CS1 Week 1 Annotated

Introduction, Control Architectures, Motivation

Kissan Varatharajan

- 5^{th} Semester Mechanical Engineering Bachelor
- TA for Informatik II in the past
- Interests: Robotics, Controls, AI
- Previously software/controls @ NAUTILUS ARIS
- Focus Project at the Robotic Systems Lab

RSL
Robotic Systems Lab

Exercise Classes

1. Theory Recap from the lecture (generally 1st hour)

- In depth revision of the lecture material
- Highlighting most important concepts

2. Examples and application

3. Time for questions

- Q&A, Problem Solving, I am here for support

Feedback

I really appreciate your feedback – it makes future sessions better for everyone.

Either directly in person, via E-Mail or through this feedback form: https://docs.google.com/forms/d/e/1FAIpQLSdHl0kjWo63aNzDkAV0cnmQadCAj5L0D7v7aSh0BK7BBdEgpA/viewform?usp=header

Important

Control Systems can be seem abstract and complicated…

- Stick with the rules
- I'll provide examples and exam prep as we go along
- Don't worry, it will all make sense in the end

Other Subjects

Control Systems combines knowledge from several other subjects:

- Linear Algebra II (system of ODEs)
- Mechanics III (Modeling)
- Thermodynamics I (Modeling)
- Analysis III (Laplace & Fourier transform)
- Electrical Engineering I (Transfer functions)

As Frazzoli would say…

Exam

- 150 minutes
- 1 sheet standardized official summary (will be updated throughout the course)
- Box, SC and MC questions
- Mostly follow a recipe (but understanding can be beneficial)

Prüfungsblock I — MAVT — alle Studiengänge — davon Repetenten

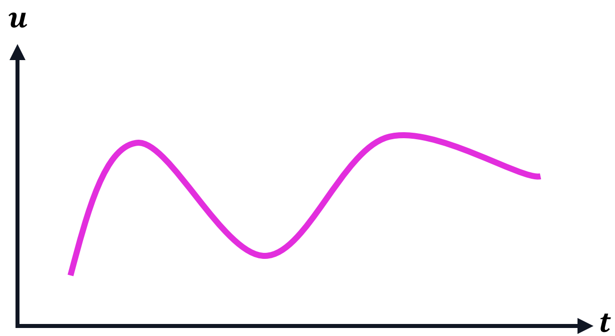
	# Stud.		Ø		std. dev.		# best.		# nicht best.		bestanden	
Gesamt	482	20	4.72		0.56		430	14	41	3	91.3%	82.4
Thermodynamik I	483		4.12	4.12	0.78	0.79					67.1%	
Mechanics III	568		4.64	4.60	0.66	0.67					86.6%	
Control Systems I	494		4.89	4.89	0.61	0.62					94.7%	
Elektrotechnik	490		4.83	4.82	0.75	0.77					87.6%	
Analysis III	499		5.07	5.06	0.67	0.68					95.4%	

Today

1. Introduction
2. Control Architectures
3. Motvation

1. Introduction

Signals and Systems

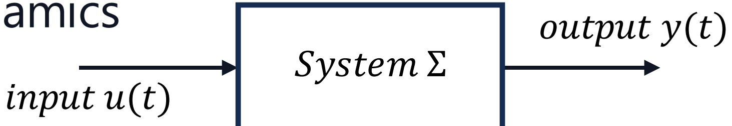


Signal

- a function of time
- can be any physical observable
- represents inputs and outputs

System

- transforms a signal and maps input $u(t)$ to output $y(t)$
- models dynamics of system can be influenced
- however you cannot change the system dynamics



