CHEM. ENGINEERING 4E03: DIGITAL COMPUTER PROCESS CONTROL
COURSE OUTLINE, FALL 2024

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TEACH. ASSIST: Arman Khani (khania4@mcmaster.ca), Saeed Mohammadi Khafajeh (mohas53@mcmaster.ca), office hours by appointment

DESCRIPTION: This course addresses the design and analysis of discrete-time control laws (predominantly model-based), suitable for implementation on digital computers. Material covered will include continuous- and discrete-time dynamic models, statistical empirical identification of process models, analysis of discrete-time systems and design of digital control systems, key of which is model predictive control – a widely used advanced control strategy in the chemical process industry. Control algorithms will be implemented and their performance evaluated through state-of-the-art simulation software. The course material will be relevant to engineering practice and also provide a useful background for further independent or graduate study in process control.

OBJECTIVES: Most industrial processes control systems are computer based. The key objectives of this course are to provide participants with (a) theoretical knowledge and tools to enable them to design and analyze digital control systems, (b) an in-depth understanding of the relationship between digital and continuous-time control systems of the type covered in CHEM ENG 3P04, (c) the facility to analyze and simulate digital control systems using commercially available software, and (d) a comprehensive introduction to model predictive control (MPC).

OUTLINE: See page 3.

FORMAT: The course will consist of classroom instruction, which will include lectures and workshops. The course material will be supplemented by regular assignments that will include the use of computer-aided tools.

GRADING SYSTEM (subject to change):

	% of course grade
Assignments	10
Project	20
Mid-term	20
Final exam	50

ASSIGNMENTS: Approximately 5.

The final percentage grades will be converted in letter grades using the Registrar's recommended procedure. Adjustment to the final grades may be done at the discretion of the instructor.

CALCULATOR: The use of any calculator during examinations is allowed.

COURSE TEXT: Swartz, C.L.E., *Digital Computer Process Control. Dynamic Models, Analysis Tools and Control Algorithms.* Available for download from Avenue2Learn.

AVAILABLE IN THODE

1. Bequette, B.W., *Process Control. Modeling, Design and Simulation*, Prentice-Hall, 2003.
2. Brosilow, C. and B. Joseph, *Techniques of Model-Based Control*, Prentice-Hall, 2002.
3. Maciejowski, J.M., *Predictive Control with Constraints*, Prentice Hall, 2002.
4. Marlin, T.E., *Process Control: Designing Processes and Control Systems for Dynamic Performance*, 2nd Edn., 2000.
5. Ogunnaike, B. and H. Ray, *Process Dynamics, Modeling, and Control*, Oxford University Press, London, 1994
6. Seborg, D., T. Edgar, and D. Mellichamp, *Process Dynamics and Control*, Wiley, New York, 1989

PROVISIONAL COURSE OUTLINE

[Approximate number of lectures in square brackets.]

1. Introduction [1]
2. Introduction to Model Predictive Control (MPC) [1]
3. Continuous-time Dynamic Models [4]
    - Fundamental models
    - Linearization
    - State-space representation
    - Transfer function representation
    - Translation between representations
    - Dynamic simulation of nonlinear and linear systems
4. State-space Discrete-time Models [3]
    - Discretization of continuous-time models
    - Dynamic response of linear and nonlinear discrete-time models
5. Model Predictive Control (MPC) [9]
    - Introduction
    - Unconstrained MPC – SISO systems
    - Unconstrained MPC – MIMO systems
    - Closed-loop properties
    - Constrained optimization – a brief introduction
    - Constrained MPC
    - MPC variants and implementation considerations
6. Input-output Discrete-time Models [5]
    - z-transforms
    - Pulse transfer function
    - Conversion between representations
    - Finite step and impulse response models
    - Dynamic response
7. System Identification [4]
    - Least-squares formulation and solution for first-order models
    - First-order-plus-deadtime models
    - General ARMA models
    - Diagnostic evaluation
    - Input test signal and data pre-processing
8. Closed-Loop Analysis of Discrete-time systems (Feedback Control) [5]
    - Closed-loop transfer functions of sampled-data systems
    - Stability analysis
9. Digital Control Design [4]
    - Discretization of continuous-time control laws
    - Direct approach

APPROVED ADVISORY STATEMENTS

Academic Integrity

You are expected to exhibit honesty and use ethical behaviour in all aspects of the learning process. Academic credentials you earn are rooted in principles of honesty and academic integrity. **It is your responsibility to understand what constitutes academic dishonesty.**

Academic dishonesty is to knowingly act or fail to act in a way that results or could result in unearned academic credit or advantage. This behaviour can result in serious consequences, e.g. the grade of zero on an assignment, loss of credit with a notation on the transcript (notation reads: "Grade of F assigned for academic dishonesty"), and/or suspension or expulsion from the university. For information on the various types of academic dishonesty please refer to the Academic Integrity Policy, located at https://secretariat.mcmaster.ca/university-policies-proceduresguidelines/

The following illustrates only three forms of academic dishonesty:

- plagiarism, e.g. the submission of work that is not one's own or for which other credit has been obtained.
- improper collaboration in group work.
- copying or using unauthorized aids in tests and examinations.

