Spring 2019
ME 578: Digital Control

INSTRUCTOR: KARTIK B. ARIYUR

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Office Hours: **Flexible schedule for online/ in person meetings**

COURSE TEXT: There is no textbook for the course. Course notes, lecture handouts, supplementary material and MATLAB/SIMULINK code will be available for download from your course BLACKBOARD LEARN site. https://mycourses.purdue.edu

REFERENCES:

[1] *Computer-Controlled Systems – Theory and Design*, K.J. Astrom and B. Wittenmark, Prentice-Hall, 3rd Ed., 1997.

[2] *Digital Control Systems*, B. C. Kuo, Saunders College Publishing, 2nd Ed, 1992.

Other reference materials will be provided via Purdue Blackboard

PREREQUISITE: ME475/575 or the consent of the instructor.

OBJECTIVES: This course picks up the control system development where ME475/575 left off. It is intended to facilitate the students to gain:

- familiarity with sample theory, z-transform, and other analysis tools that are used to analyze and design digital control systems,
- familiarity with the state space and input/output representation, modeling and analysis of digital control systems, including sensor and actuator integration,
- familiarity with the design of digital controller through emulating continuous-time controllers,
- familiarity with modern control design methodologies for continuous-time and discrete-time systems that include but not limited to: state feedback control, state observer design, observer-based compensator design, LQ optimal control, Kalman filtering, LQG design, internal model-based design, servo control, and LMI formulations with some observer design, feedback linearization/backstepping for nonlinear systems.
- understanding the issues arising in digital controller implementation.

This course seeks to simulate the work environment of the modern control engineer. It aims at familiarity with results, design and analysis tools, the ability to obtain relevant information to formulate and solve problems arising in practice, and write controls software.

GRADING POLICY:

COURSE PROJECT: 50% **WEEKLY QUIZZES: 50%**

The weekly quizzes test your understanding of course material and your project updates test your ability to apply the course material on a problem of your choice.

Bonus points for in-class questions—everyone will get a chance—2 points per correct solution. Final grading will be cluster based.

You must receive a passing grade on the project to pass the course.

PROJECT POLICY:

Project reporting has to be done each week. ***Project updates have to be submitted via Blackboard on the following Sundays before midnight*** **(January 29; February 3, 10, 17; March 3, 10, 24, 31; April 7, 21)**. This includes your work of the previous week and your MATLAB/SIMULINK code (clearly documented). *No late submissions will receive points*. Since projects are an integral part of the course content, they are to be an individual effort. However, study group discussion, acquiring information and code from the web and library, MATLAB/SIMULINK code sharing/reuse, and cross-checking each other's work, are strongly encouraged. Project updates must be uploaded in the format specified, in pdf, and must NOT add more than 2 pages to the overall document submitted each week. The final document must occupy 15 pages or less. You can trim/modify prior sections when you update the report on each submission.

Each project update will be worth 50 points. 10 points will be deducted for each of consistency, correctness, formatting/typographic/referencing, coding/code formatting, and spelling/grammar. There will be 10-point bonuses for exceptional accomplishments from time to time. Project updates will consist approximately in the following steps:

1. Problem background, motivation and formulation with references
2. Sampling and quantization issues
3. Discrete model/sampled model
4. Transfer function and state space representations+system ID
5. Stability, sensitivity and robustness, controllability/observability analysis
6. Control designs via input-output approach
7. Control designs via polynomial approach
8. Control designs via state space approach
9. Optimal control designs with optimal estimation (Kalman filters)
10. Implementation on high fidelity models

ONLINE QUIZ POLICY:

Quizzes will be posted on **Monday afternoons (January 14, 21, 28; February 4, 11, 18, 24; March 4, 11, 18, 25; April 8, 15) and are due Sunday night**. Grading will be based on the correct answer and the correct method. Each quiz will be worth 50 points and will consist in a single question—the best 10 scores will be considered for your grade. You will receive **ZERO** points for incorrect answers or for correct answers with incorrect methods (if that happens). The questions may have multiple correct answers. The quiz will be open notes—you can use the internet or any software, class slides and required reading material. **You will have one or two hours to submit your solution in scanned pdf once you access the quiz**. *The time taken will be tracked on Blackboard Learn.*

BONUS QUESTION POLICY:

Bonus questions will be asked at random in any class. They will be written on the board or put on class slides. All who come up with unique and correct answers within the week of the question will get credit. The answers should be posted along with the questions on the course blog.

Grading will be performed in the week of the project update submission or quiz and posted on BLACKBOARD, so you can check on your performance regularly.

COMPUTER USAGE:

Course communication—announcements, lecture notes, scores and averages—will be through the course web site at https://mycourses.purdue.edu, accessible through your Purdue login. You will be expected to use MATLAB/SIMULINK for the course project. It is strongly advised that you go through a self-paced MATLAB tutorial such as the one at http://www.engin.umich.edu/class/ctms/ if you are not comfortable with MATLAB. The tutorial can be accessed through. It is a bit outdated but the fundamentals are the same.

TENTATIVE COURSE OUTLINE

1. **Introduction** — **1 week**
   - Issues relating to digital control
   - Design process
2. **Sample Theory** — **1 week**
   - Sampling Theory
   - Aliasing
   - Reconstruction: Zero-Order Hold (ZOH)
3. **z-Transform and Difference Equations** — **1 week**
   - Properties
   - Difference Equation
4. **Representation of Sample Data Systems** — **1.5 weeks**
   - Pulse Transfer Function Representation
   - State Space Representation
   - System Identification
5. **Analysis of Sampled Data Systems** — **1.5 weeks**
   - Stability
   - Sensitivity and Robustness
   - Controllability/Observability
   - Pole/Zero Cancellation
6. **Design of Discrete-Time Controller – Input/Output Approach** — **1 week**
   - Emulating Continuous-Time Controller
   - Invariant Methods
   - Direct Design
7. **Design of Discrete-Time Controller – Polynomial Approach** — **1.5 weeks**
   - Problem Formulation
   - Pole Placement Design
   - Model Matching Problem
8. **Design of Discrete-Time Controller – State Space Approach** — **1 week**
   - State Feedback
   - State Estimation (Observer)
   - Observer Based Compensator
9. **LQ Optimal Control** — **1.5 weeks**
10. **Kalman Filtering** — **2.5 weeks**
11. **Implementation and advanced topics** — **1.5 weeks**