ELEC-C8201:
Control & Automation

Lecturers: Kai Zenger and Valeriy Vyatkin

Assistant (for the control part): Taha Heidari
Assistant (for the automation part): Udayanto Atmojo, Pranay Jhunjhunwala

Email (control part): kai.zenger(at)aalto.fi, taha.heidari(at)aalto.fi

(automation part): valeriy.vyatkin(at)aalto.fi, udayanto.atmojo(at)aalto.fi, pranay.jhunjhunwala(at)aalto.fi

Aalto University
School of Electrical Engineering

Aalto University
School of Electrical Engineering

Course structure and teachers

1. Control part (8 lectures, 8 exercise sessions, 8 Quizzes, 4 homework problems)

- Kai Zenger (Maarintie 8, TuAs, room 3574)
- Taha Heidari, assistant, (available in exercise sessions)

2. Automation part (4 lectures, 4 exercises, 2 homework problems. Details of the automation part will be published, when that part begins, March 14th)

- Valeriy Vyatkin (TuAs, 3575)
- Atmojo Udayanto, assistant, (TuAs, 3558)
- Pranay Jhunjhunwala, assistant, (TuAs, 3577)

Material

The control part consists of lectures, exercise sessions, quiz problems and home assignments.

The course book (control part) is (R.C.Dorf, R.H. Bishop: Modern Control Systems, Pearson Education International, 12th,13th or 14th edition; available in the net. Other editions are Ok also, but the section numbering etc. can vary). Note: the book is large and is intended to be used when needed and on your own choice. It is possible to pass the course based on teaching and material given in course pages only.

Lecture slides and exercises with solutions will appear in course pages (MyCourses).
Quiz problems and homework assignments will also appear in course pages. **The solutions must be submitted in due time in the portal. Late submissions are not accepted nor evaluated.** Quiz problems will be given once a week, homework assignments approximately every two weeks.

Requirements to pass the course

Final exam: Tuesday, April 18, 2023, 9:00-12:00, AS1. You do not have to register to the exam, registration to the course is enough. However, for later exams (next: Monday, 15th of May 2023, 16:30-19:30) you have to register.

Homework assignments: 4 homework assignments in the control part, 2 homework assignments for the automation part.
First homework will be published during the second lecture week.
Solution time approximately two weeks.

Quiz problems: Each Quiz is published **24 hours before the lecture starts**, and the deadline (Quiz closes) is 15 minutes **before the lecture starts**. The Quiz problems concern the material of the previous lecture.

Exception: The first Quiz will be published on the day of the first lecture, and the solution time is 48 hours. The topic of the Quiz is related to the first lecture.

Aalto University
School of Electrical Engineering

Grading

Grading is based on the following formula

$$AS\% = \frac{Quiz}{12} * 10 + \frac{Homework}{36} * 30 + \frac{Exam}{60} * 60$$

(An additional feedback bonus of 3 AS% is given to those who give feedback.)

12 Quiz problems, max 12x1=12 points
6 Homework assignments, max 6x6=36 points
Exam: 6 problems max 10 points each, max 60 points.

The weights: Quiz 10%, Homework 30%, Exam 60%

Grading: AS%: 40: 1, 50:2, 60:3, 70:4, 80:5
(if you have reached 40%, then grade is 1, etc.)

Note: The Quiz and homework points remain valid, until the course starts again (next year)

Aalto University
School of Electrical Engineering

Schedule

January 10: Introduction, models of physical systems, Laplace transformation, Block diagram algebra, (Dorf and Bishop: Ch1, Ch2.2-2.6)

January 17: State-space representation, relation between state-space-representation and transfer function (Ch 3)

January 24: Stability, poles, zeros, performance, steady-state error (Ch 5)

January 31: Routh-Hurwitz stability criterion (Ch 6.1-6.2)

February 7: The Root locus method (Ch 7.1-7.5)

February 14: Frequency response methods (Ch 8.1-8.5)

Week 8: Evaluation and examination week: no teaching in the course

February 28: The Nyquist stability criterion (Ch 9.1-9.4)

March 7: Controllability and observability (Ch 11.1-11.5)

