Module 01
Course Syllabus, Prerequisites, Policies, Course Overview

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EE 5143: Linear Systems and Control

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Course Instructor: Background & Interests

Background

- Born and raised in Beirut, Lebanon
- Finished my Ph.D. in ECE from Purdue University in August 2015
- Undergraduate education: American University of Beirut — Class of 2011, B.E., ECE
- Assistant Professor, ECE Department @ UTSA
- At UTSA since August 10, 2015

My Ultimate Objective

Understand how complex systems (and the world) operate and utilize this knowledge to create tools & control algorithms that would be leveraged to solve system-level challenges

Essentially, this should improve the quality of our lives...Hopefully!

Module 01 Outline

1. You will introduce yourselves
2. Course syllabus and expectations *(very high ones, believe me!)*
3. Course outline
4. Homework #1
5. The fun stuff starts — we'll start talking about the fun world of control theory

Part I — Your Turn to Introduce Yourselves! ☺

Part II — Course Syllabus, Outline & HW # 1

Course webpage & Communication

Course Pages:

- UTSA Blackboard: http://utsa.blackboard.com
- My Webpage: http://engineering.utsa.edu/~taha
- *Email is the best form of communication!*
- Students are required to write exactly the following in the subject line of the email: [EE 5143] – ...

Office Hours:

- Tuesdays & Thursdays, 16:00 – 17:00
- Or by appointment

Course Description

- Modern control theory
- Linear systems analysis and design
- State space representations and transfer functions
- Discrete and continuous time systems
- Stability, controllability, observability of dynamical systems

Main References

- Lecture notes will be provided as handouts or presentation slides
- However, you will need to refer to the following textbook:
  - C. T. Chen, *Linear System Theory and Design*, Oxford University Press.
- You do not need to buy the above book (you can download the ebook if you want)

Prerequisites

- Mild linear algebra
- Multivariable calculus
- Integration and differentiation
- Love to multiply and add things
- Quick wit
- *And most importantly, the will to learn—that I cannot change*
- Remember that you guys are grad students (or about to become graduate students)
- Also: shoutout to the brave undergrads here ;)

Learning

- Education and teaching are all about learning
- There's a reason why infants learn faster than us—they wanna learn
- There are people who want to learn and change...
- And people who do not want to do so
- I'll try my best, but you'll have to do the hard work
- Forget about the grades, focus on learning
- I'll be very generous with grades if you show me that you're learning
- Let's have some fun this semester

Grading Policy

- Homework assignments and unannounced, in-class quizzes **(25%)**
- Exam 1 **(20%)**
- Exam 2 **(20%)**
- Final Exam **(30%)**
- Attendance and instructor evaluation **(5%)**

Course Grade Cutoffs [God, I hate this part]

- A−, A, A+: 85–100
- B−, B, B+: 70–84
- C−, C, C+: 55–69
- D: 50–54
- F: $\leq$ 49

Programming Tools

- MATLAB will be required for homework assignments and course projects
- Students can obtain the discounted student version of MATLAB
- Most answers to homework questions can be verified via MATLAB or Simulink

Class Policies

- Regular attendance
- Smartphone break
- Active feedback loop
- Emailing me
- Showing up early
- Homeworks (discrete grading), quizzes (a lot of them), exams (easy ones, trust me)
- Course projects
- Late submission policy
- Changes to the syllabus
- Campus Carry

Tentative Class Schedule

Part I — Control Systems Introduction & Background .... ≈ 1–2 classes

- Course introduction & syllabus, prerequisites, major applications, assessment exam

Part II — Transfer Functions, Linear Algebra Review, State Space .... ≈ 3–4 classes

- A review of transfer functions of linear systems, intro to state space representation

Part III — State Space Solutions, Exponential of a Matrix .... ≈ 3–4 classes

- Analytical computations of state and output solutions, exponential of a matrix

Part IV — Discrete Time Systems .... ≈ 1–2 classes

- Introduction to discrete time systems and their analytical solutions

Part V — Stability of Continuous and Discrete-Time Systems .... ≈ 3–4 classes

- Input-output stability, internal stability, Lyapunov theorem

Part VI — Controllability and Observability .... ≈ 2–3 classes

- Metrics for controllability and observability of linear systems

Part VII — State Feedback Control .... ≈ 2–3 classes

- Design of feedback controllers to stabilize linear systems

Part VIII — State Observation & Estimation of Control Systems .... ≈ 3–4 classes

- Introduction to dynamic estimators (observers) of control systems

Part IX — Model-Free Control Systems .... ≈ 1–2 classes

- System Identification, Special Topics

Part X — Advanced Topics in Control Theory .... ≈ 1–2 classes

- Optimal control, estimation of uncertain dynamical systems, perturbation theory

Homework #1

- It's not really a homework, so take it easy
- Deadline: Sunday, August 27th, 23:59:59
- Be serious about it
- I'll get to see your handwriting later, so please type your output
- LaTeX Template

My Objective for This Course

- I love control theory and its applications
- So, I am naturally biased to research/teaching of control
- My objective here is to learn more about control theory with you
- ...And to dig deep into the awesome world of control
- **So...Why learn control theory? Why is it awesome?**
- Well, *control theory is the glue that stitches together all other engineering fields*
- Understanding control theory and its intuition is necessary for all engineering/design fields
- Forget about the heavy math, it should all make sense

