Dynamic System Modeling and Control Design

Intro. to Control, First-Order Discrete Time Systems

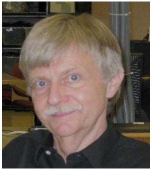
September 4, 2024

Outline

1. Course Logistics
2. Feedforward and Feedback Control
3. Discrete Time and Continuous Time Control
4. Block Diagram and Key Control Questions
5. First Order System and Proportional Control

Course Staff

Lecturers



Dennis Freeman

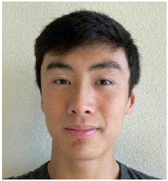
Vince Monardo

Pulkit Argawal

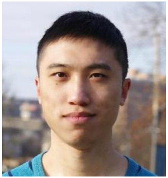
TAs

Jack Readlinger

Cole Paulin



Brian Li



Zhijian Ren

Meeting Times

Lectures: Monday, Wednesday from 3pm-4pm, 32-155

Labs (all in 38-545, starting this week):

- Thursday, 2pm-5pm
- Friday, 10am-1pm
- Friday, 2pm-5pm

Office Hours (all in 38-545, starting next week):

- TBD

Please sign up on Piazza.

Reminder: Please Submit the Lab Schedule Form!

6.310

Dynamic System Modeling and Control Design (Fall 2024)

Room Change: The first lecture in 6.3100/6.3102 will be held on Wed, Sep 4, at 3pm in 2-190

Hello Vince Monardo (monardo@mit.edu).
Welcome to 6.3100/6.3102.

Please schedule your lab section ASAP.
Our first lab will be held this Thursday, September 5.
Please fill out the lab schedule form to request a lab section.

Course Content

Course Website: `https://introcontrol.mit.edu/`

Course Content:

Part 1: Classical control

- Discrete time (steady state error, stability)
- Continuous time (sinusoidal steady state)

Part 2: Introduction to modern control

- State space representation
- Pole placement, LQR
- Observers

Pre-requisites: (8.02 (GIR) and (18.06 or 18.C06)) or consult an instructor.

Course Components

6 labs (2 weeks per lab)

- Based on in-person checkoffs
- Need to complete a lab before the next lab
- Need to submit the post-lab before the next lab

Written post-lab problems – graded by the TAs

- Solutions are posted immediately after the deadline

Online pre-lab problems

Extensions and late policies

Lab and post lab:
Please contact one of the course instructors and S^3 if you find yourself falling behind. We will do all that we can to provide accomodations if unplanned issues arise.

Online prelab:
No late penalty

Grade in 6.310 (Undergraduate Subject)

To get an A, you must

- complete all checkoffs in all labs,
- submit correct answers to at least 90% of prelabs,
- receive a grade of C or higher on each of the postlabs, and
- receive an average grade of A on the postlabs (after dropping lowest postlab score).

To get a B, you must:

- complete all checkoffs in all labs,
- submit correct answers to at least 80% of prelabs,
- receive a grade of C or higher on each of the postlabs, and
- receive an average grade of B on the postlabs (after dropping lowest postlab score).

Grade in 6.3102 (Graduate Subject)

To get an A, you must

- satisfy all of the criteria for an A in 6.310 and
- receive an average grade of A on the graduate problems.

To get a B, you must:

- satisfy all of the criteria for an B in 6.310 and
- receive an average grade of B on the graduate problems.

Classes of Control Systems

Control designs fall broadly into two classes:

- **Feedforward**: control action is not dependent on sensor information
- **Feedback**: control action depends on real-time sensor feedback

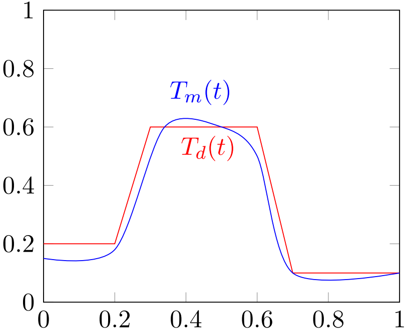
Examples:

- **Feedforward**: kicking a ball; the control signal is based on prior results. Once kicked, we cannot influence the trajectory of the ball.
- **Feedback**: driving a car; requires us to observe our surroundings and provide continual instructions

Understanding Time in Control

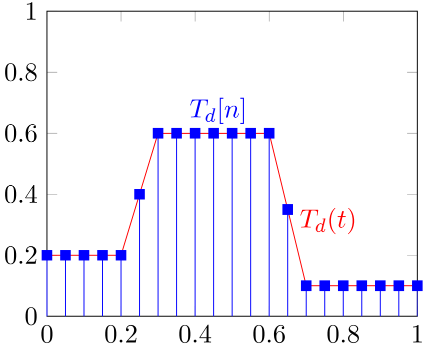
Physical systems operate in *continuous time* (CT). For example, suppose we want to operate a system at a desired temperature. We can then measure the actual temperature.