March 14: Industrial Automation Software

March 21: Programming in IEC 61499

March 28: State machine design and implementation

April 4: Design of Automation Applications

Control part: Lectures and exercises

Aalto University
School of Electrical Engineering

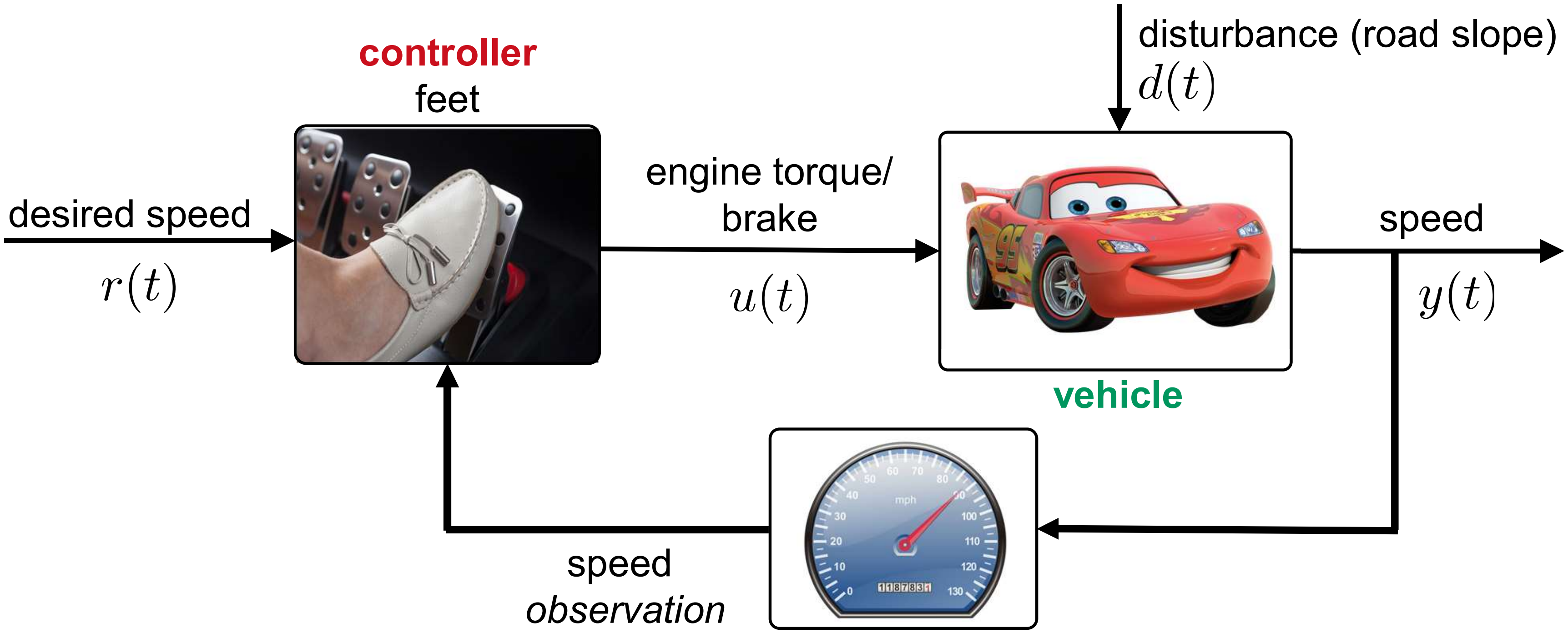
Teaching is in classroom only. Quizzes and homework problems appear in course MC pages and are submitted there on the given time-table. The time table is strict and no late submissions are evaluated. Lecture slides and exercises with solutions are published in MC pages as the course proceeds.

Lectures are on Tuesdays 10:15-12 in class AS2, Maarintie 8 (TuAs). The exercises are on Thursdays 10:15-12, same week as the lecture, room TU6 (1199), Maarintie 8 (TuAs).

Note: In the Automation part (starting 14th of March) some different teaching methods may be used. These are introduced then. However, the evaluation principles (grading) remain the same.

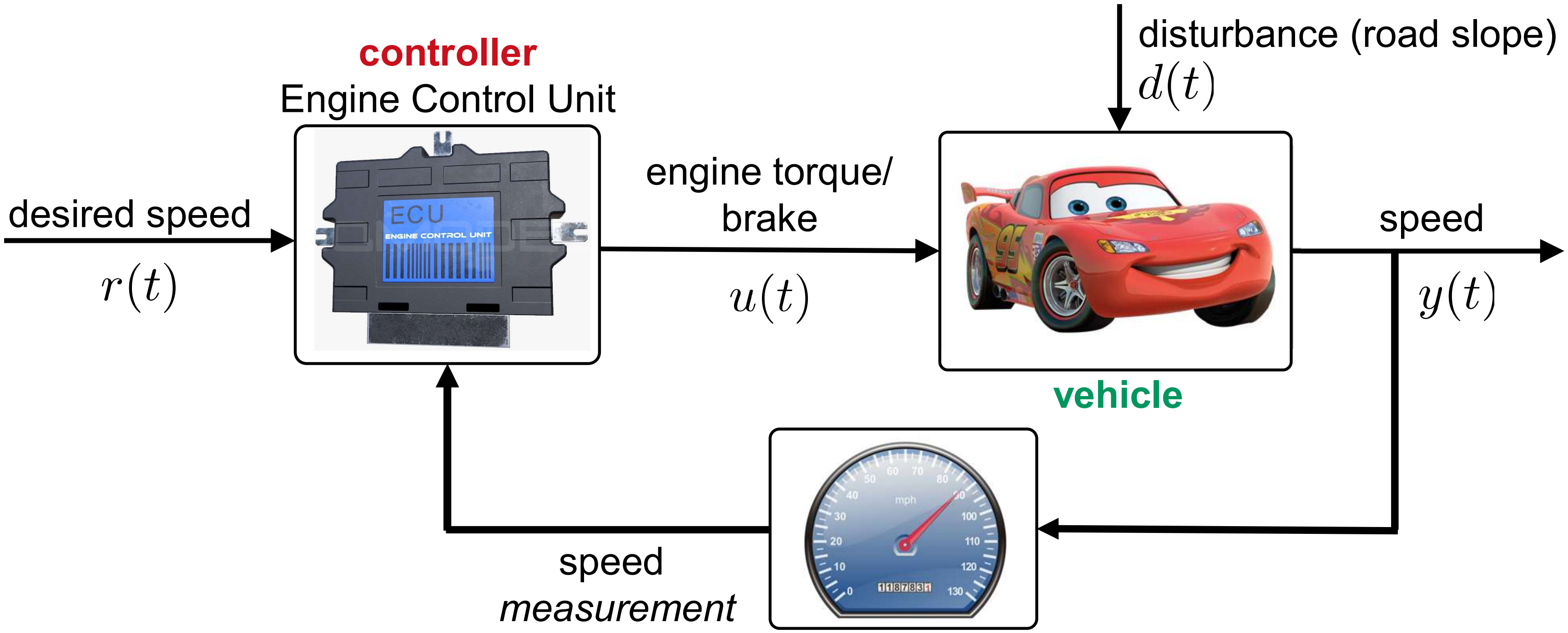
What is control?

