Introduction to Modern Controls

Introduction

The power of controls

- Our internal body temperature is regulated around 37° C or 98.6° F, whether in a sauna room or outside at the north pole.
- The power of *feedback controls*: it allows us to make a precision device out of a crude one that works well even in changing environments.
- We also use *prediction and feedforward controls*: as kids, we had learned to wear T-shirts in summer, long sleeves and coats in winter. With such predictive and feedforward controls, the burden of feedback control is greatly lifted.

Analysis and control of linear dynamic systems

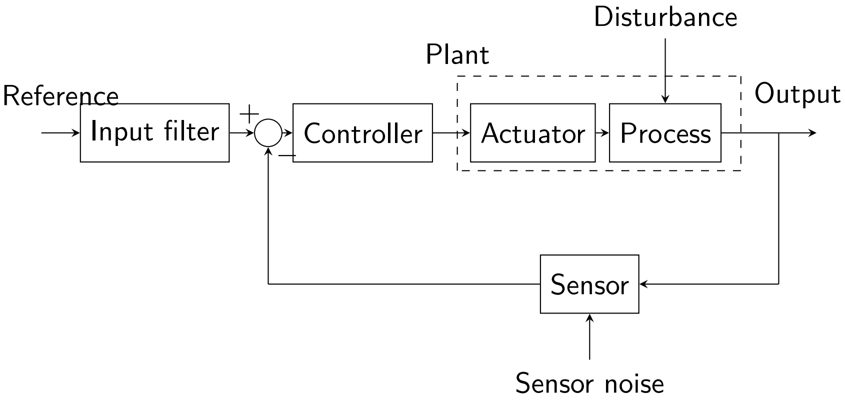
- System: an interconnection of elements and devices for a desired purpose
- Control System: an interconnection of components forming a system configuration that will provide a desired response
- Feedback: the use of information of the past or the present to influence behaviors of a system

Why automatic control?

A system can be either manually or automatically controlled. Why automatic control?

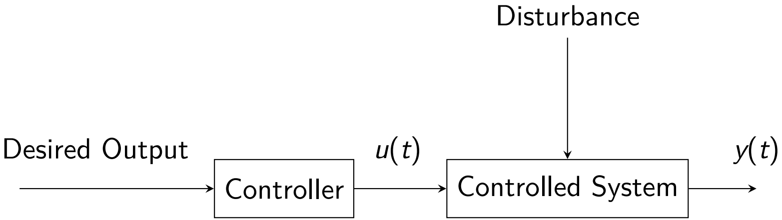
- Stability/Safety: difficult/impossible for humans to control the process or would expose humans to risk
- Performance: cannot be done "as well" by humans
- Cost: Humans are more expensive and can get bored
- Robustness: can deliver the requisite performance even if process behaves slightly differently

Terminologies



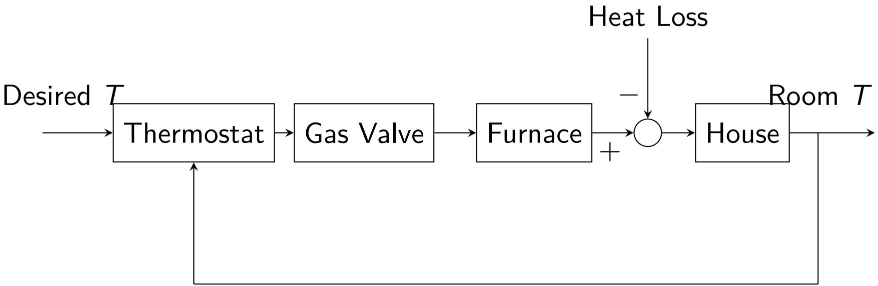
- Process: whose output(s) is/are to be controlled
- Actuator: device to influence the controlled variable of the process
- Plant: process + actuator
- Block diagram: visualizes system structure and the flow information in control systems

