Embedded Control and Mechatronics (ECE-456)

Instructor:

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Course URL: http://heera.engr.siu.edu/staff1/pour/courses/ece456/

Syllabus:
The course syllabus is available on balckboard (ECE-456)

Textbook:
Dingyu Xue, YangQuan Chen and Derek P. Atherton, ***Linear Feedback Control – Analysis and Design with MATLAB***, SIAM, 2007.

Course Materials

- Model-based design (MBD) approach:
  - Textbook materials (Xue, et al. 2007): modeling, analysis, and control (MAD) techniques,
  - Handouts: state-space techniques, selected tutorials,
  - Webinars: Matlab/Simulink & other toolboxes,
  - Microcontroller programming: Microchip, Arduino,
  - Laboratory experiments: motor control, etc.

Course Requirements

- Pre-requisite:
  - Courses: Math Methods in Engineering (315), Systems and Control (356),
  - Subject materials: classical undergraduate control, signals and systems,
  - Minimum knowledge of Matlab/Simulink programming
- See course syllabus on **blackboard.**

Course Expectations

- Class attendance will be observed.
- Homework:
  - Homework problems must be simulated and verified using Matlab/Simulink and other toolboxes.
    - Late submissions may lose up to 20% per day.
- Lab projects (groups of two)
  - Lab reports must be concise, include measured data, schematic of the set-up, Matlab analysis, control design, Simulink simulation and verification, implementation results and plots, conclusion, and signature of the TA verifying the completion of the lab project.
- Final project (groups of two or three)
  - An extension of the lab project (submit a brief proposal for project approval)
  - Implement, verify, and submit a final report
    - Must involve MAD process (**modeling, analysis, and control design**), using **Matlab and other Mathworks toolboxes**, for Arduino implementation.
  - Each student will be given a microcontroller kit (Aduino board, etc.).
  - The complete Arduino kit must be returned back at the end of the semester.

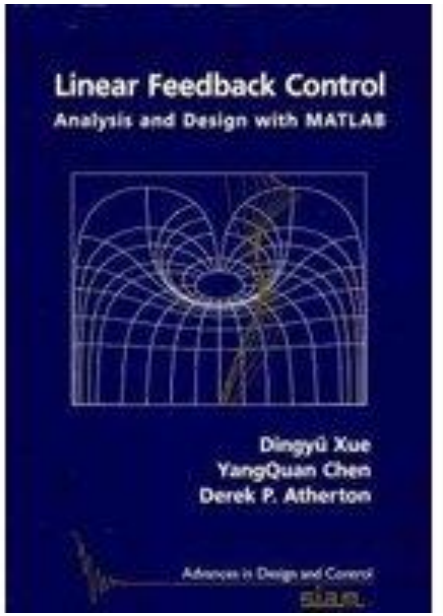
Chapter 1 – Introduction

- Embedded control design is a multidisciplinary subject, involving
  - Dynamic systems analysis
  - Modeling, estimation, and control
  - Simulation and signal processing
  - Microcontrollers and programming
  - Power electronics and drives

- An industry approach to this problem is “Model Based Design”
  - Based on modeling, analysis, and design (MAD) approach

Book Materials To Be Covered

- **Chapter 1** – Introduction to Feedback Control:
  Historical background and basic guide to Matlab
- **Chapter 2** – Mathematical Models of Feedback Control Systems:
  Physical modeling and corresponding Matlab commands
- **Chapter 3** – Analysis of Linear Control Systems:
  Algorithms for analysis of linear systems with Matlab
- **Chapter 4** – Simulation Analysis of Nonlinear Systems:
  Simulation and analysis of nonlinear systems with Simulink
- **Chapter 5** – Model-Based Controller Design:
  Control designs based on known or estimated models of systems using Matlab
- **Chapter 6** – PID Controller Design:
  Matlab-based PID control design
- **Chapter 7** – Robust Control Systems Design:
  Advanced control design techniques with Matlab
- **Chapter 8** – Fractional-Order Controller - An Introduction:
  Optional materials (if time allowed)



