Spring 2021

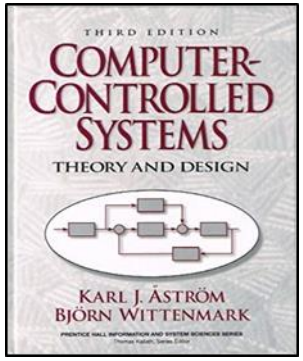
數位控制系統
Digital Control Systems

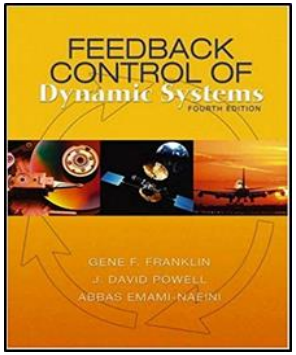
DCS-02
Project

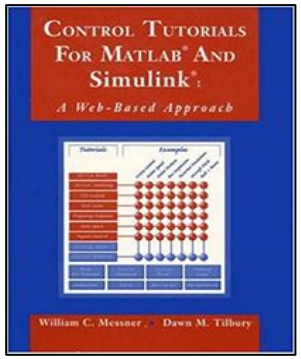
Feng-Li Lian

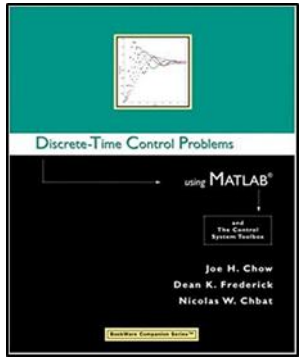
NTU-EE

Feb – Jun, 2021









Syllabus

- Lecture Information:
  - Time: Tuesdays 1:30pm-4:20pm
  - Room: MD-303
  - Office Hours: by e-mail appointment
  - Website: http://cc.ee.ntu.edu.tw/~fengli/Teaching/DigitalControl
- Instructor:
  - 連豊力(Feng-Li Lian)
  - Office: MD-717
  - Email: fengli@ntu.edu.tw
  - Phone: 02-3366-3606
- Grading:
  - Homework (30%) bi-week
  - Midterm (30%) on x/y
  - Project (40%) on x/y
- Textbooks:
  - Computer-Controlled Systems: Theory & Design, 3rd. Ed., (1997), by Astrom & Wittenmark
  - Discrete Time Control Problems Using Matlab and the Control System Toolbox, (2003), by Chow, Frederick & Chbat
- References:
  - Digital Control of Dynamic Systems, 3rd Ed., (1998), by Franklin, Powell, Workman
  - Real-Time Systems, (1997), by Krishna & Shin
  - Real-Time Computer Control: An Introduction, 2nd Ed., (1994), by Bennett
  - Control in an Information Rich World, Report of the Panel on Future Directions in Control, Dynamics, and Systems. http://www.cds.caltech.edu/~murray/cdspanel/report/cdspanel-15aug02.pdf

Grading: Term Project (60%)

- Team members:
  - About 1-3 students of different levels
  - Auditing/Visiting students are encouraged to join a team
- Subject/Title:
  - Theoretical study
    - Study any digital control theory and derive possible new results
  - Simulation study
    - Detailed and thorough simulation study of one application
  - Software package development of digital control systems
    - Develop toolkits similar to CCSDemo and Control Tutorial
- Agenda:
  - 5/3: Form a team and submit one-page proposal
  - 6/14: Progress Report
  - 6/25: Final Report

Grading: Term Project (60%)

- "Economy" Class:
  - Only 1 student
  - Simulation study of one typical control application
    - Such as flight, DVD/HD, motor, robot, etc.
    - Should include modeling, (timing) analysis, design, and simulation validation

- "Business" Class:
  - >= 2 students
  - >= 10 digital-control-related IEEE journal papers
  - Could only focus on one or two of the following areas:
    - Modeling, (system or timing) analysis, design, etc.
  - Strongly suggest to re-do the simulation results in the survey papers

- "First" Class:
  - <= 3 students
  - >= 20 digital-control-related IEEE journal papers
  - Generate good/nice (possibly new) theoretical results
  - Develop different (possibly useful) digital-control-related software package

Grading: Term Project (60%)

