Introduction

July 30, 2015

Outline

1. Course overview
2. Systems theory
3. Real life examples
4. Control theory
5. Open-loop vs. closed-loop systems
6. Automatic control

Course overview

1. Introduction
2. Classification of systems
3. System modeling
4. Discrete-time systems
5. Continuous-time systems
6. Frequency response of dynamical systems
7. Sampling and reconstruction of signals
8. Discretizations of continuous-time systems
9. Introduction to control
10. Root Locus Analysis
11. Design in the frequency domain and Nyquist stability criterion
12. Lead and lag compensators
13. PID control

Methodology and evaluation

- Prof. dr. ir. Bart De Moor [Bart.DeMoor@esat.kuleuven.be]
- 20 lectures, 8 excercise sessions
- Learning platform: Sofia, Toledo
  `www.sofialearn.com`
  Course: Systems and control theory
  Material from the lectures (powerpoints, video's), assignments for exercise sessions and supplementary material (downloads, tutorials, books, links, journals, conferences)

Exam

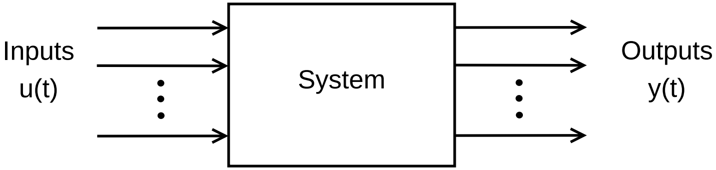
- Written exam
- You can bring: course book, calculator, notes from exercise sessions
- Duration: 4h

Chapter 1: Introduction

Outline

Systems theory

System theory occupies itself with the mathematical description and study of systems. Models describe the connections between input and output.



Systems theory

Next to inputs and outputs, states (denoted by $\mathbf{x}(t)$) are a third type of variable used to describe a system. They represent the internal state of the system at a given time.

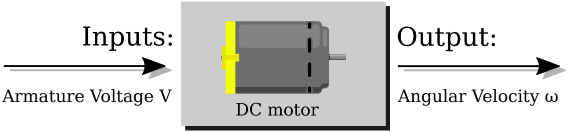
$$\dot{x}(t) = f(x(t), u(t))$$
$$y(t) = g(x(t), u(t))$$

The order of a system is the number of state-variables (i.e. the size of the vector $\mathbf{x}$).

Dynamical system

A dynamical system is a constantly changing system that connects outputs and inputs.
The word dynamical refers to the fact that its current output depends on past input, contrary to static systems where the current output only depends on current input. This means that in a dynamical system the output changes with time if the system is not in a state of equilibrium.

Everything is a dynamical system.
Example:



Outline

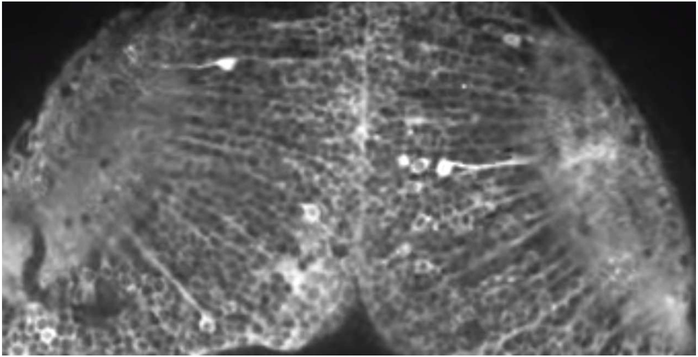
Millenium Bridge

Resonance on the Millenium Bridge in London due to the rithm of walking people.