Getting Started with Matlab

- MATLAB (R20010a) is installed in labs E136, E237, and E230
- The installed toolboxes can be browsed via MATLAB start menu
- Stations in E230 have extra toolboxes used for this course
- A student version is available for $100 plus $30 per added toolbox
  http://www.mathworks.com/store/default.do
- Online tutorial for MATLAB is available at
  http://www.mathworks.com/academia/student_center/tutorials/

Learning Matlab

- Matlab stands for matrix lab, which is a product of Mathworks. Mathworks products include Matlab, Simulink, and many other toolboxes (control systems, system identification, …).
- Introductory tutorials are available from links at the top of the workspace console when MATLAB is launched
- Media and help are also available from the Mathworks website:

  http://www.mathworks.com/index.html
- Documentation and help are available at:

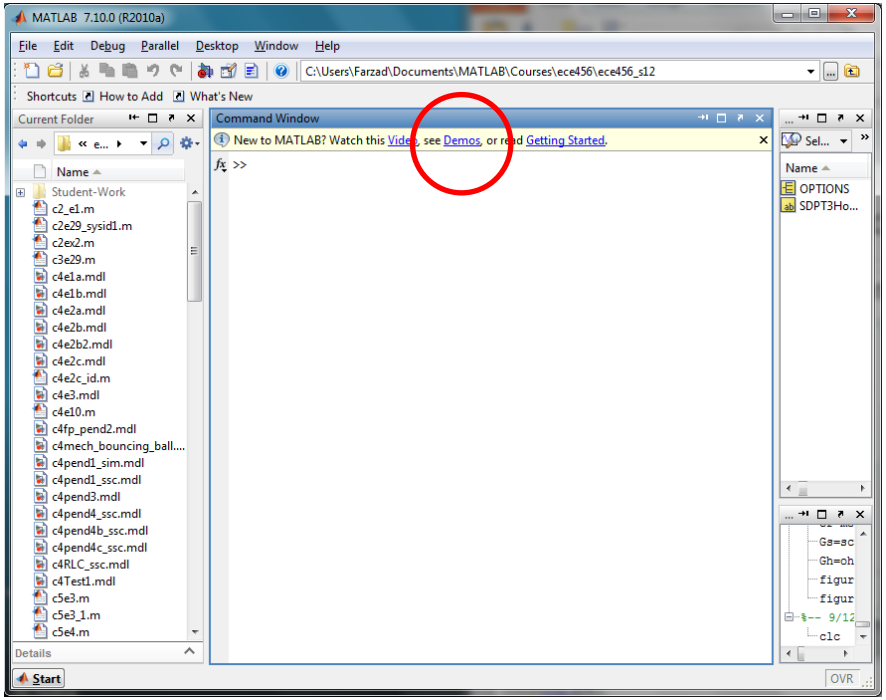
  http://www.mathworks.com/help/?s_cid=HP_FF_S_Doc
- Webinar archives can be browsed at:

