Introduction

July 28, 2015

Course overview
Systems theory
Real life examples
Control theory
Open-loop vs. closed-loop systems
Automatic control

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Course overview

1. Introduction
2. Classification of systems
3. System modelling
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

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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

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Chapter 1: Introduction

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Systems theory

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

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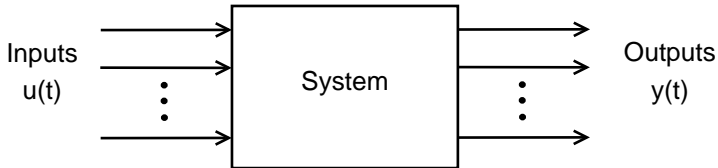
Systems theory

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 $\mathbf{x}$).

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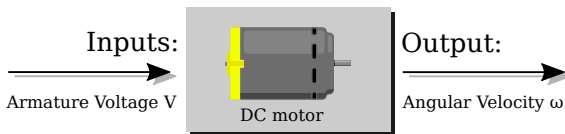Open-loop vs. closed-loop systems
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Dynamical system

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:

Inputs:

Armature Voltage V

DC motor

Output:

Angular Velocity ω

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Millenium Bridge

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

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

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Neuronal acitvity

Real-time visualization of neuronal activity in the zebrafish brain
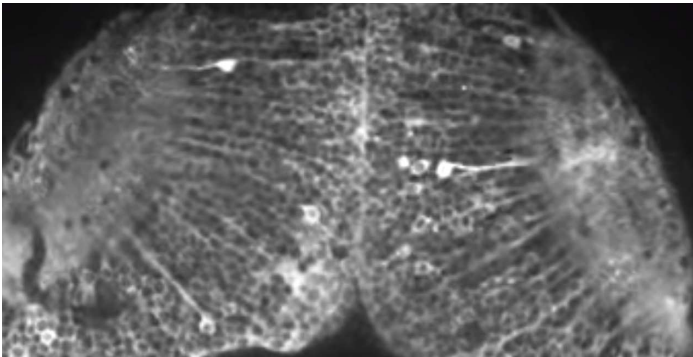
https://youtu.be/_rGEkYfQVwY

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Drumstick hitting a cymbal

Drumstick hitting a cymbal at 1000 frames/sec

https://youtu.be/kpoanOlb3-w
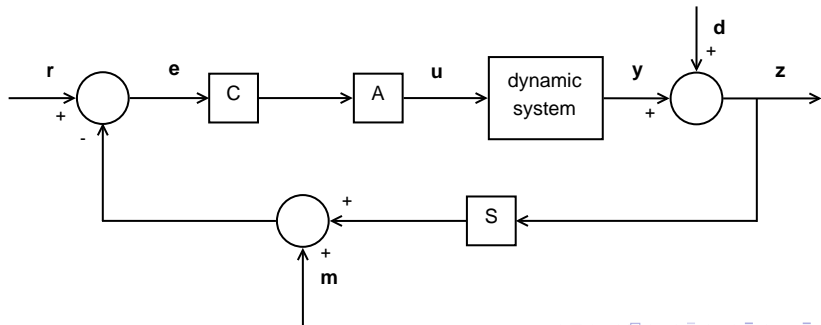
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Pilot making a risky maneuvre

Experienced pilot making a risky maneuvre

https://youtu.be/gGnyWgXnZ6g

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Synchronized metronomes

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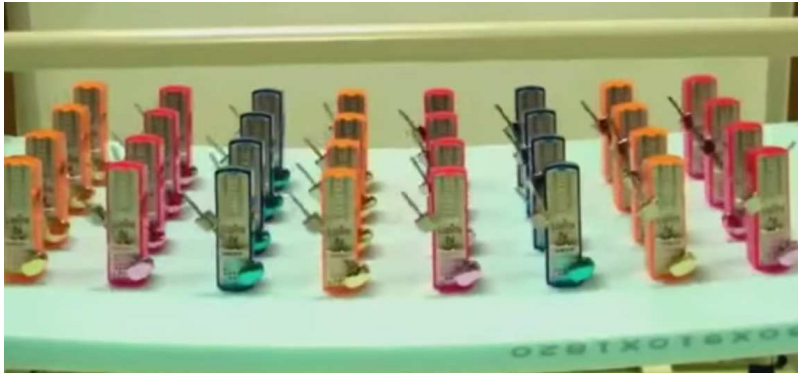
https://www.youtube.com/watch?v=5v5eBf2KwF8

