents the content level code as defined by the CEAB. blank = not applicable; I = introduced (introductory); D = developed (intermediate) and A = applied (advanced).

Ra%ng: I – The instructor will introduce the topic at the level required. It is not necessary for the student to have seen the material before. D – There may be a reminder or review, but the student is expected to have seen and been tested on the material before taking the course. A – It is expected that the student can apply the knowledge without promp%ng (e. g. no review).

COURSE MATERIALS: Weekly content and guides for the laboratories will be available on the course OWL site. The material for this course will be taught in both lectures and labs; therefore, it is imperative that you attend each lecture and lab.

UNITS: SI

COURSE TOPICS AND SPECIFIC LEARNING OUTCOMES:

The following table summarizes the course learning outcomes along with CEAB GAIs where the GAIs in bold indicate ones to be measured and reported annually.

Course Topics and Specific Learning Outcomes	CEAB Graduate ASribute Indicators
1. Systems: continuous-time vs. discrete-time, nonlinear vs. linear At the end of this section, students will be able to: a. Describe basic properties and mathematical models of continuous-time and discrete-time systems b. Distinguish between linear and nonlinear systems c. Describe basic properties of linear time-invariant systems **2. State space approach to control and estimation** At the end of this section, students will be able to: a. Describe a linear time-invariant system in the form of a state space model. b. Convert state space model of an LTI system into its transfer function and vice versa. c. Define the notion of controllability and determine if a given LTI system is controllable. d. Define the notion of observability and determine if a given LTI system is observable. e. For a given controllable LTI system, design an optimal linear-quadratic regulator f. For a given controllable/observable LTI system, design an optimal full state estimator, and implement linear-quadratic Gaussian control **3. System Identification** At the end of this section, students will be able to: a. For a given LTI system, implement basic algorithms for identification of a model using data-driven techniques **4. Adaptive control** At the end of this section, students will be able to: a. For a given LTI system, implement basic adaptive control algorithms **5. Data-driven control: MPC, neural network control, extremum seeking control** At the end of this section, students will be able to: a. For a given LTI system, Implement basic model predictive control algorithms b. For a given LTI system, implement basic neural network control algorithms c. For a given LTI system, implement an adaptive extremum seeking control algorithm	

EVALUATION:

Name	% Worth
Labs (Total = 9)	40%
Quizzes (Total = 2)	20%
Final Examination	40%

Marks will be assigned on the basis of method of analysis and presentation, correctness of solution, clarity and neatness.

COURSE POLICIES: All work submitted must be of professional quality in the requested format. Material that is handed in dirty, illegible, disorganized, or in an unapproved format will be returned to the student for resubmission and the late submission penalty will take effect. An additional penalty of 10% may be deducted for poor grammar, incoherence, or lack of flow in the written reports.

LABORATORIES: There will be 9 laboratory sessions. Specific schedule will be announced. Attendance at all laboratory sessions is mandatory. Students who miss a lab with academic consideration are required to contact the course instructor within 3 days for further instructions. Failure to do so will result in a zero mark for that lab. Reports must be written individually and submitted electronically through OWL before the deadline indicated in the laboratory manual and/or course website.

A minimum average of 50% across all laboratory exercises is required to pass the course.

QUIZZES: There will be two 1-hour quizzes that will take place on October 22nd and November 19th, respectively, during the regularly scheduled lecture hours. The quizzes are closed book. Necessary equations are provided. No programmable calculators are allowed.

FINAL EXAMINATION: The final exam will take place during the regular examinafon period. The final exam will be three hours long, closed book. Only simple, nonprogrammable calculators are allowed. To obtain a passing grade in the course, a mark of 50% or more must be achieved on the final examinafon. A final examinafon mark < 50% will result in a final course grade of 48% or less. If the above condifons are not met, your final grade cannot be greater than 48%. Students who have failed this course (i.e., final average < 50%) must repeat all components of the course.

LATE SUBMISSION POLICY: Advise the instructor if you are having problems complefng the assignment on fme prior to the due date of the assignment and be prepared to submit an Academic Considerafon Request and provide documentafon if requested by the instructor at: hlps://www.eng.uwo.ca/undergraduate/academic-considerafon-for-absences.html

If you are granted an extension, establish a due date with the instructor. The approval of the Chair of your Department is not required if assignments are completed prior to the last day of classes. Extensions beyond the end of classes must have the consent of the instructor, the department Chair and the Associate Dean, Undergraduate Studies. Documentafon is mandatory.

ATTENDANCE: Attendance is mandatory for all lectures and labs.

FACULTY OF ENGINEERING POLICIES:
Students must familiarize themselves with the policies of the Faculty of Engineering
https://www.eng.uwo.ca/electrical//pdf/2025-UG-Policy-and-Procedures.pdf