- Agenda:
  - 5/1: Submit one-page proposal
    - > Including title, team members, affiliation, etc., and one or two paragraphs describing your ideas
  - 6/19: Presentation slides and Video and other files:
    - > One zipped file of the related electronic files including videos, documentation (docx) or presentation (pptx), matlab (m) files, etc.
      - » Presentation slides in PPTX
      - » Presentation video of 10-15 mins
      - » Submit the report to NTU-Cool
        Deadline: By 11pm, 6/19
  - 6/29: Grading (Evaluation) Report
    - » Please submit the grading (evaluation) report to NTU-Cool
      Deadline: By 11pm, 6/29

4/13: Title, Systems, Models

- Proposal by 5/1, 2021:
  - Page 1:
    - Title:
    - Team: Name, ID, Department
    - Date:
  - Page 2:
    - Systems:
      - > Edit a few paragraphs/keywords to describe the specifications of the system and design goals
      - > Might include 1-2 pictures
  - Page 3:
    - Models:
      - > Continuous-Time Models: Transfer Function, State Space
      - > Discrete-Time Models: Transfer Function, State Space
  - Page 4:
    - References: Books, Papers, Websites, etc.

- Presentation Slides, Video, Other files by 6/19, 2021:
  - Page 1:
    - Title:
    - Team: Names, IDs, Departments
    - Date:
    - etc.
  - Pages 2:
    - Outline and Summary
  - Pages 3:
    - Systems:
      - > Edit a few paragraphs/keywords to describe the specifications of the system and design goals
      - > Might include 1-2 pictures

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Presentation Slides and Video by 6/19, 2021:

- Pages 4, etc.:
  - Modeling:
    - > CT vs DT models, (TF/SS) in terms of different sampling times
  - Analysis:
    - > Stability, Controllability, Observability, in terms of different sampling times
  - Design:
    - > Different controllers, observers, etc.,
      vs different sampling times, performance specification
  - Simulation studies with:
    - > Different sampling times
    - > Different design parameters
    - > Different performance specifications

- Page zzz:
  - References: Books, Papers, Websites, etc.

Grading: Term Project (60%)

- Grading (60%):
  - Writing style & contents (10%)
  - Technical content (20%)
  - Evaluation by other students, teaching assistant, instructor (20%)
  - Your evaluation quality (10%)

Grading: Term Project (60%)

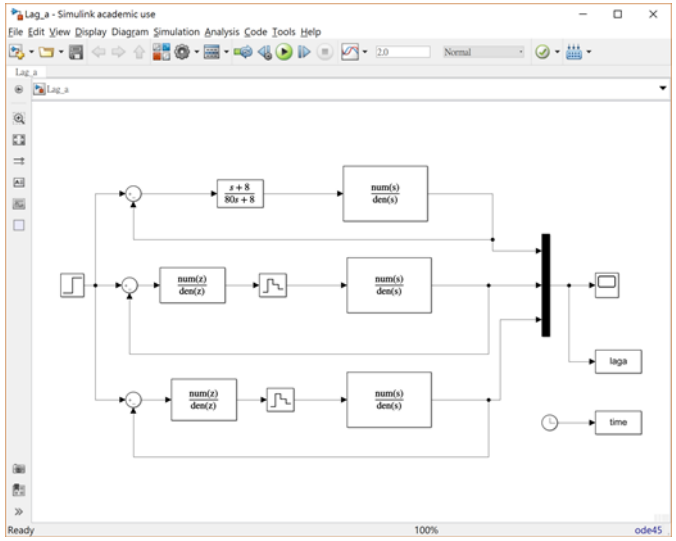
- Grading (60%):
  - Writing style & contents (10%)
    - Title
      - Does “title” actually and precisely reflect the content of this report?
    - Introduction
      - Does it provide enough background information about this study?
      - Are references properly cited?
    - Main results, including theoretical derivation or simulation study
      - Do it explicitly and concisely describe the results?
      - Are they good or solid enough to give readers any useful information?
    - Discussions, summary/conclusions
      - Does it conclude anything and provide good suggestion for the future?
    - References
      - Does it list enough cited papers?
  - Technical content (20%)
    - The contents on main result and discussions

Grading: Term Project (60%)

- Grading (60%):
  - Evaluation by other students, teaching assistant, instructor (20%)
  - Your evaluation quality (10%)
  - Suggested Format:
    - > Each group should use PPTX to give a formal presentation.
    - > Every group member should video-record 10-15-min talk.
    - > Every student should grade other presentation precisely.