sometimes called plant

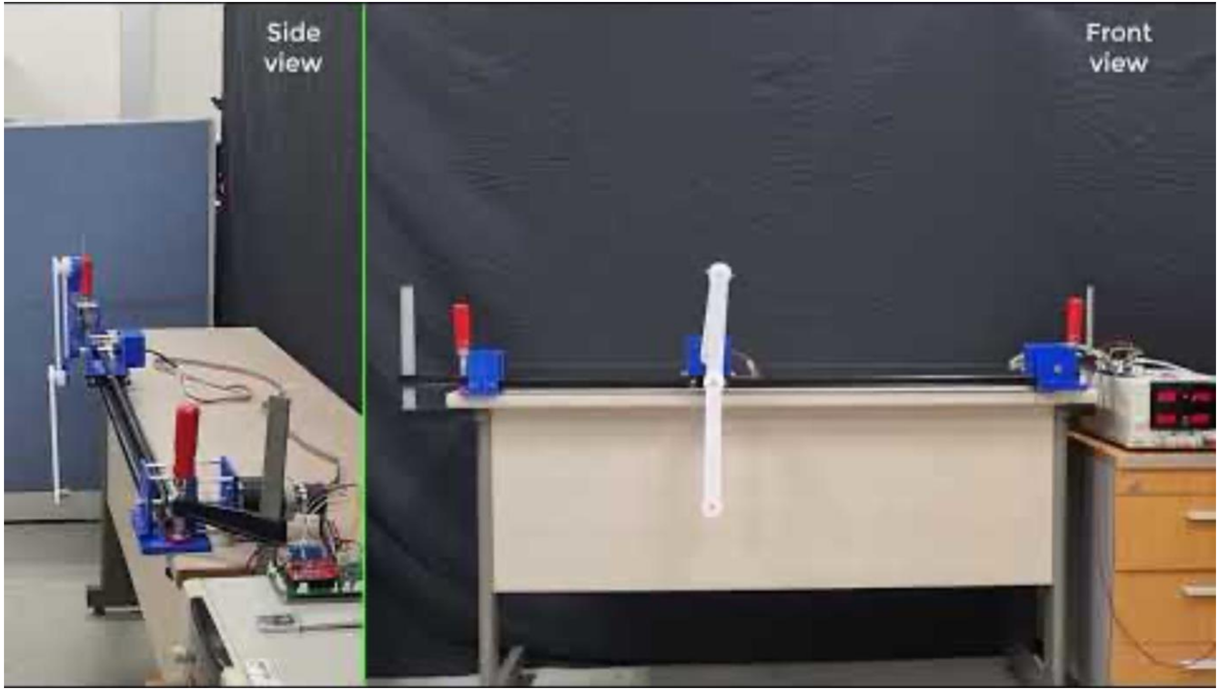
Example Airplane as System:

input: thrust

system/plant: Boeing 747

output: altitude

Example: Inverted Pendulum



Example: Inverted Pendulum

Reference r:

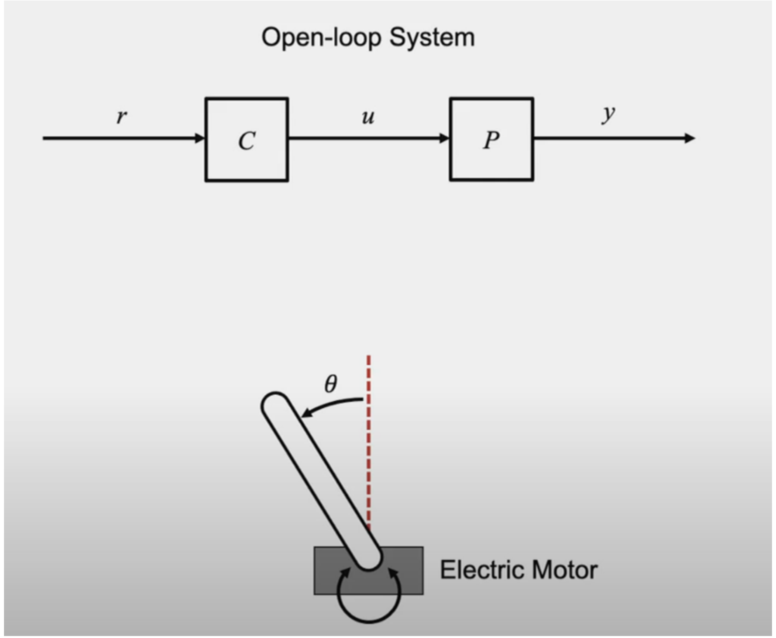
- Some desired angle θ

Input u:

- Electrical signal to motor

Output y:

