ME451: Control Systems

Lecture 1
Introduction

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Instructor

- **Class Instructor:** Dr. Jongeun Choi,
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- **Office Hours**
  - 2459 EB, MW 2:00-3:00pm, Extra hours by appointment

- **Laboratory Instructor:** Dr. C. J. Radcliffe,
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Course information

- **Lecture:**
  - When: MWF: 11:30am-12:20pm,
  - Where: C103 McDonel Hall

- **Class website:**
  - [http://www.egr.msu.edu/classes/me451/jchoi/2008/](http://www.egr.msu.edu/classes/me451/jchoi/2008/)

- **Laboratory website:**
  - [http://www.egr.msu.edu/classes/me451/radcliff/lab](http://www.egr.msu.edu/classes/me451/radcliff/lab)

- **Required Text:**

Main components of the course

- **Lectures (about 40 lectures)**

- **Midterm1 (October 3rd, Friday, in class)**

- **Midterm2**

- **Final (Final exam period)**

- **Laboratory work**

- **Grading:**
  - Homework (15%), Exam 1 (15%), Exam 2 (15%), Final Exam (comprehensive) (30%), 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

\[ Y_d \quad \text{Controller (Actuator)} \quad u \quad \text{Plant} \quad y \]

- Calibration is the key!
- Can be sensitive to disturbances
Example: Toaster

- A toaster toasts bread, by setting timer.

  Setting of timer ➔ Toaster ➔ Toasted bread

- **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.

  Program setting ➔ Machine ➔ Washed clothes

- 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

Ex: Automobile direction control

- Attempts to change the direction of the automobile.

  Desired direction ➔ Error ➔ Brain ➔ Hand ➔ Auto ➔ Direction

  Error ➔ Sensor ➔ Controller ➔ Actuator ➔ Plant ➔ Output

- 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!
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!

Basic elements in feedback control systems

Control system design objective
To design a controller such that the output follows the reference in a “satisfactory” manner even in the face of disturbances.

Systematic controller design process

1. Modeling
2. Analysis
3. Design
4. Implementation

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
**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 Appendix A, B of the textbook.