Grading: Term Project (40%)

- Grading (40%):
  - Report (30% from group performance):
    - Technical content (20%)
      - > Simulation studies with:
        - » Different sampling times
        - » CT vs DT models, in terms of different sampling times



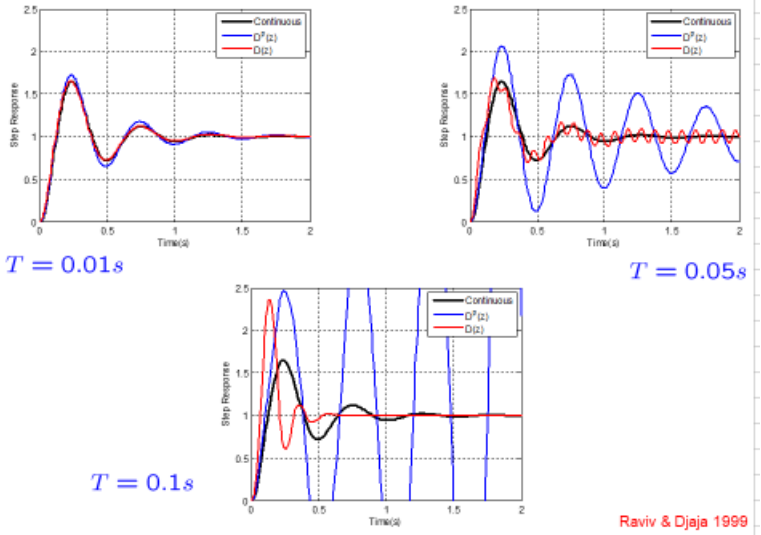
$$\Rightarrow \quad G_c(s) = \frac{1}{80}\frac{(s+8)}{(s+0.1)}$$

- D'(z): by Tustin

Table 1

	D'(z)	Multiplier	D(z)
T = 0.01 s	$\frac{0.0130z-0.0120}{z-0.9990}$	$\frac{2z}{z+1}$	$\frac{0.0260z^2-0.0240z}{z^2+0.0010z-0.9990}$
T = 0.05 s	$\frac{0.0150z-0.0100}{z-0.9950}$	$\frac{2z}{z+1}$	$\frac{0.0299z^2-0.0200z}{z^2+0.0050z-0.9950}$
T = 0.1 s	Unstable $\frac{0.0174z-0.0075}{z-0.9900}$	$\frac{2z}{z+1}$	Unstable $\frac{0.0348z^2-0.0150z}{z^2+0.0100z-0.9900}$
T = 0.1 s	Unstable $\frac{0.0174z-0.0075}{z-0.9900}$	$\frac{2(z-0.2)}{(z+0.6)}$	$\frac{0.0348z^2-0.0219z+0.0030}{z^2-0.3900z-0.5940}$

