EENG307: Course Introduction*

Lecture 1

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1 Motivation for the Course

Feedback control systems can be found practically everywhere these days. Some are very simple, such as the float controller for the water level in your toilet tank. Others are extremely complicated, such as the many control systems used by a modern jet airplane. In fact, modern feedback control theory and practice largely co-evolved with the aerospace industry. You'll find feedback control concepts taught in multiple departments at many universities, especially in Electrical, Mechanical, Aerospace, and Chemical Engineering programs.

Feedback controllers can be useful in solving a wide variety of real-world problems. One common example in the news these days is autonomous vehicles. This video https://www.youtube.com/watch?v=cdgQpa1pUUE gives an early example from 2012 of a self-driving car and how it can enhance the quality of life for a person who is legally blind. Of course, we would be remiss to avoid pointing out that autonomous vehicles have also been in the news lately with negative outcomes like accidents, even resulting in death. Like most engineered systems, they are far from perfect, which is a good reminder for all of us engineers to think about the consequences of our engineering design decisions, both in terms of how we define and how we solve problems.

Feedback Control Overview

Let's take a look at a feedback control system for a set of solar panels tracking the sun as it moves across the sky:

https://www.youtube.com/watch?v=bE179wgm164

How do these concepts connect with what we'll learn this semester? Compare the video to the schedule at the end of the Syllabus and you'll see that...

- you'll learn the basic principles of modeling – meaning creating differential equation or Laplace-domain representations for – physical systems starting in Lecture 2: Modeling Mechanical Systems.
- we'll do a quick review of some differential equation concepts that will remind you of the connection between an integral and the Laplace-domain function $\frac{1}{s}$ in Lecture 4: Laplace Transform Review.

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- we'll talk more about using Simulink to model systems in Lecture 6: Mechanical Impedance and Introduction to Modeling with Simulink
- you'll learn more about the block diagram representation that is used in Simulink in Lecture 8: Block Diagrams.
- we'll design closed-loop feedback controllers in a number of lectures, starting with Lecture 9: Introduction to Control Concepts and More on Stability.
- you'll learn specifically about modeling rotational mechanical systems (like the solar panels) in Lecture 14: Rotational and Fluid Systems.
- you'll learn how to model DC motors in Lecture 20: Modeling DC Motors.
- and more!

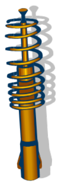
Some definitions

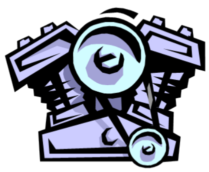
The subject of this course is feedback control of dynamic systems. These color-coded terms are defined in the next couple of pages.

What are systems?

- A system is an interconnected subset of the universe!

- Example Systems:

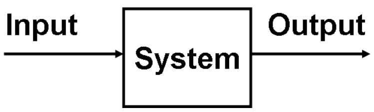




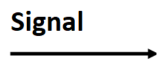
In this class, we will represent systems using blocks.

Input and Output *Signals*

- By definition, we have to separate a system from the rest of the world
  - Input signals: connection variables that we will determine
  - Output signals: connection variables that we will observe, whether by predicting (using mathematical models) or measuring



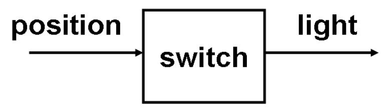
Signals are represented by arrows.



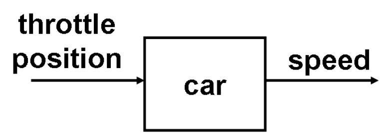
It can be useful to categorize systems as either *static* or *dynamic*.

Static vs. Dynamic Systems

- Static System



- Dynamic System



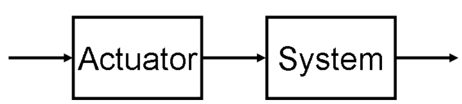
- What is the difference?

A static system does not depend on the state of the system at previous times. In other words, the light will be on whenever the light switch is in the position corresponding to "on" (usually up), no matter whether it has been on or off in the past. A dynamic system, however, does depend on the state of the system in the past. In the car example, if the car starts at 0 mph, a given throttle position will result in a slower speed 3 seconds later than that same throttle position for a car that is already moving at 30 mph.

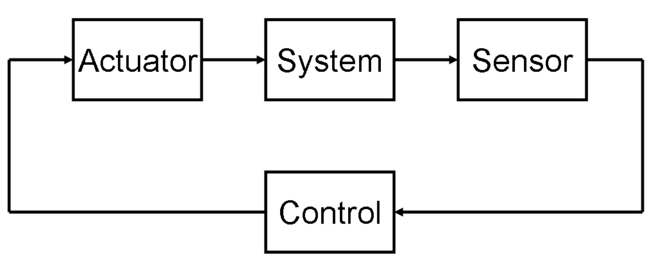
In this class, we will primarily concern ourselves with dynamic systems. We will create mathematical models of these systems using differential equations (time domain) or Laplace-domain equations.