- Current angle θ of pendulum



Example: Inverted Pendulum

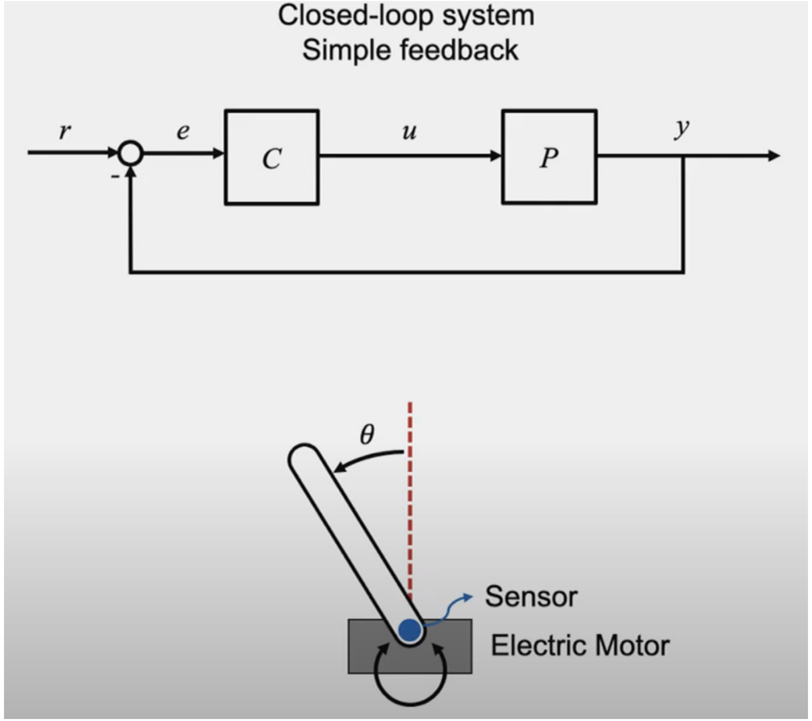
If we have some disturbances (e.g. wind blowing) we need a closed loop