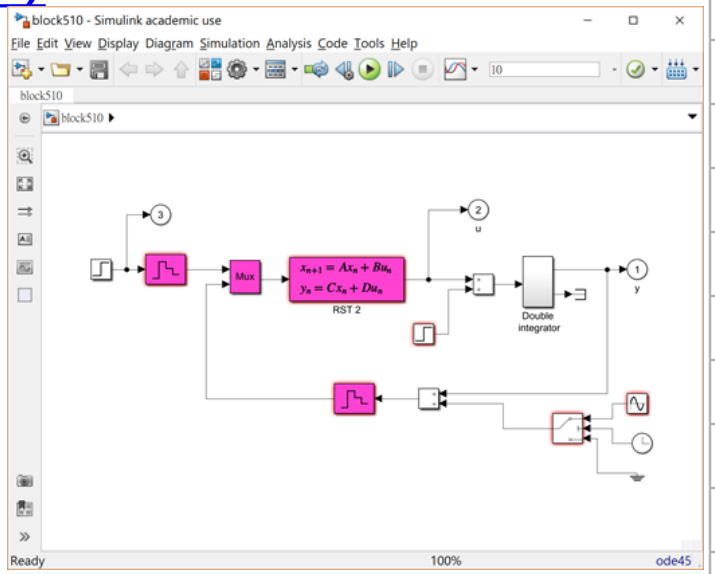
Raviv & Djaja 1999

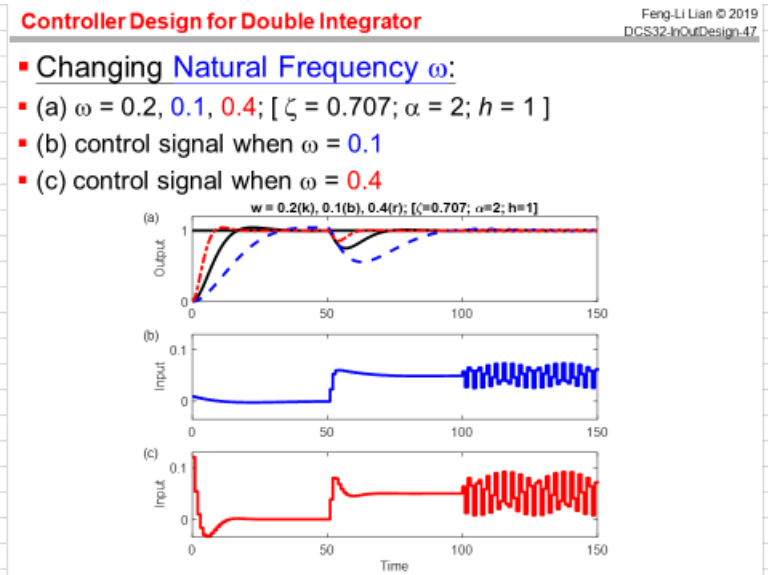


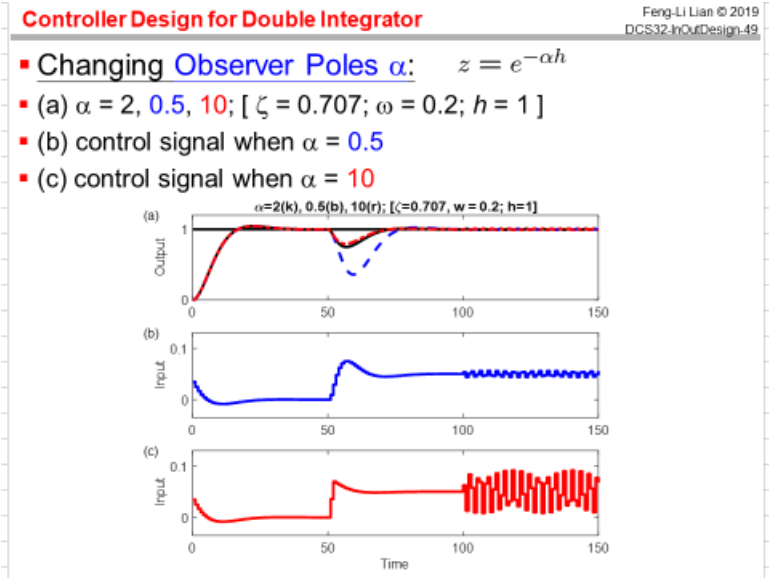
Raviv & Djaja 1999

Grading: Term Project (40%)

- Grading (40%):
  - Report (30% from group performance):
    - Technical content (20%)
      - > Simulation studies with:
        - » Different performance specifications
        - » Different controllers, observers, etc., vs different sampling times, performance specification







Grading: Term Project (40%)

- Grading (40%):
  - Presentation (10% from individual performance):
    - Evaluation by instructor (5%)
    - Evaluation by other students (5%)
    - Suggested Format:
      - > Each group should use PowerPoint to give a formal presentation.
      - > Every group member should provide at least 7-min talk.
      - > After everyone's presentation, we will have Question-&-Answer session!

