

# Introduction

August 14, 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 Discretization 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 controllers

# Methodology and evaluation

- Prof. dr. ir. Bart De Moor [Bart.DeMoor@esat.kuleuven.be]
- 20 lectures, 8 exercise sessions
- Learning platform: Sofia, Toledo  
[www.sofialearn.com](http://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

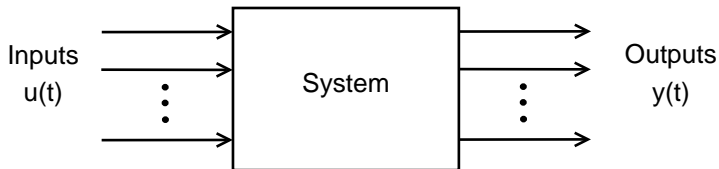
# Chapter 1: Introduction

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# Systems theory

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



# Systems theory

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

$$\begin{aligned}\dot{x}(t) &= f(x(t), u(t)) \\ y(t) &= g(x(t), u(t))\end{aligned}$$

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



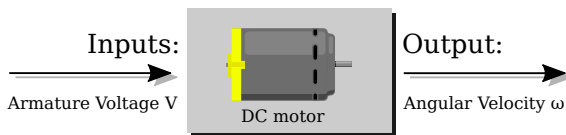
# Dynamical system

A dynamical system is a constantly changing system that connects inputs and outputs.

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:



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# Millenium Bridge

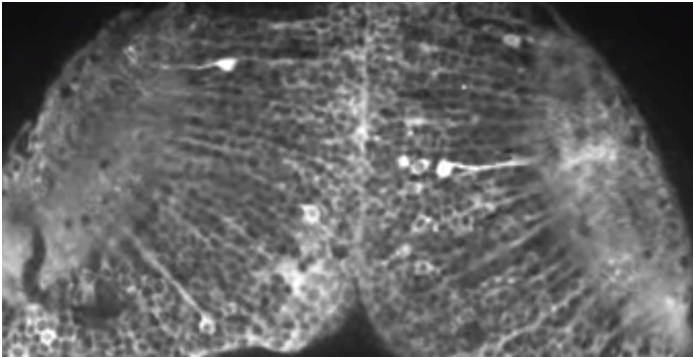
Resonance on the Millenium Bridge in London due to the rithm of walking people.



[https://www.youtube.com/watch?v=eAXVa\\_\\_XWZ8](https://www.youtube.com/watch?v=eAXVa__XWZ8)

# Neuronal acitvity

Real-time visualization of neuronal activity in the zebrafish brain



[https://youtu.be/\\_rGEkYfQVwY](https://youtu.be/_rGEkYfQVwY)

# Drumstick hitting a cymbal

Drumstick hitting a cymbal at 1000 frames/sec



<https://youtu.be/kpoan0lb3-w>

# Pilot making a risky manoeuvre

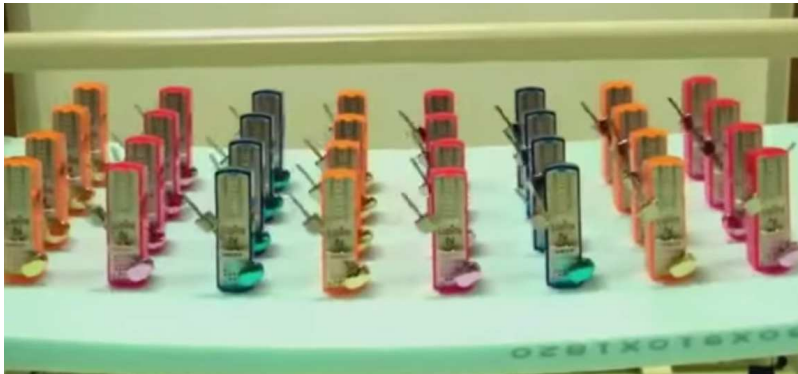
Experienced pilot making a risky manoeuvre



