Dynamic System Modeling and Control Design

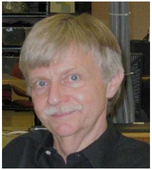
Intro. to Control, First-Order Discrete Time Systems

September 4, 2024

Outline

Course Staff

Lecturers



Dennis Freeman

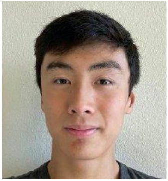
Vince Monardo

Pulkit Argawal

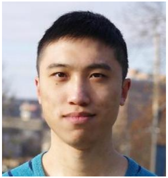
TAs

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

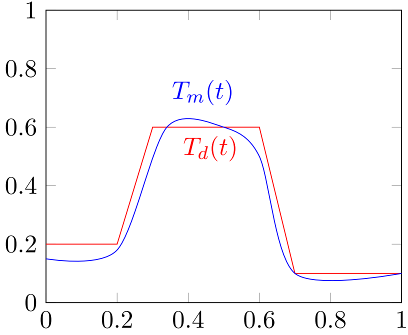
Examples:

- **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

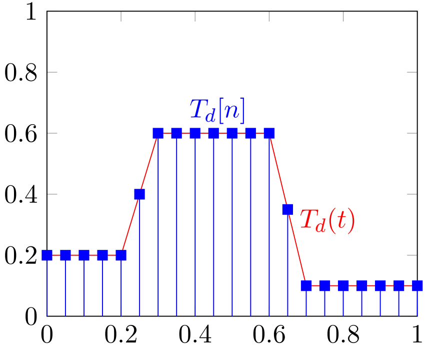
Physical systems operate in *continuous time* (CT). For example, suppose we want to operate a system at a desired temperature. We can then measure the actual temperature.

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



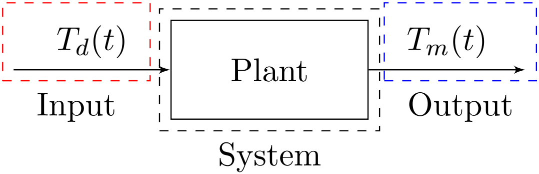
From Continuous to Discrete Time

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



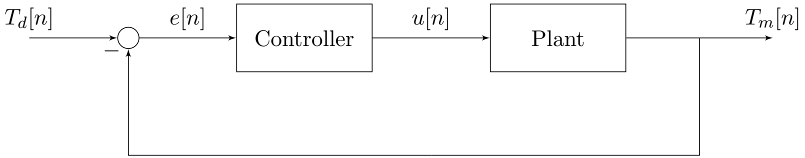
Open-Loop Block Diagram

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:

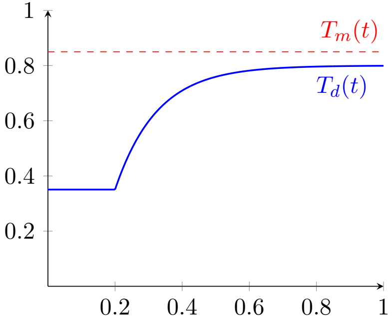


Identify:

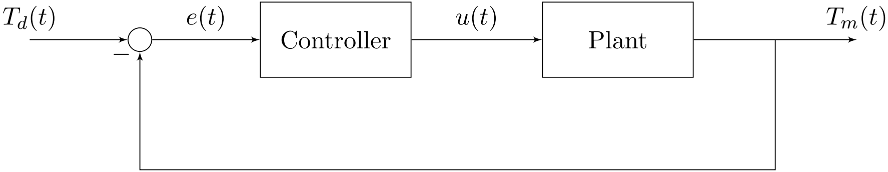
- Input to the system
- Output of the system
- The error, i.e., difference between $T_d[n]$ and $T_m[n]$
- The control signal

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

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

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!