Introduction: Course Outline

- Digital Control Systems
  - From Analog to Digital World
  - Design Consideration
  - Z-transform
  - Controller Design
- Computer Control Systems (Single Centralized Control)
  - Real-Time Operation Systems
  - Analog to Digital
  - Digital to Analog
- Networked Control Systems (Multiple Distributed Control)
  - Control Networks Protocols
  - Networked Controllers & Managers
  - Networked Sensors
  - Networked Actuators

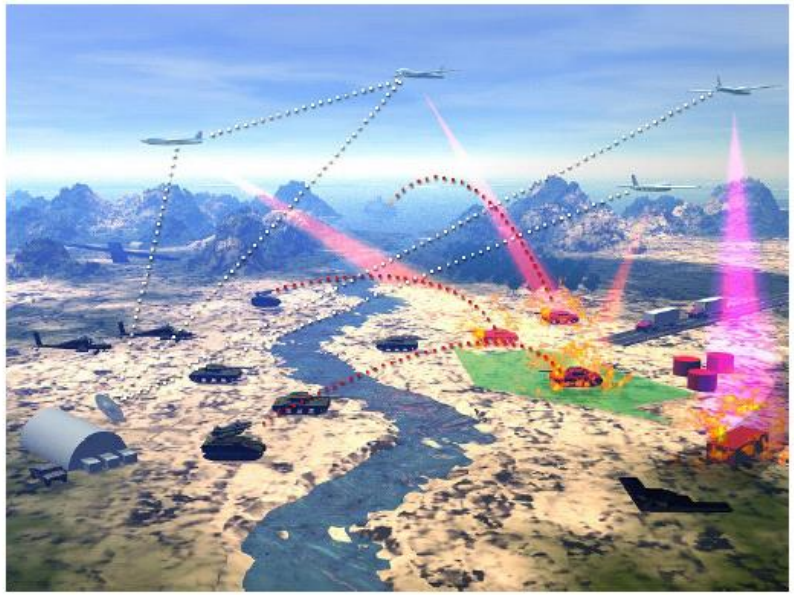
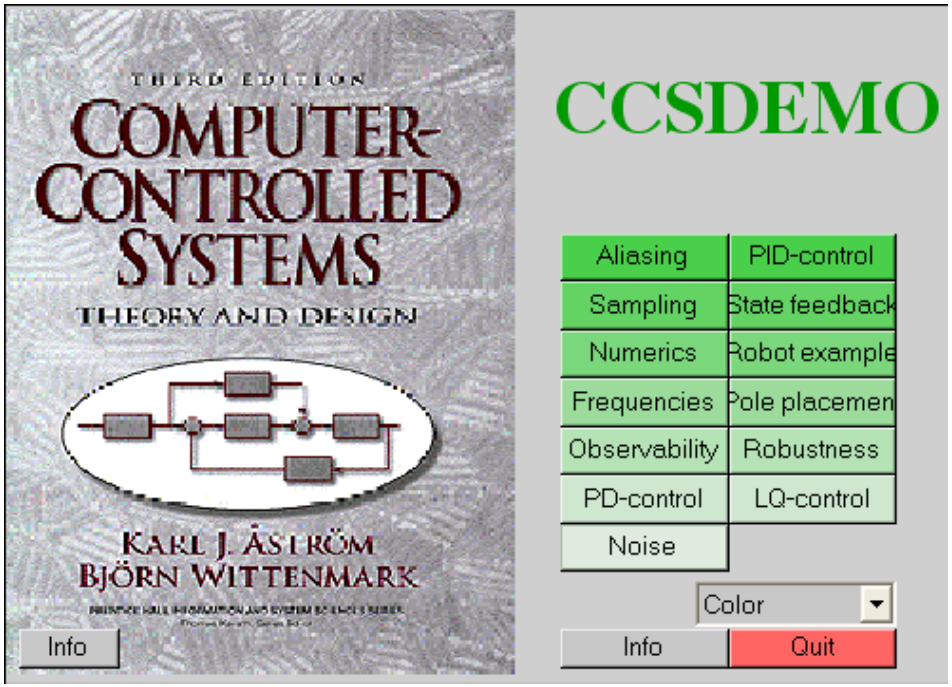
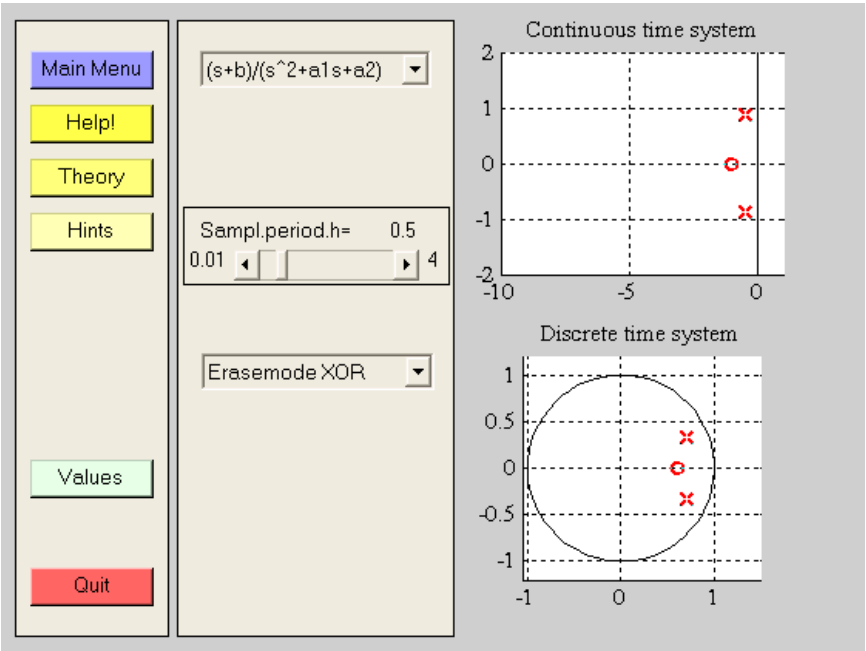


