

# Module 01

## Course Syllabus, Prerequisites, Policies, Course Overview

**Ahmad F. Taha**

**EE 5143: Linear Systems and Control**

*Email:* [ahmad.taha@utsa.edu](mailto:ahmad.taha@utsa.edu)

*Webpage:* <http://engineering.utsa.edu/ataha>



January 15, 2019

# 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 Yourself! 😊*

---

# *Part II — Course Syllabus, Outline & HW # 1*

---

# Course webpage & Communication

## Course Pages:

- UTSA Blackboard: <http://utsa.blackboard.com>
- My Webpage: <http://engineering.utsa.edu/ataha>
- *Email is the best form of communication!*

## Office Hours:

- Tuesdays & Thursdays, 14:00 – 15:30
- 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 (**0%**)
- Unannounced, in-class quizzes (**20%**) based on homework
- Exam 1 (**20%**)
- Exam 2 (**20%**)
- Final Exam (**35%**)
- 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
- 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
- Homework, quizzes (a lot of them), exams (easy ones, trust me)
- Course projects
- Late submission policy
- Changes to the syllabus
- Campus Carry

# Tentative Class Schedule

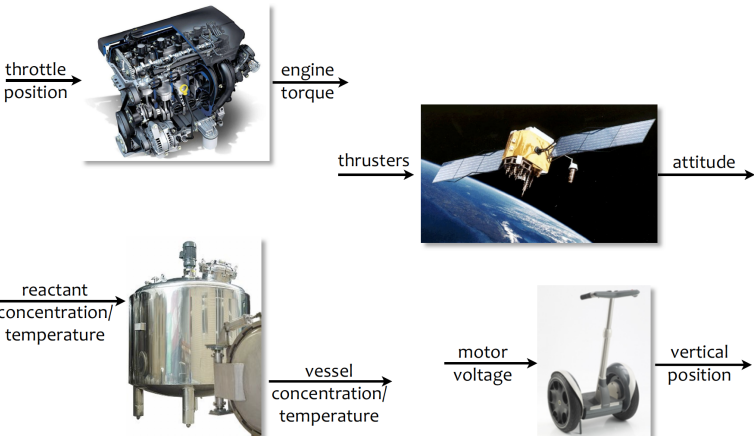
- Part I — Control Systems Introduction & Background .....  $\approx$  1–2 classes  
 █ Course introduction & syllabus, prerequisites, major applications, assessment exam
- Part II — Transfer Functions, Linear Algebra Review, State Space .....  $\approx$  3–4 classes  
 █ A review of transfer functions of linear systems, intro to state space representation
- Part III — State Space Solutions, Exponential of a Matrix .....  $\approx$  3–4 classes  
 █ Analytical computations of state and output solutions, exponential of a matrix
- Part IV — Discrete Time Systems .....  $\approx$  1–2 classes  
 █ Introduction to discrete time systems and their analytical solutions
- Part V — Stability of Continuous and Discrete-Time Systems .....  $\approx$  3–4 classes  
 █ Input-output stability, internal stability, Lyapunov theorem
- Part VI — Controllability and Observability .....  $\approx$  2–3 classes  
 █ Metrics for controllability and observability of linear systems
- Part VII — State Feedback Control .....  $\approx$  2–3 classes  
 █ Design of feedback controllers to stabilize linear systems
- Part VIII — State Observation & Estimation of Control Systems .....  $\approx$  3–4 classes  
 █ Introduction to dynamic estimators (observers) of control systems
- Part IX — Model-Free Control Systems .....  $\approx$  1–2 classes  
 █ System Identification, Special Topics
- Part X — Advanced Topics in Control Theory .....  $\approx$  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: January 20th, 23:59:59**

# Dynamic Linear Systems

- **Dynamic System:** objects that evolve over time
- **Linear Dynamic System:** input-output relationships are linear
- **Examples** on linear vs. nonlinear relationships



# 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
- Industrial engineer: design a PID controller for a robotic arm in a factory
- Aerospace engineer: air-traffic control, aircraft speed control, disturbance/wind rejection

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

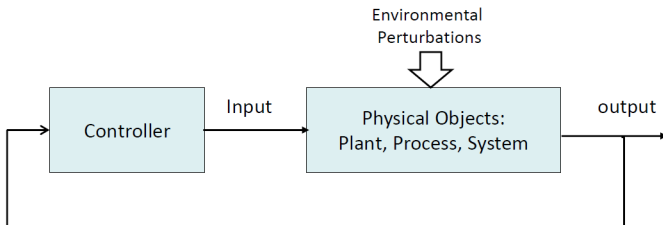
- **System:** a collection of interacting components—motor, airplane, biological unit such as the human arm are examples of systems
- **Control:** use of information to affect the operation of a device, machine, system, a human being...pretty much everything
- **Control system:** a mechanism that alters 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!

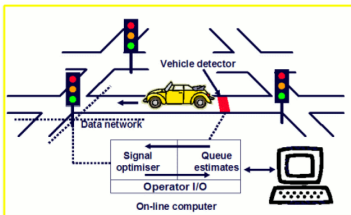
- CSs vary in complexity, size, type, but...
- In this room, in your tablets and phones
- In traffic lights, robots, the Internet, sports, music
- In your kitchen: fridge, toaster, coffee maker
- Hoverboards and Segways
- Most complex control system: *the human body*

# CSs Basic Definitions & Lingo

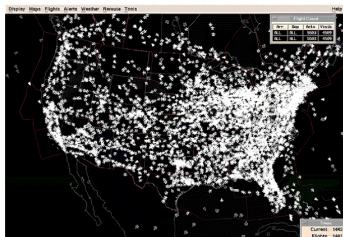
- **Plants:** the physical object you're tryna control, impact, influence
- In this class we study how to **control plants'** behavior
- **Control Objective:** what is it that we want to achieve?
- **Input:** the signals you're using to control a plant
- **Output:** your measurements, data, what you're 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

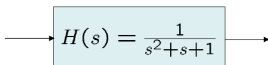
## (1) *Black Box Strategy:*

- **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:*

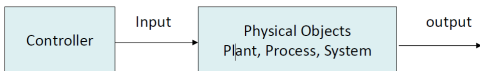
- **Build a mathematical model through equations**
- Equations relate system inputs to outputs
- Advantages? Disadvantages?



# Two Classes of Model-Based Strategies

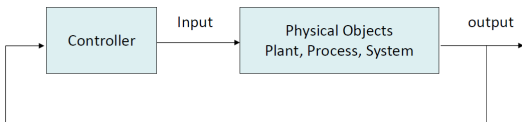
## (1) Open-Loop Control Strategy:

- 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

[engineering.utsa.edu/ataha](http://engineering.utsa.edu/ataha)

**IFF** you want to know more 😊