Open-loop control v.s. closed-loop control



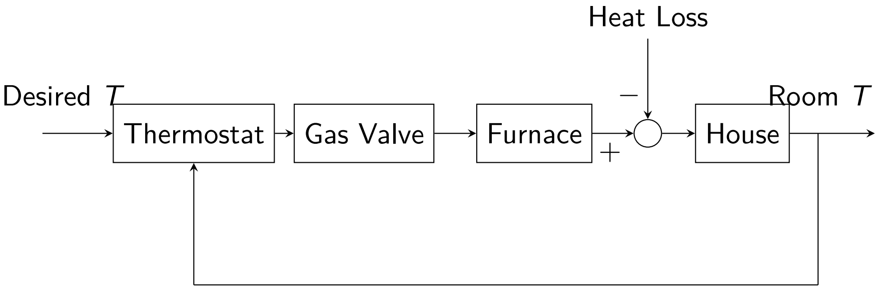
- the output of the plant does not influence the input to the controller
- input and output as *signals*: functions of time, e.g., speed of a car, temperature in a room, voltage applied to a motor, price of a stock, electrical-cardiograph, all as functions of time.

Open-loop control v.s. closed-loop control

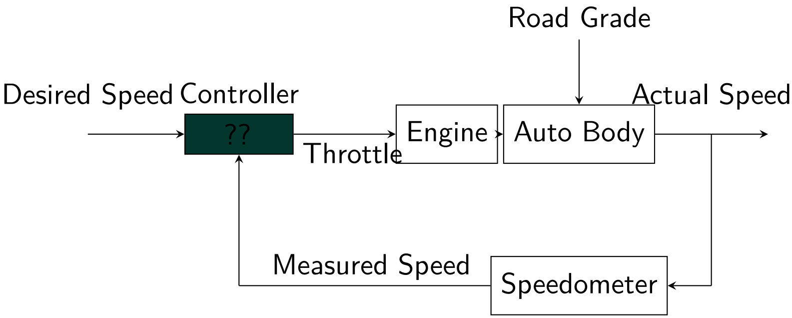


- multiple components (plant, controller, etc) have a closed interconnection
- there is always feedback in a closed-loop system

Closed-loop control: regulation example



Regulation control example: automobile cruise control



- What is the control objective?
- What are the process, process output, actuator, sensor, reference, and disturbance?

Control objectives

- Better stability
- Improved response characteristics
- *Regulation* of output in the presence of disturbances and noises
- Robustness to plant uncertainties
- *Tracking* time varying desired output

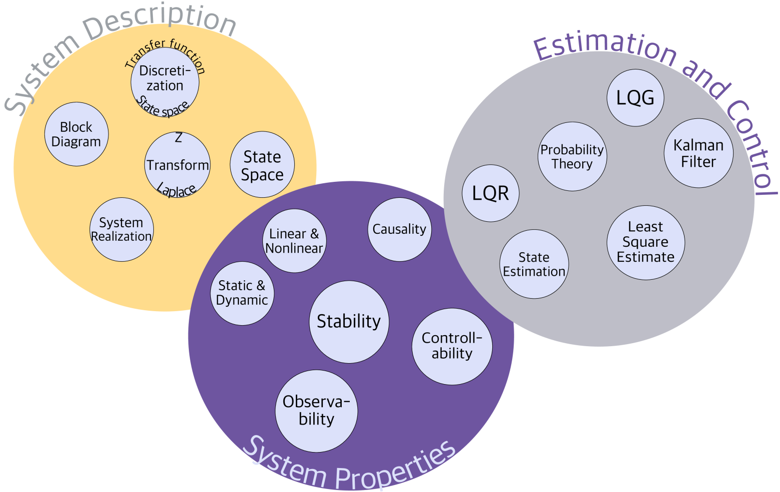
There are some aspects of control objectives that are universal. For example, we would always want our control system to result in closed-loop dynamics that are insensitive to disturbances. This is the disturbance rejection problem. Also, as pointed out previously, we would want the controller to be robust to plant modeling errors.