Reference r:
- Some desired angle θ

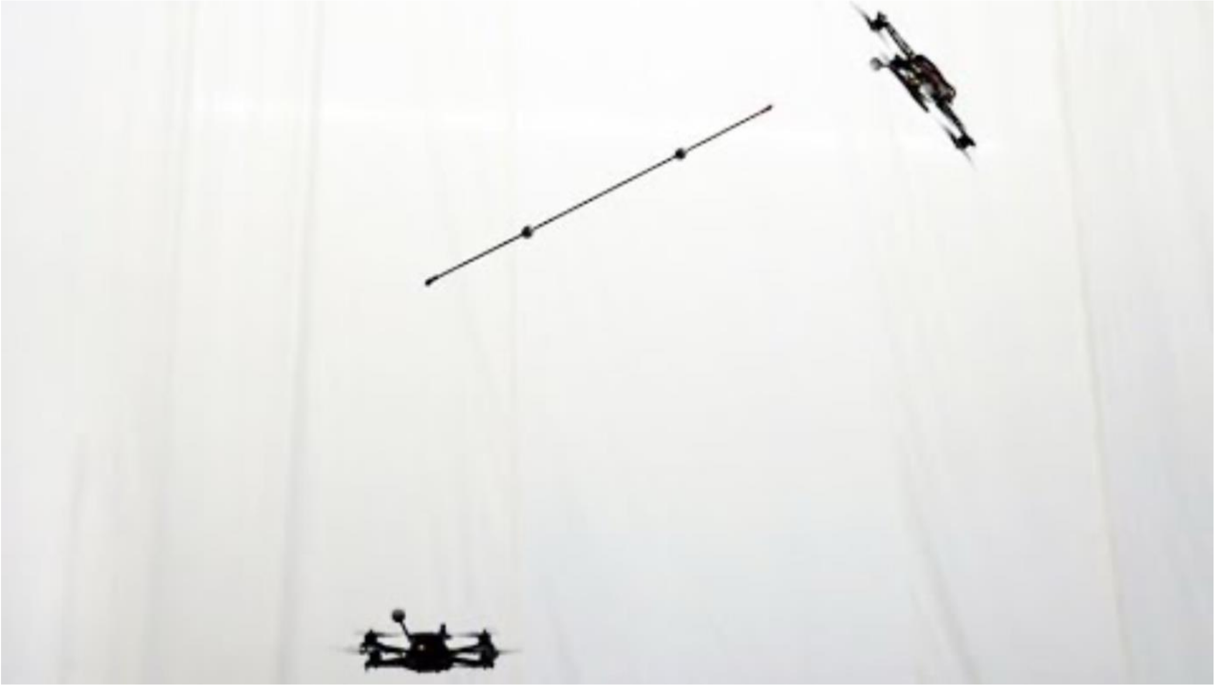
Input u:
- Electrical signal to motor

Output y:
- Current angle θ of pendulum

Error e:
- difference between reference and current angle $e = r - y$

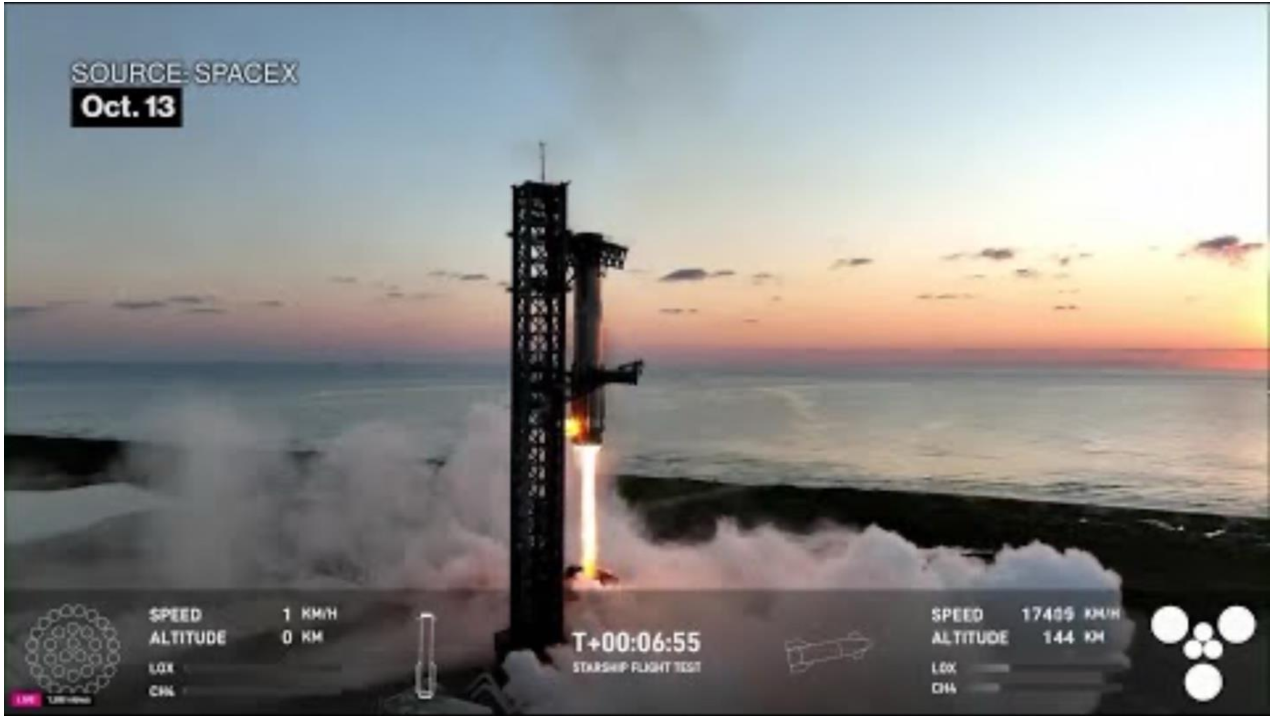


Quadrocopter Pole Acrobatics



DAS in F1

SpaceX Catching a Rocket 🚀



Objectives of CS

Perfomance:

- be accurate as possible
- plane should follow desired trajectory fast and accurate

Robustness:

- perform well in presence of disturbances and noise
- the plane can deal with turbulence and noise in sensors

Stability:

- system doesn’t blow up, outputs stay under control.
- plane doesn't start oscillating up and down
- plane doesn't crash

2. Control Architectures

Definitions

block diagram: schematic representation of our system

input $u(t)$:
- signal that goes in system
- what we can influence

output $y(t)$: what you measure

reference signal $r(t)$: the desired value your output should reach

error $e(t)$: in closed loop $e(t) = y(t) - r(t)$ (output – reference)

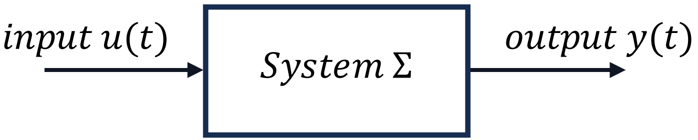
Open Loop vs. Closed Loop

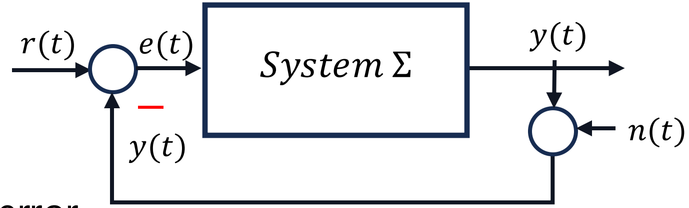
Open Loop:

- no feedback / input doesn't depend on output
- simple, but imprecise – controller follows input and doesn't know output

Closed Loop:

