ME451: Control Systems

Lecture 1
Introduction

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Instructor

- Class Instructor: Dr. Jongeun Choi,
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- Office Hours
  - 2459 EB, MWF 10:10-11:00am, Extra hours by appointment

- Laboratory Instructor: Dr. Ranjan Mukherjee,
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Course information

- Lecture:
  - When: MWF: 11:30pm-12:20pm
  - Where: 226 Erickson Hall
  - Class and Laboratory website: [http://www.egr.msu.edu/classes/me451/jchoi/Fall2011/](http://www.egr.msu.edu/classes/me451/jchoi/Fall2011/)

- Required Textbook:
Course information

- Lecture:
  - When: MWF: 12:40pm-1:30pm
  - Where: 2243 Engineering Building
  - Class and Laboratory website: http://www.egr.msu.edu/classes/me451/jchoi/2012/
- Required Textbook:

Main components of the course

- Lectures (about 40 lectures)
- Old Math Quiz
- Midterm1, Midterm2
- Final (Final exam period)
- Laboratory work
- Grading:
  - Homework plus Math Quiz (10%), Exam 1 (20%), Exam 2 (20%), Final Exam (comprehensive) (25%), Laboratory work (25%)
  - Homework will be due in one week from the day it is assigned

Tips to pass this course

- Come to the lectures as many times as you can.
- Print out and bring lecture slides to the lecture.
- Do “Exercises” given at the end of each lecture.
- Do homework every week.
- Read the textbook and the slides.
- Make use of instructor’s office hours.
- If you want to get a very good grade…
  - Read the textbook thoroughly.
  - Read optional references too.
  - Do more than given “Exercises”.
  - Use and be familiar with Matlab.

What is “Control”?

- Make some object (called *system, or plant*) behave as we desire.
- Imagine “control” around you!
  - Room temperature control
  - Car/bicycle driving
  - Voice volume control
  - “Control” (move) the position of the pointer
  - Cruise control or speed control
  - Process control
  - etc.
What is “Control Systems”?  
- Why do we need control systems?  
  - Convenient (room temperature control, laundry machine)  
  - Dangerous (hot/cold places, space, bomb removal)  
  - Impossible for human (nanometer scale precision positioning, work inside the small space that human cannot enter)  
  - They exist in nature. (human body temperature control)  
  - Lower cost, high efficiency (factory automation), etc.  
- Many examples of control systems around us

Open-Loop Control
- Open-loop Control System  
  - Toaster, microwave oven, shooting a basketball

Example: Toaster
- A toaster toasts bread, by setting timer.
- Objective: make bread golden browned and crisp.
- A toaster does not measure the color of bread during the toasting process.
- For a fixed setting, in winter, the toast can be white and in summer, the toast can be black (Calibration!)
- A toaster would be more expensive with sensors to measure the color and actuators to adjust the timer based on the measured color.

Example: Laundry machine
- A laundry machine washes clothes, by setting a program.
- A laundry machine does not measure how clean the clothes become.
- Control without measuring devices (sensors) are called open-loop control.
Closed-Loop (Feedback) Control

- Compare actual behavior with desired behavior
- Make corrections based on the error
- The sensor and the actuator are key elements of a feedback loop
- Design control algorithm

\[ y_d \rightarrow e \rightarrow \text{Controller} \rightarrow \text{Actuator} \rightarrow \text{Plant} \rightarrow y \]

Ex: Automobile direction control

- Attempts to change the direction of the automobile.
- Manual closed-loop (feedback) control.
- Although the controlled system is “Automobile”, the **input** and the **output** of the system can be different, depending on **control objectives**!

\[ \text{Brain} \rightarrow \text{Hand} \rightarrow \text{Auto} \rightarrow \text{Direction} \]

Ex: Automobile cruise control

- Attempts to maintain the speed of the automobile.
- Cruise control can be both manual and automatic.
- Note the similarity of the diagram above to the diagram in the previous slide!

\[ \text{Controller} \rightarrow \text{Actuator} \rightarrow \text{Auto} \rightarrow \text{Speed} \]

Basic elements in feedback control systems

- Control system design objective:
  To design a controller s.t. the output follows the reference in a “satisfactory” manner even in the face of disturbances.
Systematic controller design process

1. Modeling
   - Modeling as a transfer function and a block diagram
     - Laplace transform (Mathematics!)
     - Mechanical, electrical, electromechanical systems

2. Analysis
   - Step response, frequency response
   - Stability: Routh-Hurwitz criterion, (Nyquist criterion)

3. Design
   - Root locus technique, frequency response technique, PID control, lead/lag compensator

4. Implementation

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Goals of this course

To learn basics of feedback control systems

- **Modeling** as a transfer function and a block diagram
  - Laplace transform (Mathematics!)
  - Mechanical, electrical, electromechanical systems

- **Analysis**
  - Step response, frequency response
  - Stability: Routh-Hurwitz criterion, (Nyquist criterion)

- **Design**
  - Root locus technique, frequency response technique, PID control, lead/lag compensator
  - Theory, (simulation with Matlab), practice in laboratories

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Course roadmap

**Modeling**
- Laplace transform
- Transfer function
- Models for systems
  - Mechanical
  - Electrical
  - Electromechanical
- Linearization

**Analysis**
- Time response
  - Transient
  - Steady state
- Frequency response
  - Bode plot
- Stability
  - Routh-Hurwitz
  - Nyquist

**Design**
- Design specs
- Root locus
- Frequency domain
- PID & Lead-lag
- Design examples

(Matlab simulations & laboratories)

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Summary & Exercises

- **Introduction**
  - Examples of control systems
  - Open loop and closed loop (feedback) control
  - Automatic control is a lot of fun!

- **Next**
  - Laplace transform

- **Exercises**
  - Buy the course textbook at the Bookstore.
  - Read Chapter 1 and 2.