Means to achieve the control objectives

- Model the controlled plant
- Analyze the characteristics of the plant
- Design control algorithms (controllers)
- Analyze performance and robustness of the control system
- Implement the controller

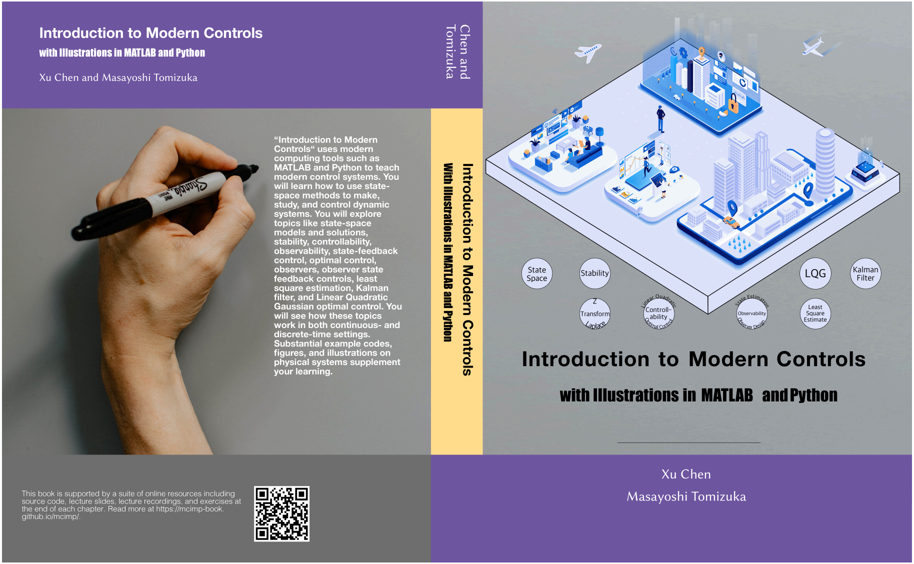
About this course

- a first-year graduate course on modern control systems



- a prerequisite to most advanced control courses

Textbook


Introduction to Modern Controls
with Illustrations in MATLAB and Python
Xu Chen and Masayoshi Tomizuka
Chen and Tomizuka
“Introduction to Modern Controls“ uses modern computing tools such as MATLAB and Python to teach modern control systems. You will learn how to use state-space methods to make, study, and control dynamic systems. You will explore topics like state-space models and solutions, stability, controllability, observability, state-feedback control, optimal control, observers, observer state feedback controls, least square estimation, Kalman filter, and Linear Quadratic Gaussian optimal control. You will see how these topics work in both continuous- and discrete-time settings. Substantial example codes, figures, and illustrations on physical systems supplement your learning.
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This book is supported by a suite of online resources including source code, lecture slides, lecture recordings, and exercises at the end of each chapter. Read more at https://mcimp-book.github.io/mcimp/.
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Linear Quadratic
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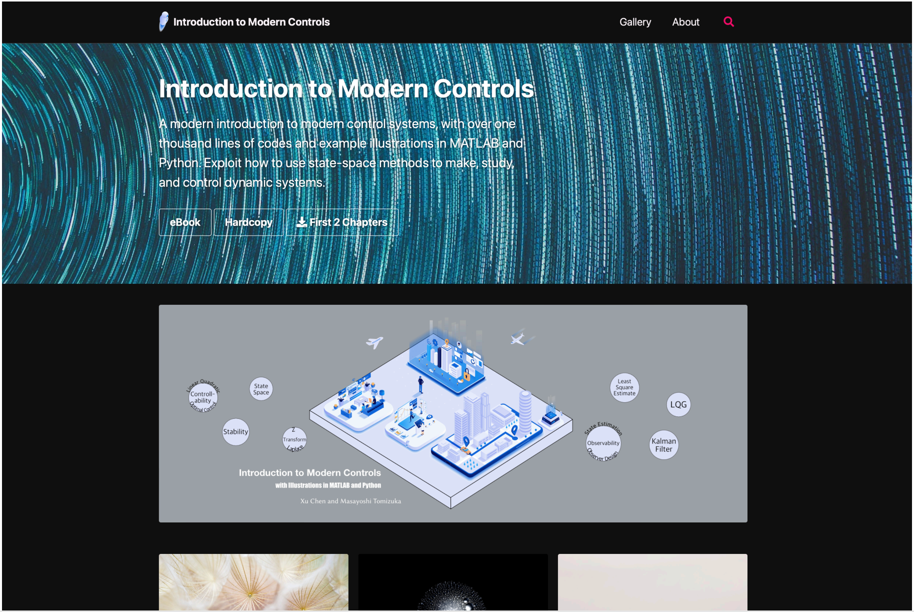