Open vs. Closed-Loop Control Systems

- Open Loop System



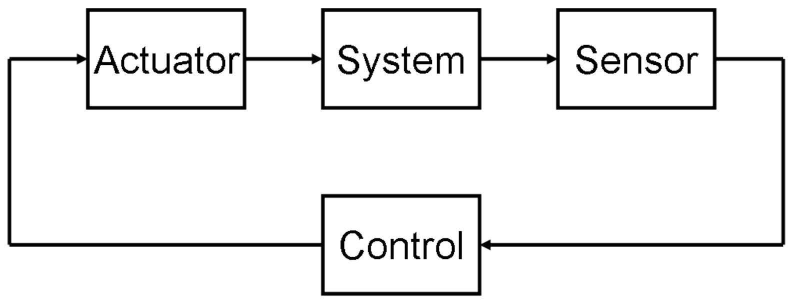
- Closed Loop Control (Feedback Control)



An open-loop control system is one in which you must determine the input signal (arrow going in to the “Actuator” block in the first example above) ahead of time to achieve a desired output signal (arrow coming out of the “System” block). Open loop control is usually ineffective for anything but the simplest systems. It requires you to know the system and actuators perfectly and that there be no unexpected disturbances.

A closed-loop system is one in which you can start at any point along the system, traveling through the systems (blocks) and signals (arrows) until you reach your starting point again. Closed-loop control can be very effective since it relies on a measurement (arrow coming out of the “Sensor” block) of the output signal (arrow connecting the “System” and “Sensor” blocks), which the controller uses to determine the input signal to the actuator. Feedback control can correct for a wide variety of problems and is a key focus of this class.

Feedback Control Elements



The elements in the feedback control loop include

- the “System", often called the “Plant” or “Plant System”, which is whatever you are trying to control. For example the relationship between the force generated by the engine and speed of a car can be defined as a system.
- the “Sensor,” which measures the output signal. On a car, this would be your speedometer.
- the “Controller” (labeled “Control” in this article), which is typically performed by a computer to determine the throttle position needed by the engine to generate the desired amount of force (or power).
- the “Actuator,” which in this car example would be the relationship from the throttle position to the engine’s force (or power). In this class, we will usually not consider the actuator separately from the plant system but will instead combine them assuming a perfect actuator.

2 Lecture Highlights

The primary takeaways from this article include

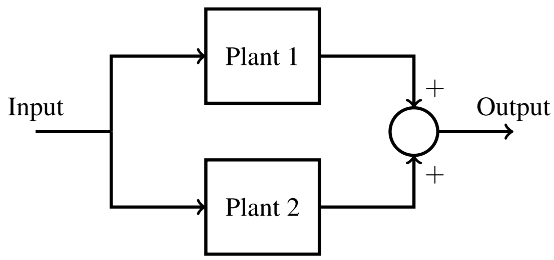
1. Feedback control impacts many aspects of our modern lives and is important to a number of engineering disciplines.
2. We’ll be working with both signals (represented by arrows, sometimes called variables) and systems (represented by boxes) in this class.
3. Control is most effective when it is configured in feedback (closed-loop), which allows for things like imperfect models and disturbance inputs. However, we’ll still need to develop mathematical models for open-loop plant systems in this class so that we can use these to build the best controllers.

3 Quiz Yourself

3.1 Questions

1. What kinds of control systems are used in this system (a stovetop and oven)?

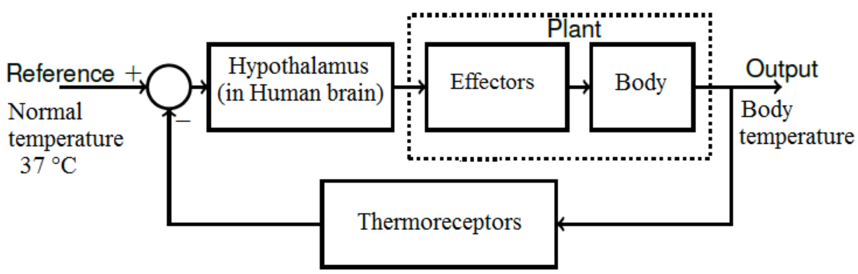
2. True or false: the figure below is of a closed-loop (feedback) system.



3. In a human body, the normal temperature fluctuates around 37 Â°C, but many factors can affect this, e.g., diseases, hormones, etc. These factors could lead to a low or high temperature. The temperature regulation process is controlled by human brain. Sketch and label the signals (arrows) and system(s) (block(s)) involved in the process of regulating human body temperature. Make it clear to the reader what dose each block represents.

3.2 Solutions

1. The stovetop burners typically use *open loop* control: you set the burner knob to your desired setting, and the burners heat up accordingly. (Some people would call this a "human-in-the-loop" controller because you might turn the knob up or down depending on how your cooking is going.) The oven is typically a closed-loop control system because a thermometer inside the oven measures the oven's temperature and automatically turns the oven heater on or off to maintain the desired temperature.
2. False. Although two branches exist, if you start on any arrow in this system and follow the arrow directions through the systems and summing block you will end up at the output signal, not back at the arrow where you started. This is actually an example of a parallel system, which we will study in more detail in Lecture 8: Block Diagrams.
3. The feedback loop described is shown in the image below.



In the feedback loop, the **thermoreceptors** act as sensors, detecting changes in body temperature. The **hypothalamus** controls a variety of effectors that respond to the change in body temperature. There are several **effectors** that are the actuators and are controlled by the hypothalamus that can respond to body temperature change. These include blood vessels near the skin and skeletal muscles.