Figure 3.2. *Battle space management scenario illustrating distributed command and control between heterogeneous air and ground assets. Figure courtesy of DARPA.*

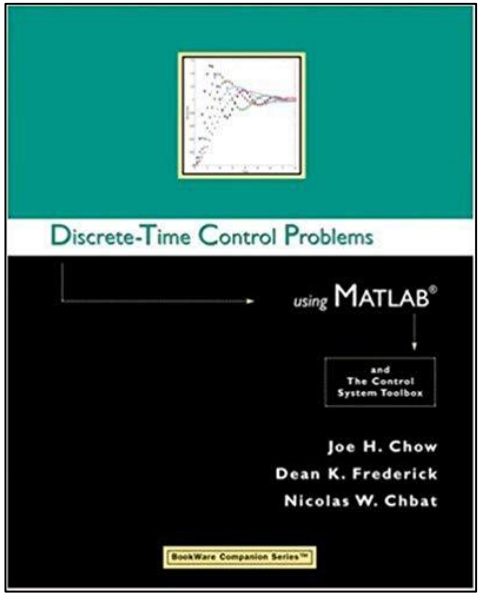
- CCSDEMO by Astrom & Wittnemark of Lund





Introduction: Computer Aided Tools

- Discrete Time Control Problems
  Using Matlab and the Control System Toolbox, (2003)
  - by Joe H. Chow, Dean K. Frederick, Nicholas W. Chbat
- Table of Content:
  - 1. INTRODUCTION
  - 2. SINGLE-BLOCK MODELS AND THEIR RESPONSES
  - 3. BUILDING AND ANALYZING MULTI-BLOCK MODELS
  - 4. STATE-SPACE MODELS
  - 5. SAMPLE-DATA CONTROL SYSTEMS
  - 6. FREQUENCY RESPONSE, DIGITAL FILTERS, AND DISCRETE EQUIVALENTS
  - 7. SYSTEM PERFORMANCE
  - 8. PROPORTIONAL-INTEGRAL-DERIVATIVE CONTROL
  - 9. FREQUENCY-RESPONSE DESIGN
  - 10. STATE-SPACE DESIGN METHODS
  - A: Models Of Practical Systems.
    - Ball and Beam System
    - Inverted Pendulum
    - Electric Power System
    - Hydro-Turbine and Penstock
  - B: Root-Locus Plots. Discrete Fourier Transform.
  - C: Matlab Commands.



- Control Tutorial for Matlab & Simulink

  by Tilbury of UMich & Messner of CMU

  http://ctms.engin.umich.edu/CTMS/