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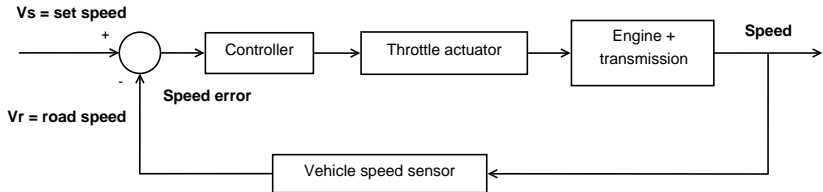
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Control theory
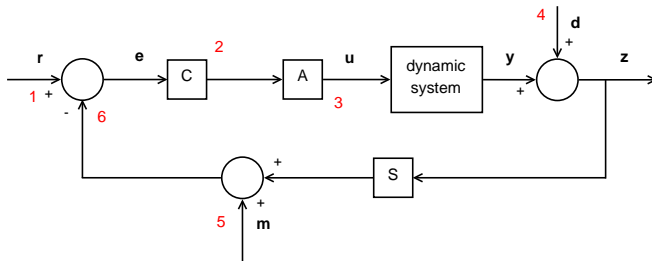
1. Reference signals: the desired output signals
2. Controller
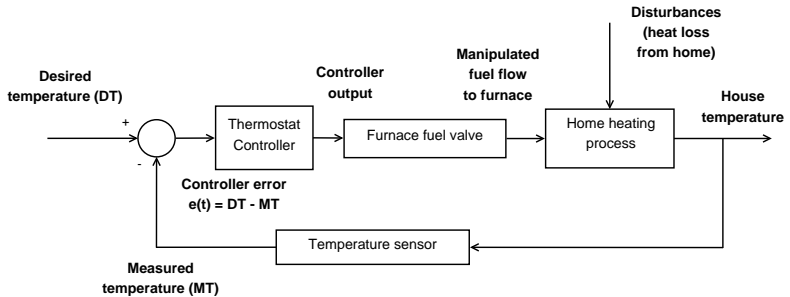3. Actuators
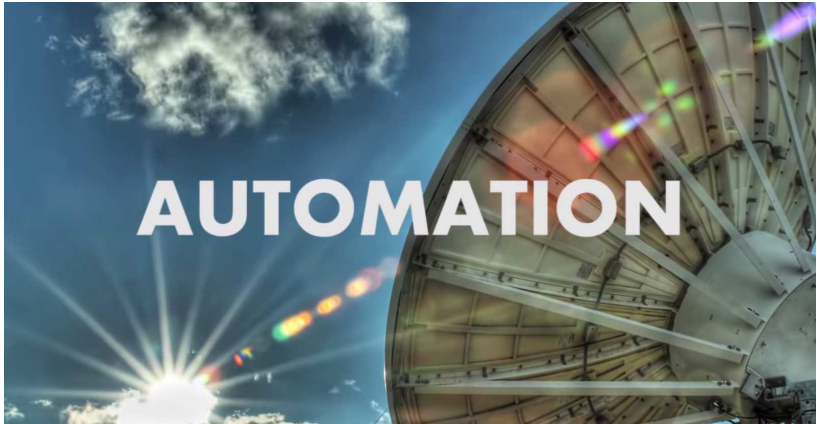4. Noise
5. Measurement noise
6. Negative feedback

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Example

Speed control system

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Example

Temperature control system

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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.

Reference
signal   output

→ | Controller | → | System | →

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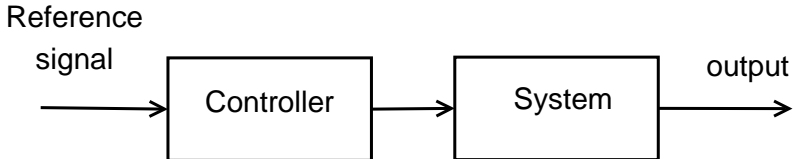
Open loop

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!