Authenticity / Plagiarism

Some courses may use a web-based service (Turnitin.com) to reveal authenticity and ownership of student submitted work. For courses using such software, students will be expected to submit their work electronically either directly to Turnitin.com or via an online learning platform (e.g. Avenue to Learn, etc.) using plagiarism detection (a service supported by Turnitin.com) so it can be checked for academic dishonesty.

Students who do not wish their work to be submitted through the plagiarism detection software must inform the Instructor before the assignment is due. No penalty will be assigned to a student who does not submit work to the plagiarism detection software. **All submitted work is subject to normal verification that standards of academic integrity have been upheld** (e.g., on-line search, other software, etc.). For more details about McMaster's use of Turnitin.com please go to www.mcmaster.ca/academicintegrity.

Courses with an On-line Element

Some courses may use on-line elements (e.g. e-mail, Avenue to Learn, LearnLink, web pages, capa, Moodle, ThinkingCap, etc.). Students should be aware that, when they access the electronic components of a course using these elements, private information such as first and last names, user names for the McMaster e-mail accounts, and program affiliation may become apparent to all other students in the same course. The available information is dependent on the technology used. Continuation in a course that uses on-line elements will be deemed consent to this disclosure. If you have any questions or concerns about such disclosure please discuss this with the course instructor.

Online Proctoring

Some courses may use online proctoring software for tests and exams. This software may require students to turn on their video camera, present identification, monitor and record their computer activities, and/or lock/restrict their browser or other applications/software during tests or exams. This software may be required to be installed before the test/exam begins.

Conduct Expectations

As a McMaster student, you have the right to experience, and the responsibility to demonstrate, respectful and dignified interactions within all of our living, learning and working communities. These expectations are described in the Code of Student Rights & Responsibilities (the "Code"). All students share the responsibility of maintaining a positive environment for the academic and personal growth of all McMaster community members, **whether in person or online**.

It is essential that students be mindful of their interactions online, as the Code remains in effect in virtual learning environments. The Code applies to any interactions that adversely affect, disrupt, or interfere with reasonable participation in University activities. Student disruptions or behaviours that interfere with university functions on online platforms (e.g. use of Avenue 2 Learn, WebEx or Zoom for delivery), will be taken very seriously and will be investigated. Outcomes may include restriction or removal of the involved students' access to these platforms.

Academic Accommodation of Students with Disabilities

Students with disabilities who require academic accommodation must contact Student Accessibility Services (SAS) at 905-525-9140 ext. 28652 or sas@mcmaster.ca to make arrangements with a Program Coordinator. For further information, consult McMaster University's Academic Accommodation of Students with Disabilities policy.

Requests for Relief for Missed Academic Term Work

In the event of an absence for medical or other reasons, students should review and follow the Policy on Requests for Relief for Missed Academic Term Work.

Academic Accommodation for Religious, Indigenous, or Spiritual Observances (RISO)

Students requiring academic accommodation based on religious, indigenous or spiritual observances should follow the procedures set out in the RISO policy. Students should submit their request to their Faculty Office **normally within 10 working days** of the beginning of term in which they anticipate a need for accommodation or to the Registrar's Office prior to their examinations. Students should also contact their instructors as soon as possible to make alternative arrangements for classes, assignments, and tests.

Copyright and Recording

Students are advised that lectures, demonstrations, performances, and any other course material provided by an instructor include copyright protected works. The Copyright Act and copyright law protect every original literary, dramatic, musical and artistic work, **including lectures** by University instructors.

The recording of lectures, tutorials, or other methods of instruction may occur during a course. Recording may be done by either the instructor for the purpose of authorized distribution, or by a student for the purpose of personal study. Students should be aware that their voice and/or image may be recorded by others during the class. Please speak with the instructor if this is a concern for you.

Extreme Circumstances

The University reserves the right to change the dates and deadlines for any or all courses in extreme circumstances (e.g., severe weather, labour disruptions, etc.). Changes will be communicated through regular McMaster communication channels, such as McMaster Daily News, Avenue to Learn and/or McMaster email.