- $T_d(t)$: desired temperature
- $T_m(t)$: measured temperature



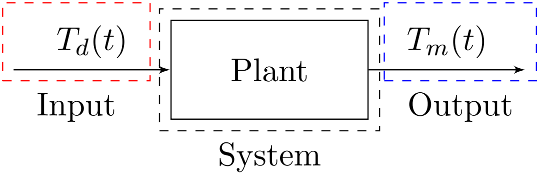
From Continuous to Discrete Time

Systems controlled by microcontrollers operate at a fixed rate, i.e., in *discrete time* (DT).



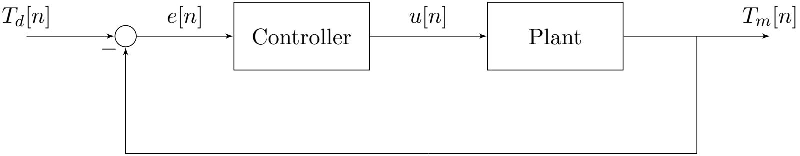
Open-Loop Block Diagram

Block diagrams are critical for analyzing the logic of the control system. For example, here is our simple open-loop control diagram:



Check Yourself: Closed-Loop Block Diagram

Consider the following closed-loop control diagram:

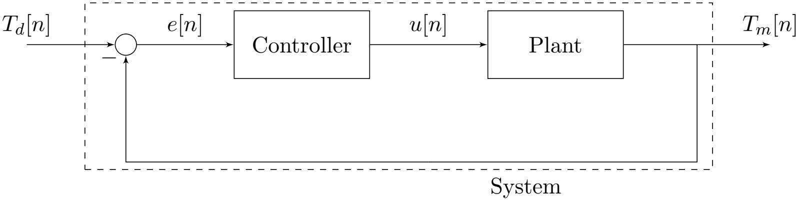


Identify:

- Input to the system
- Output of the system
- The error, i.e., difference between $T_d[n]$ and $T_m[n]$
- The control signal

Check Yourself: Closed-Loop Block Diagram

Consider the following closed-loop control diagram:

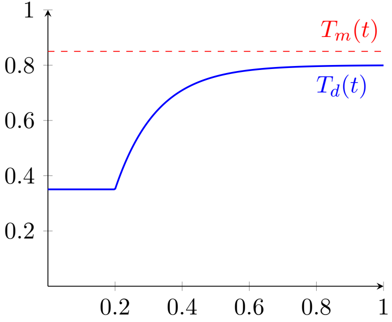


Identify:

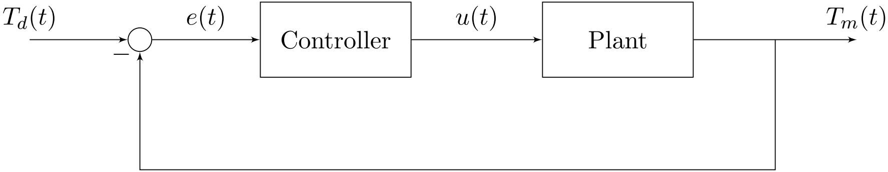
- Input to the system: $T_d[n]$
- Output of the system: $T_m[n]$
- The error, i.e., difference between $T_d[n]$ and $T_m[n]$: $e[n]$
- The control signal: $u[n]$

Key Design Questions

- **Stability**: will the control input be finite?
- **Steady-state error**: $\lim_{t\to\infty} |T_m(t) - T_d(t)|$
- **Convergence rate**: How fast does $T_m(t)$ approach $T_d(t)$?
- **Noise rejection**: How well does the controller deal with unexpected disturbance?



First Order CT Systems



The first order differential equation that describes our system is:

$$\frac{dT_m(t)}{dt} = \gamma u(t).$$

First Order Systems

The first order differential equation that describes our system is:

$$\frac{dT_m(t)}{dt} = \gamma u(t).$$

However, with our microcontroller we need to discretize the equation:

$$\frac{T_m[n] - T_m[n-1]}{\Delta T} = \gamma u[n-1]$$

A simple type of controller is called proportional control:

$$u[n] = K_p e[n] = K_p(T_d[n] - T_m[n])$$

How do we pick K_p? Next lecture!