<https://youtu.be/gGnyWgXnZ6g>

# Synchronized metronomes

## Synchronized metronomes



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

# Outline

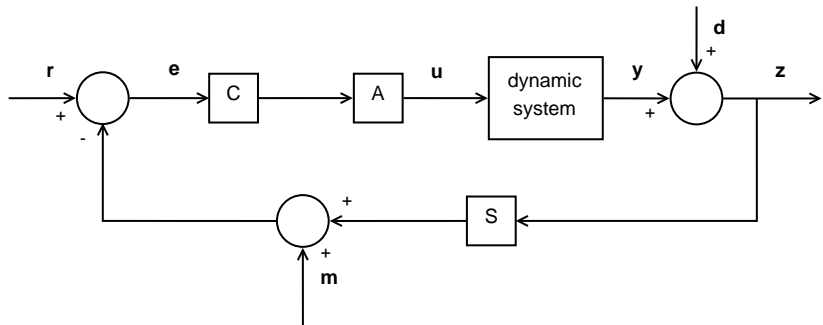
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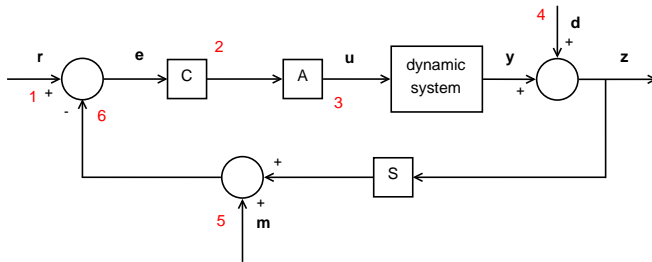
# Control theory

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.



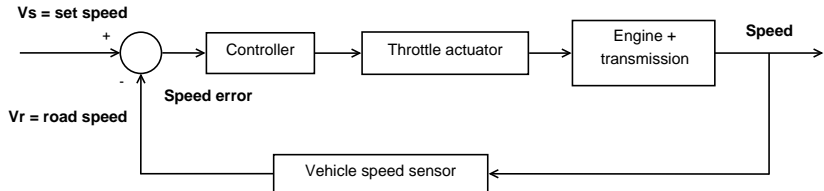
# Control theory



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

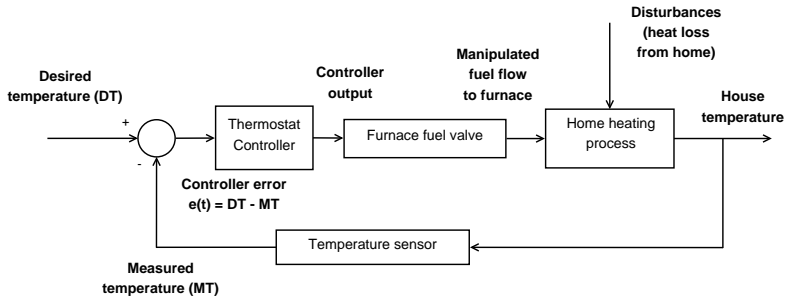
# Example

## Speed control system

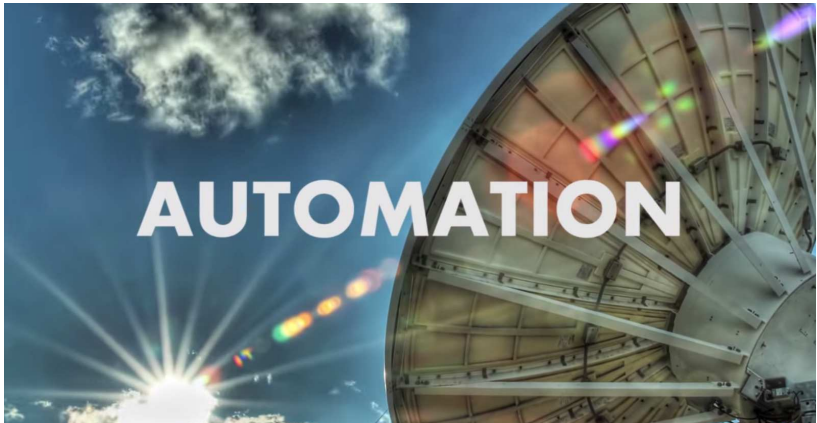


# Example

## Temperature control system



# Automation



<https://youtu.be/XJLMW6l303g>

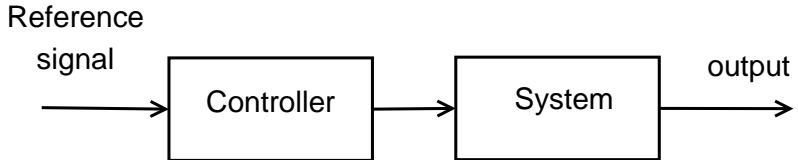
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# Open loop

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.

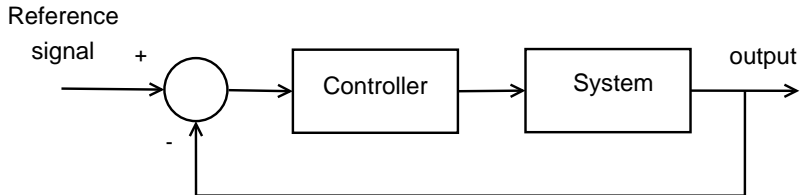


The solution is evident: look at the glass while pouring!



## Closed loop (feedback)

In a closed loop system, the error signal, which is the difference between the input signal and the reference, 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 subtracted from it (negative feedback).

