ME451: Control Systems

Lecture 1
Introduction

Dr. Jongeun Choi
Department of Mechanical Engineering
Michigan State University
Instructor

- **Class Instructor:** Dr. Jongeun Choi,
  - Website: [http://www.egr.msu.edu/~jchoi/](http://www.egr.msu.edu/~jchoi/)
  - Associate Professor at ME department,
  - 2459 Engineering Building,
  - Email: jchoi@egr.msu.edu

- **Office Hours**
  - 2459 EB, MW 10:00-11:00am, Extra hours by appointment

- **Laboratory Instructor:** Dr. Jongeun Choi
Course information

- Lecture:
  - When: MWF: 11:30am-12:20pm
  - Where: **008 Urban Plan & Land Arch Bldg**
  - Class and Laboratory website:
    - [http://www.egr.msu.edu/classes/me451/jchoi/2014/](http://www.egr.msu.edu/classes/me451/jchoi/2014/)
    - [http://www.egr.msu.edu/classes/me451/me451_labs/Fall_2014/index.html](http://www.egr.msu.edu/classes/me451/me451_labs/Fall_2014/index.html)
  - Required Textbook:
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.
- Read the textbook and the slides.
- Make use of instructor’s office hours.
- If you want to get a very good grade…
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)
  - It exists in nature. (human body temperature control)
  - Lower cost, high efficiency, etc.

- Many examples of control systems around us
Open-Loop Control

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

- Calibration is the key!
- Can be sensitive to disturbances

Diagram:

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

Signal Input

Fall 2008
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**
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!
• 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 s.t. the output follows the reference in a “satisfactory” manner even in the face of disturbances.
Systematic controller design process

1. Modeling
Mathematical model

2. Analysis

3. Design

4. Implementation

Reference

Disturbance

Output

Controller

Actuator

Plant

Sensor

Controller
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
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.