Control Theory: the Glue that Stitches Engineering Fields

- Examples: switching power regulators (depend on control/feedback)
- Communication engineer: strengthen signals via feedback and controls
- Mechanical engineer: minimize vibrations and regulate damping (design isolation control system)
- Civil engineer: build a damping system to battle earthquakes
- Industrial engineer: design a PID controller for a robotic arm in a factory
- Aerospace engineer: air-traffic control, aircraft speed control, disturbance/wind rejection
- More applications: glass cup and vibrations, touch with the finger, damping, energy dissipation

My Objective for This Course

- Control theory, in a nutshell, is and should be intuitive
- Control theory is way much more than designing a PID controller or figuring out a control law
- Control theory is building models, simulating predictions, filtering noise, designing bridges, selecting hardware, testing systems, estimating unknown quantities
- Control theory is all about understanding your system, your world, and what surrounds it
- To learn more, you have to ask more, so please do

So...What Is Control? What Is Feedback?

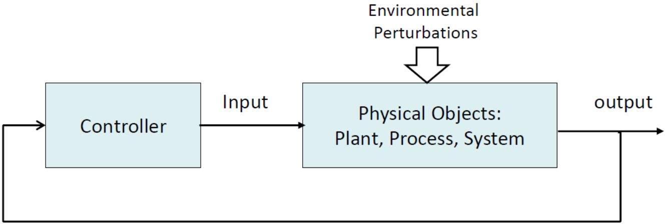
- **System:** a collection of interacting components—motor, airplane, biological unit such as the human arm are examples of systems
- **Control:** use of information to affect the operation of a device, machine, system, a human being...pretty much everything
- **Control system:** a mechanism that alters the future state of a system
- **Control theory:** a strategy to select appropriate inputs
- *Why do we do control?* Golden question: *how do I change my input to get a better output?*
- Because if we can affect the operation of something, we'll have better outcomes
- If we can control emissions, then we have a healthier environment
- If we can control room temperature, we will be more comfortable

Control Systems (CS) Are EVERYWHERE!

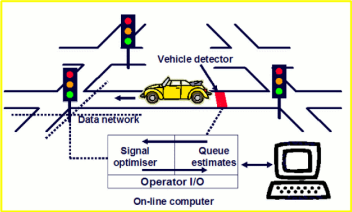
- CSs vary in complexity, size, type, but...
- In this room, in your tablets and phones
- In traffic lights, robots, the Internet, sports, music
- In your kitchen: fridge, toaster, coffee maker
- Hoverboards and Segways
- Most complex control system: *the human body*

CSs Basic Definitions & Lingo

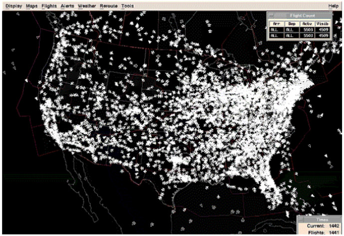
- ***Plants***: the physical object you're tryna control, impact, influence
- In this class we study how to **control plants'** behavior
- ***Control Objective:*** what is it that we want to achieve?
- ***Input***: the signals you're using to control a plant
- ***Output***: your measurements, data, what you're sensing or seeing
- ***Process***: what's happening inside the plant due to your inputs
- ***Model:*** mathematical depiction of the physics of the system
- ***Disturbances***: things that are harming the plant or the processes



Example 1 — Traffic Control



Ground Traffic



Air Traffic

- ***Plant:*** the transportation network—movement of cars, roads connectivity, highways, physics of the network
- ***Processes:*** the movement of cars, switching of traffic lights
- ***Control Objective:*** minimizing traffic
- ***Input:*** change traffic light signals
- ***Output:*** cars' movement
- ***Disturbances:*** accidents, snow, bad drivers, Snapchatters

Other CSs Examples

- Human body: temperature control—thermoregulation (a fascinating control system)
- Thermostat control: Turning heater/cooler on or off to maintain a desired room temperature
- Cruise control: maintaining constant speed given disturbances
- Robot control: changing voltage applied on the motors so that the robot hand moves in a certain way
- Nature control

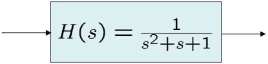
Two Control Strategies

(1) Black Box Strategy:

- **Learn by training**
- No idea what processes are happening inside your system
- Disadvantage: cannot analyze
- Advantage: no need for a physical understanding

(2) Model-Based Strategy:

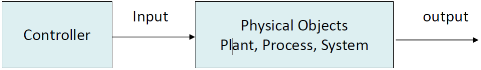
- **Build a mathematical model through equations**
- Equations relate system inputs to outputs
- Advantages? Disadvantages?



Two Classes of Model-Based Strategies

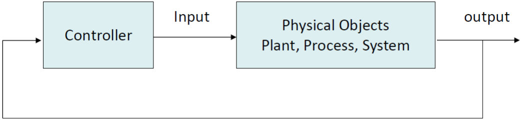
(1) Open-Loop Control Strategy:

- Controller determines the plant input without looking at output
- Advantage: only used if one has accurate **modeling** of the system
- Examples: dishwasher, washing machines, light switches, gas ovens



(2) Closed-Loop, Feedback Control Strategy:

- Controller uses plant output to help determine the plant input
- Advantages: robust to external and internal disturbances
- Examples: air conditioners, refrigerators, automatic rice cookers
- **This is what we're gonna learn here: closed-loop control!**



Questions And Suggestions?

Thank You!

Please visit

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IFF you want to know more ☺