- feedback / input may depend on output
- powerful, but also complicated.
- difficult to control





control gain k: strength of controller due to experienced error
disturbance and noise: unwanted signals that interference with input/output and hence our system → **can lead to instability of system**

Exam Question

Identify which signals are the input and output of the system

A. Input: α ; Output: ω_1, ω_2

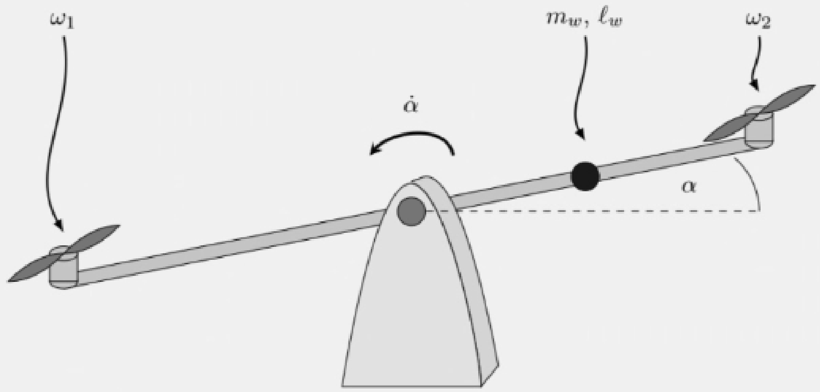
B. Input: ω_1 , ω_2; Output: α

C. Input: $\dot{\alpha}$; Output: ω_1, ω_2

D. Input ω_1 ; Output: ω_2

Box 2: Questions 4, 5

You are enthusiastic about control systems and decide to learn more about it by building a seesaw as shown in the figure below. You connect two motors with propellers on either side of the seesaw to control the angle α of the seesaw. The propellers have angular velocities ω_1 and ω_2 as shown in the figure and have a distance ℓ from the center of the seesaw. An additional point mass with weight m_w and distance to the center of the seesaw ℓ_w is present.



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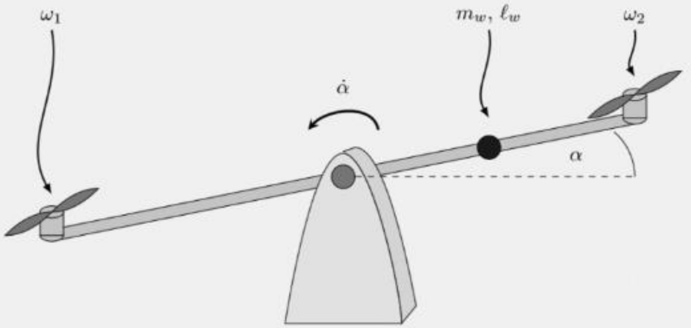

the only input we can influence are
the 2 motors → input
we want to control the angle → output

3. Motivation

Course Schedule

	Subject	Week
Modeling	Introduction, Control Architectures, Motivation	1
	Modeling, Model examples	2
	System properties, Linearization	3
Analysis	Analysis: Time response, Stability	4
	Transfer functions 1: Definition and properties	5
	Transfer functions 2: Poles and Zeros	6
	Proportional feedback control, Root Locus	7
	Time-Domain specifications, PID control, Computer implementation	8
	Frequency response, Bode plots	9
	The Nyquist condition, Time delays	10
Synthesis	Frequency-domain Specifications, Dynamic Compensation, Loop Shaping	11
	Time delays, Successive loop closure, Nonlinearities	12
	Describing functions	13
	Intro to Uncertainty and Robustness	14

The Plan

Modeling: We'll try to understand how plants/systems work and describe them mathematically

Analysis: from our mathematical description we're going to
- classify the system
- look at time responses
- learn about criteria for stability
- check if our system achieves the desired performance

Synthesis: at the end of the course, we'll learn how to create our own ways to control

Material

What you can attend:

- Lectures
- Recitals
- Study center

What you can work with:

- Lecture/Exercise Slides
- Problem Sets
- Script (disclaimer: in the making, don't use it as replacement for lecture)
- Notebooks
- Brian Douglas Playlist: https://youtube.com/playlist?list=PLUMWjy5jgHK3j74Z5Tq6Tso1fSfVWZC8L&feature=shared

TA Recommendations

- **Dynamics/Mechanics III: Otto Schulz Bongert, ML F40 Thu 8.15-10**

- **Elektrotechnik I: Lennard Voigt, Tue 10-15-12**

Feedback?

Too fast? Too slow? Less theory, more exercises?

I would appreciate your feedback. Please let me know.

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