# Guitar feedback



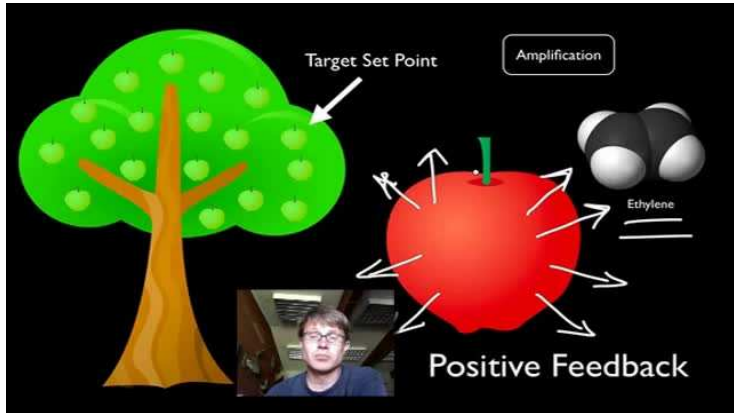
<https://youtu.be/luURyH9fzhk>

# What if there was no feedback?



<https://youtu.be/C221sI1W9Gk>

## Feedback loops in biology



[https://www.youtube.com/watch?v=CLv3SkF\\_Eag](https://www.youtube.com/watch?v=CLv3SkF_Eag)

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# Dance of the Flying Machines



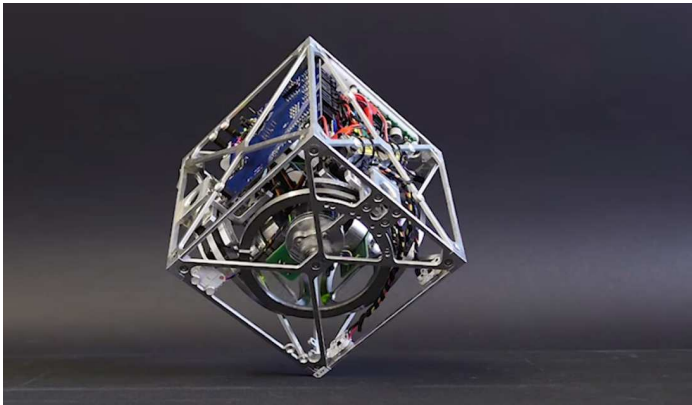
[https://youtu.be/NRL\\_1ozDQCA](https://youtu.be/NRL_1ozDQCA)

# Automated driving with precision at the physical limits



[https://youtu.be/1FVg1bJZ\\_tg](https://youtu.be/1FVg1bJZ_tg)

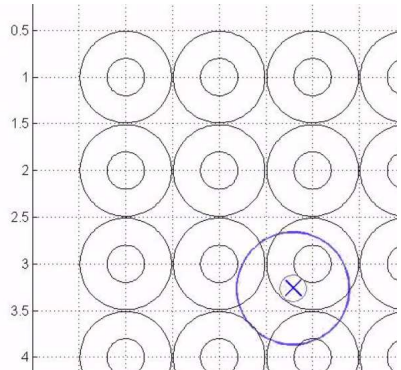
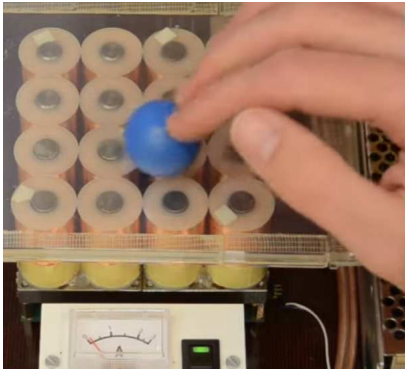
# The Cubli: a cube that can jump, balance and 'walk'



[https://youtu.be/n\\_6p-1J551Y](https://youtu.be/n_6p-1J551Y)



# Magnetic manipulator Magman and Matlab



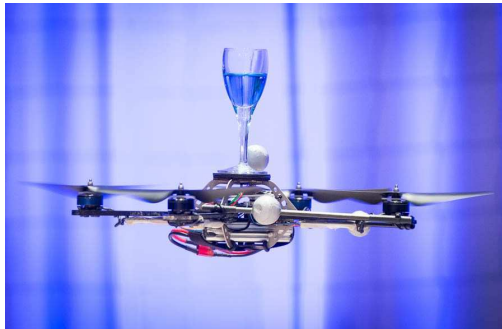
[https://youtu.be/AhS\\_2gU1qW0](https://youtu.be/AhS_2gU1qW0)

## Badminton robot



<https://youtu.be/LSax71cn6A4>

# Raffaello D'Andrea: The astounding athletic power of quadcopters



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