https://www.youtube.com/watch?v=eAXVa__XWZ8

Neuronal acitvity

Real-time visualization of neuronal activity in the zebrafish brain



https://youtu.be/_rGEkYfQVwY

Drumstick hitting a cymbal

Drumstick hitting a cymbal at 1000 frames/sec

https://youtu.be/kpoanOlb3-w

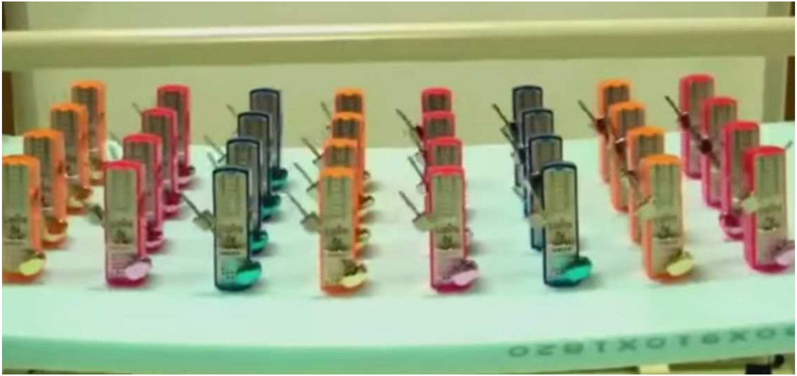
Pilot making a risky maneuvre

Experienced pilot making a risky maneuvre

https://youtu.be/gGnyWgXnZ6g

Synchronized metronomes

Synchronized metronomes

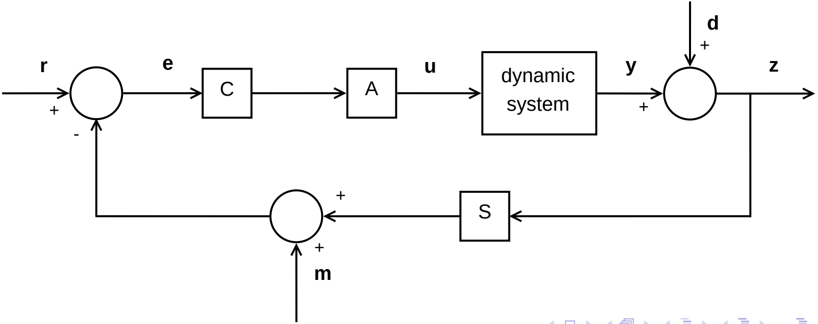


https://www.youtube.com/watch?v=5v5eBf2KwF8

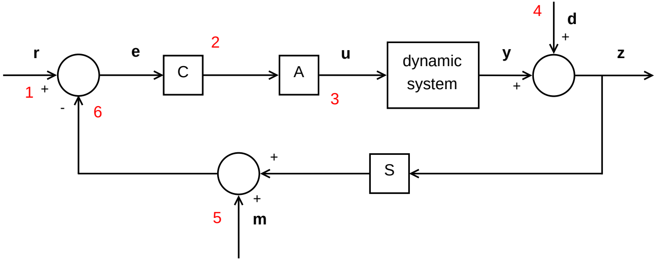
Outline

Control theory

Control theory deals with the behavior of dynamical systems and how their behavior is modified by feedback.
The output is compared to the reference signal and this *'error'* is used by the controller to adjust the system.



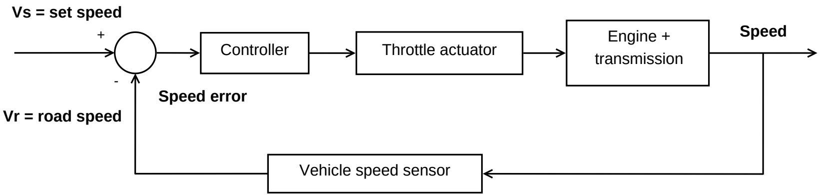
Control theory



1. Reference signals: the desired output signals
2. Controller
3. Actuators
4. Noise
5. Measurement noise
6. Negative feedback