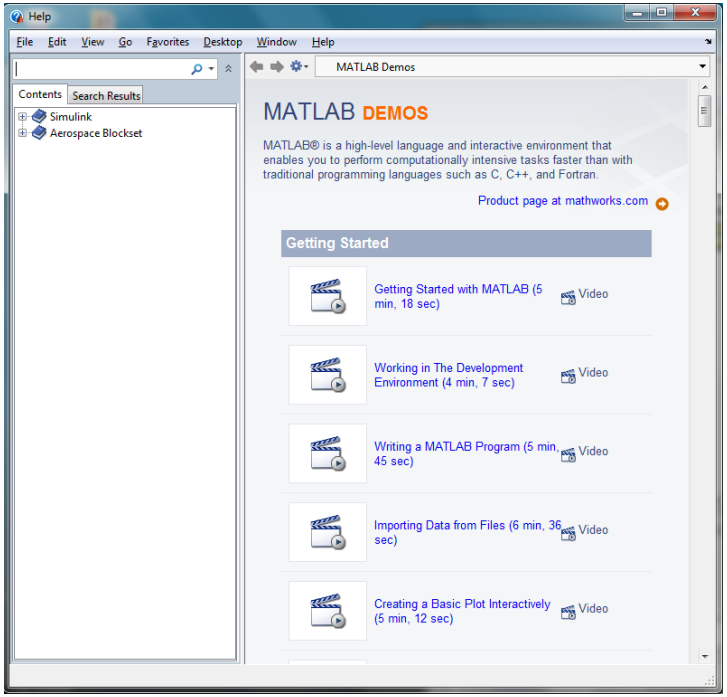
  http://www.mathworks.com/company/events/webinars/upcoming.html?s_cid=HP_FF_E_Webinars

Matlab Demos

To launch the Matlab demos

- Click on “Demo” at the top of Matlab working window
- Click on any of the “Getting Started” demo videos
  - They each are only a few minutes long





Finding and Exploring Matlab Commands and Functions

- Typing help displays a list of help topics.
- Typing help help describes the syntax for help command with examples.
- Help is available via the help menu, or by typing help followed by the command / function-name:

```
>> help [command]
```

- To find a command based on functionality, the lookfor command can be used

```
>> lookfor [string]
```

  - This returns a list of commands/functions whose name/description contain the specified string

- **Note**: when typing commands, if paused, a small window will pop over the command to suggest the command syntax

Standard Matlab Commands

- The basic element in Matlab is a complex valued matrix.
  - To enter a matrix $A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 0 \end{bmatrix}$, type:

    >> A=[1,2,3;4,5,6;7,7,8,0]; where >> is the Matlab prompt.
- The syntax of a typical function is:

  [list_of_return_values]=func_name(input_list)
  - For example, the function bode() can be called with the syntax:

    [mag,pjase]=bode(G,ω)
  - Other syntaxes could also be used:

    bode(G,ω) ; draw Bode diagram over frequency range ω

    bode(G) ; draw Bode diagram over default frequency range

    bode(G1,G2,G3) ; draw Bode diagrams for several systems together

Graphics Facilities in Matlab

- Two-dimensional curves can be drawn using the function plot()
  - The syntax is:

    plot(x1,y1,x2,y2,x3,y3,…)

    where (x1,y1) is a pair of vectors (or matrices) holding the x- and y-axis data for the plots, (x2,y2) is another pair, and so on.
  - Other functions can be used to enhance the plot, such as:
    - grid — to add or remove grids on the plot
    - Xlable() and ylable() — to add lable for the axes
    - Title() — to add a title to the plot
    - legend, text() and gtext() — to add one or more legends to plots
- Three-dimensional plots can be made using mesh() and surf() functions
- Other enhancements can be made using the graphics processor in CtrlLAB software, which is developed for the textbook
- CtrlLAB can be downloaded from: www.siam.org/books/dc14
  - Or from: www.mathworks.com/matlabcentral/fileexchange/18-ctrllab

Mathworks Academia Resources

URL: http://www.mathworks.com/academia/

Learn:

- Student Competitions
- Simulink Student Challenge
- Interactive Tutorials
- MATLAB Fundamentals Self-Paced Training new
- Books for Getting Started
- MATLAB and Simulink Student Version
- MathWorks Certification Program

Teach:

- Classroom Resources
- Hardware for Project-Based Learning
- Physical Modeling in Academia
- 1400+ Books
- Books by Cleve Moler
- Webinars
- Examples Published with MATLAB
- Free Student Version Evaluation for Instructors
- Software for High Schools
- MATLAB and Simulink Interactive Kit

Research:

- Application Areas
- Newsletters
- Technical Articles
- User Stories
- Book Program for Authors