Textbook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A modern introduction to modern control systems, with over one thousand lines of codes and example illustrations in MATLAB and Python. Exploit how to use state-space methods to make, study, and control dynamic systems.
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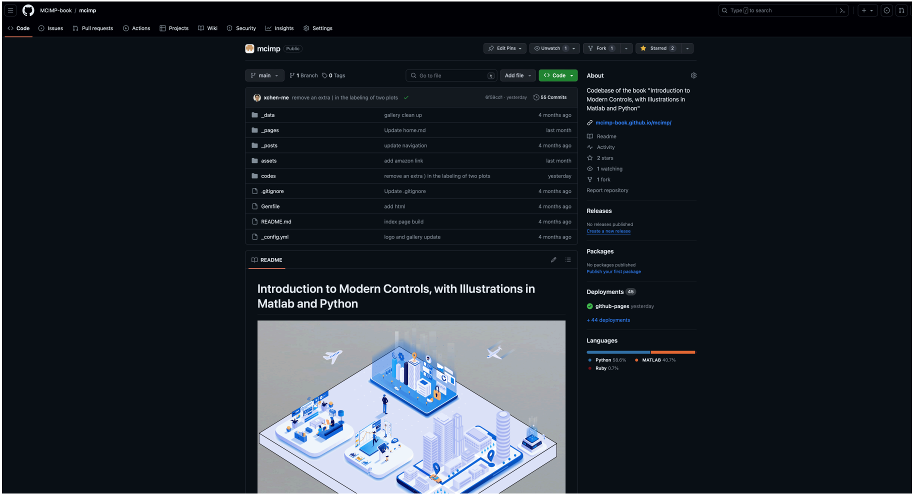
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1 Branch
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Code
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Packages
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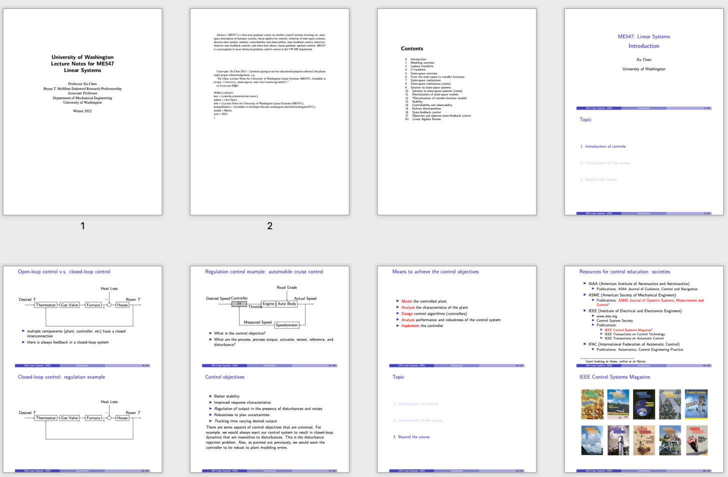
Publish your first package
Deployments 45
github-pages yesterday
+ 44 deployments
Languages
Python 58.6%
MATLAB 40.7%
Ruby 0.7%

Written materials

- Open-source Course Notes



Resources for control education: societies

- AIAA (American Institute of Aeronautics and Astronautics)
  - Publications: AIAA Journal of Guidance, Control and Navigation
- ASME (American Society of Mechanical Engineers)
  - Publications: ASME Journal of Dynamic Systems, Measurement and Control[1]
- IEEE (Institute of Electrical and Electronics Engineers)
  - www.ieee.org
  - Control System Society
  - Publications:
    - IEEE Control Systems Magazine[1]
    - IEEE Transactions on Control Technology
    - IEEE Transactions on Automatic Control
- IFAC (International Federation of Automatic Control)
  - Publications: Automatica, Control Engineering Practice

[1] start looking at these, online or at library

IEEE Control Systems Magazine