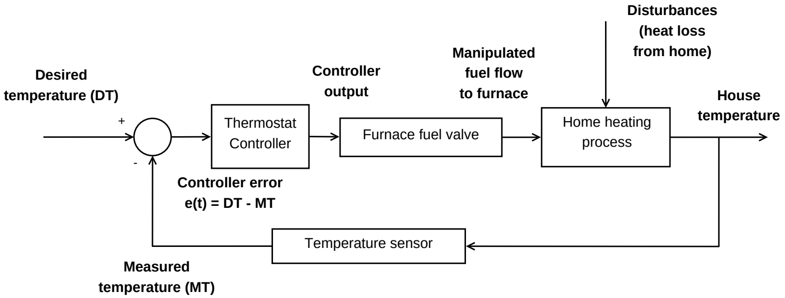
Example

Speed control system

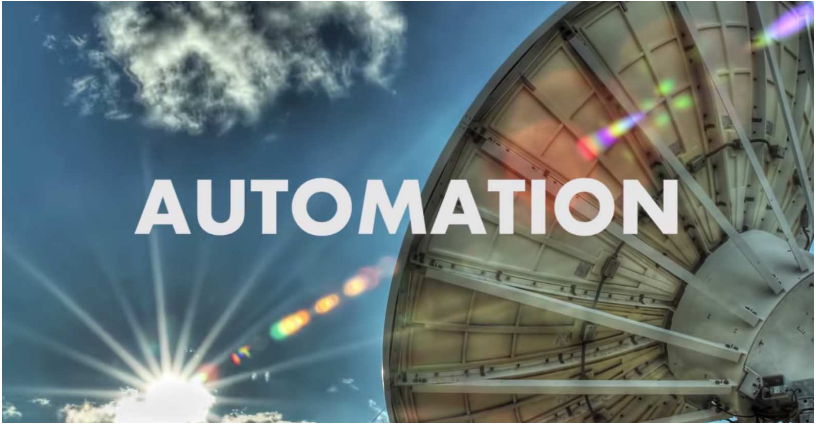


Example

Temperature control system



Automation



https://youtu.be/XJLMW61303g

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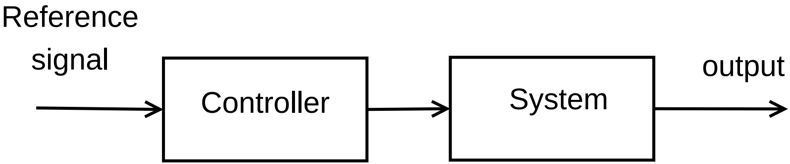
Open loop

In an open loop system, the output is not fed back into the controller. Therefore, the controller cannot *'see'* the effect of its actions.
This way it is hard to get the desired output.



Open loop

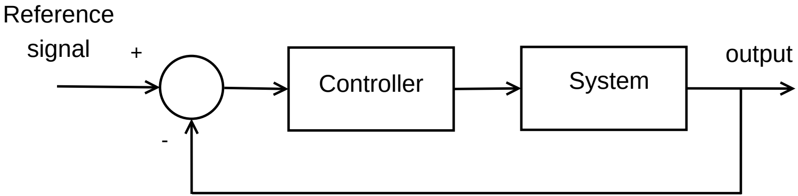
Take for example the following system:

- You are pouring a glass of water, but you **cannot look at the glass**.
- The desired output is a full glass of water within a reasonable time.
- The input can have two values: on or off (assume a quite primitive tap).
- It will not be easy to do this successfully.

The solution is evident: look at the glass while pouring!

Closed loop (feedback)

In a closed loop system, the error signal, which is the difference between the input signal and the output, is fed to the controller so as to reduce the error and bring the output to the desired value.



There are two types of feedback systems. The output can either be added to the reference input (positive feedback) or substracted from it (negative feedback).

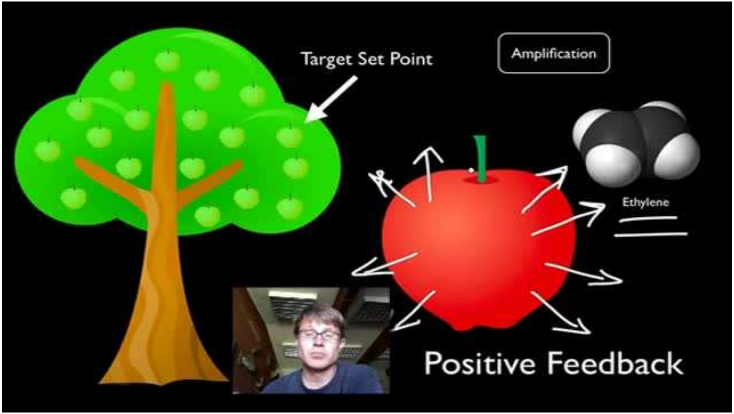
Guitar feedback

https://youtu.be/luURyH9fzhk

What if there was no feedback?

https://youtu.be/C221sI1W9Gk

Feedback loops in biology



https://www.youtube.com/watch?v=CLv3SkF_Eag

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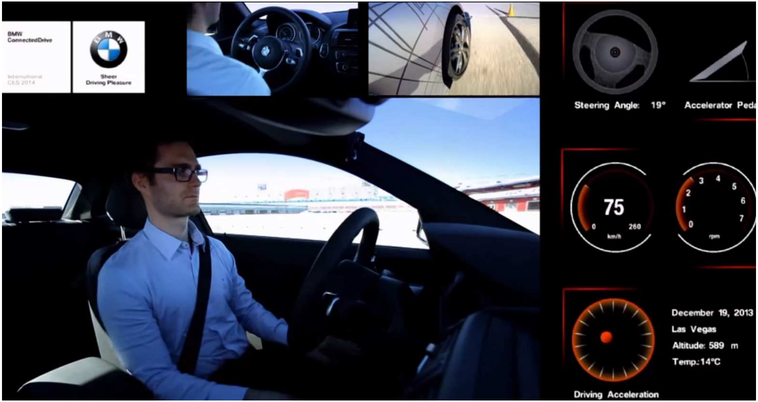
Dance of the Flying Machines

