Goals for today

• Introduce concepts to be covered in the course (w/ context)
• Course structure & administration
Control System “Standard Model”

Key elements
- Process: input/output system w/ dynamics
- Actuation: mechanism for manipulating process
- Sensing: mechanism for detecting process state
- Compute: compare actual / desired; determine action
- Environment: description of the uncertainty present in the system (bounded set of inputs/behaviors)

Advantages of feedback
- Design of dynamics
- Robustness to uncertainty
- Modularity and interoperability

Disadvantages of feedback
- Increased complexity
- Potential for instability
- Amplification of noise
Important Trends in Control in the Last 15* Years

(Online) Optimization-based control
- Increased use of online optimization (MPC/RHC)
- Use knowledge of (current) constraints & environment to allow performance and adaptability

Layering, architectures, networked control systems
- Command & control at multiple levels of abstraction
- Modularity in product families via layers

Formal methods for analysis, design and synthesis
- Build on work in hybrid and discrete event systems
- Formal methods from computer science, adapted for “cyberphysical” (computing + control) systems

Components → Systems → Enterprise
- Increased scale: supply chains, smart grid, IoT
- Use of modeling, analysis and synthesis techniques at all levels. Integration of “software” with “controls”
Design of Modern (Networked) Control Systems

Examples
- Aerospace systems
- Self-driving cars
- Factory automation/process control
- Smart buildings, grid, transportation

Challenges
- How do we define the layers/interfaces (vertical contracts)
- How do we scale to many devices (horizontal contracts)
- Stability, robustness, security, privacy

Control = dynamics, uncertainty, feedforward, feedback
Example: Autonomous Vehicles (Alice)

Vehicle
- 2005 Ford E-350 Van
- Drive-by-wire steering, brakes, accel

Sensing
- 5 cameras: 2 stereo pairs, roadfinding
- 5 LIDARs: long, med*2, short, bumper
- 2 GPS units + 1 IMU (LN 200)

Computing (2005)
- 6 Dell PowerEdge Servers (P4, 3GHz)
- 1 IBM Quad Core AMD64 (fast!)
- 1 Gb/s switched ethernet

Software
- 15 programs with ~100 exec threads
- 100,000+ lines of executable code
### Feedback Control System Examples

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<th>Bioengineering</th>
<th>Chemical Engineering</th>
<th>Questions to answer</th>
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### Questions to answer
- Controlled variable:
- Performance goal:
- Source of uncertainty:
- Inputs:
- Outputs:
- States:
Course Structure

Part I: Modeling and Analysis (W1-W3)
• State space modeling, stability, phase portraits
• Input/output response (mainly linear systems)

Part II: State Space Control Design (W4-W6)
• State feedback
• Trajectory generation

Part III: Frequency Domain Analysis (W7-W9)
• Frequency response
• Robustness and fundamental tradeoffs

Course architecture
• Monday: big picture, conceptual view
• Wednesday: analytical techniques
• Friday: computation techniques

Lectures + reading + homework => expertise
Course Administration

Prerequisites

- Ma 1 abc and Ma 2/102 or equiv
- Ability to use Python (laptop, Colab)

Course syllabus

- Instructors (lecturers, TAs)
- Lectures (MW) + Python (WF)
- Office hours, Q&A forum (Piazza)
- Course outline
- Homework (W → W + grace period)
- Grading scheme, collaboration policy
- Course text and references
- Course load: keep track of hours
- Course ombuds: send e-mail to Richard by Wed evening to volunteer

https://www.cds.caltech.edu/cds110