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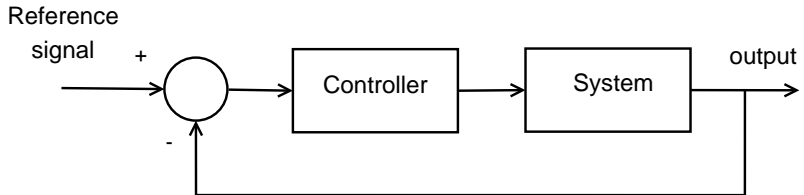
There are two types of feedback systems. The output can either be added to the reference input (positive feedback) or substracted from it (negative feedback).
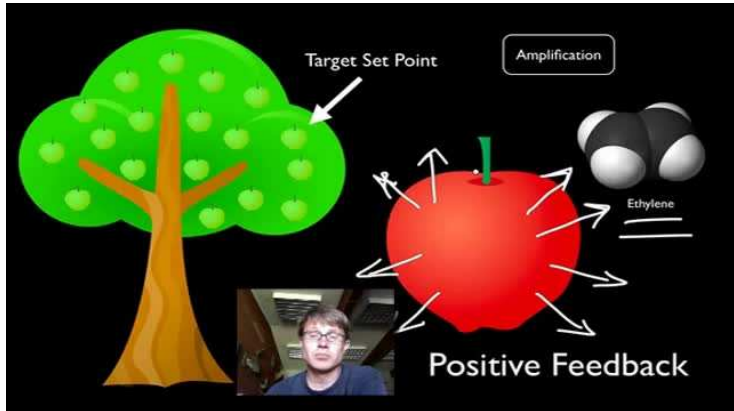
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Guitar feedback

https://youtu.be/luURyH9fzhk

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What if there was no feedback?

https://youtu.be/C221sI1W9Gk

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Feedback loops in biology

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

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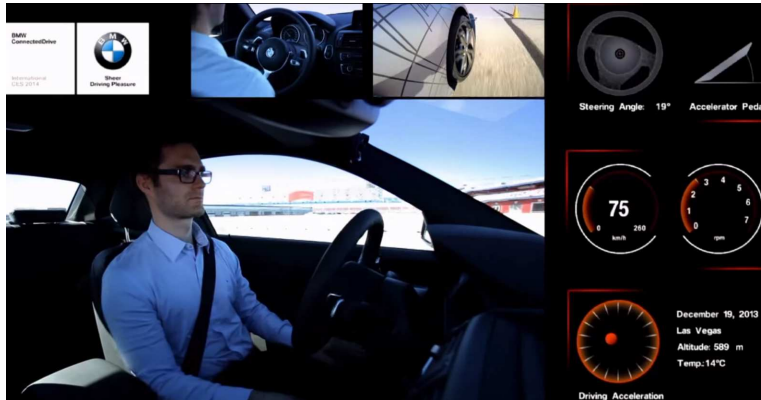Open-loop vs. closed-loop systems
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Dance of the Flying Machines

`https://youtu.be/NRL_1ozDQCA`

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Automated driving with precision at the physical limits

https://youtu.be/1FVglbJZ_tg

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

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

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Magnetic manipulator Magman and Matlab
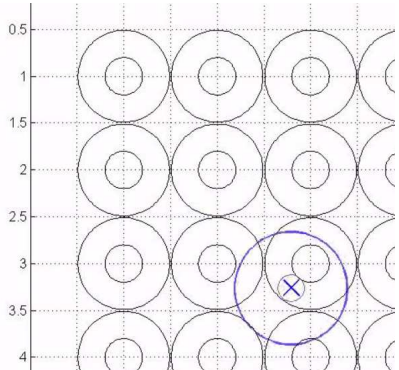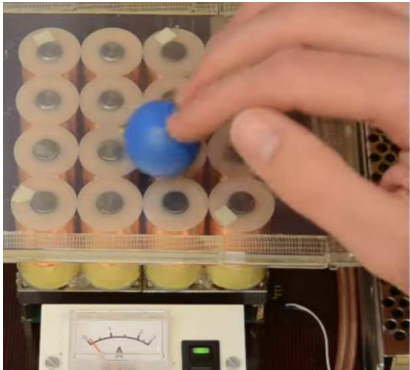
https://youtu.be/AhS_2gU1qW0

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Badminton robot

https://youtu.be/LSax71cn6A4

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Raffaello D'Andrea: The astounding athletic power of quadcopters

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