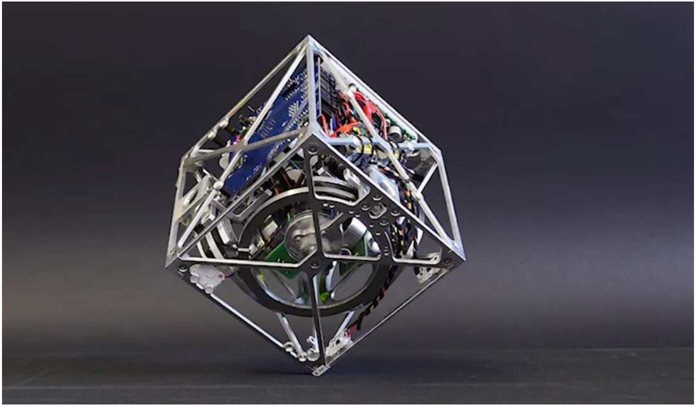
https://youtu.be/NRL_1ozDQCA

Automated driving with precision at the physical limits



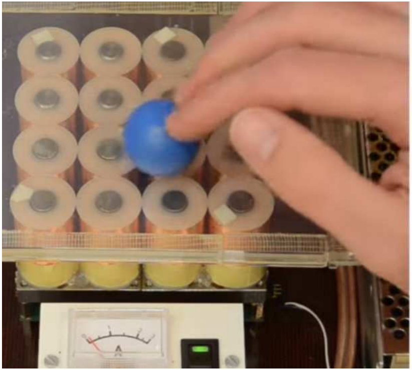
https://youtu.be/1FVglbJZ_tg

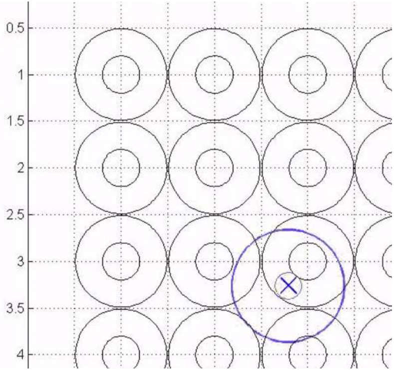
The Cubli: a cube that can jump, balance and 'walk'



https://youtu.be/n_6p-1J551Y

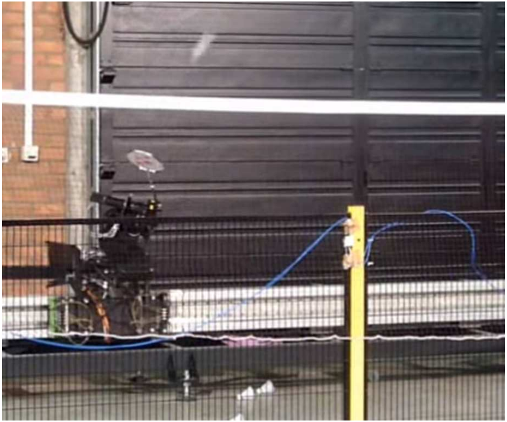
Magnetic manipulator Magman and Matlab





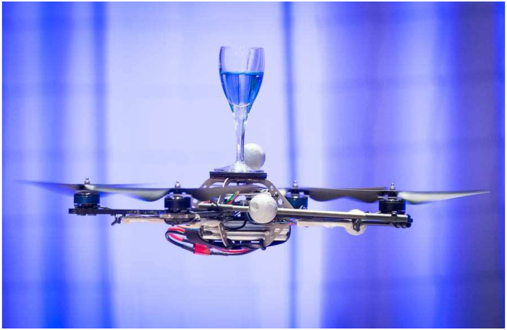
https://youtu.be/AhS_2gU1qW0

Badminton robot



https://youtu.be/LSax71cn6A4

Raffaello D'Andrea: The astounding athletic power of quadcopters



https://www.youtube.com/watch?v=w2itwFJCgFQ