Controlling your speed



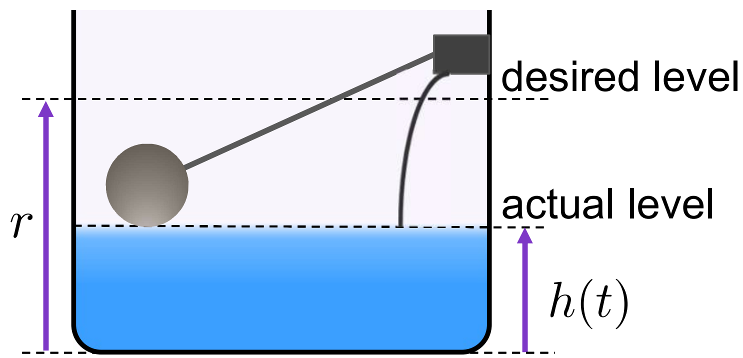
- The vehicle speed must be **controlled** in order to reach and maintain the desired speed $r(t)$…
- ... in spite of changes of road slope and desired speed $r(t)$

Automatic cruise control

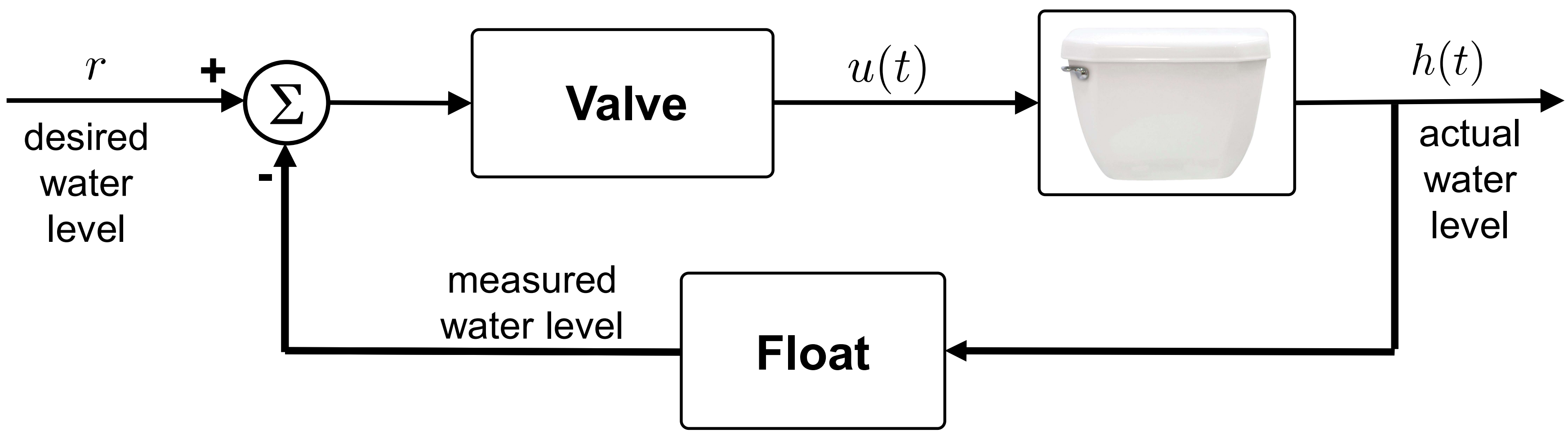


- The vehicle speed must be **controlled** in order to reach and maintain the desired speed $r(t)\ldots$
- ... in spite of changes of road slope and desired speed $r(t)$

An every day control system: the flushing toilet

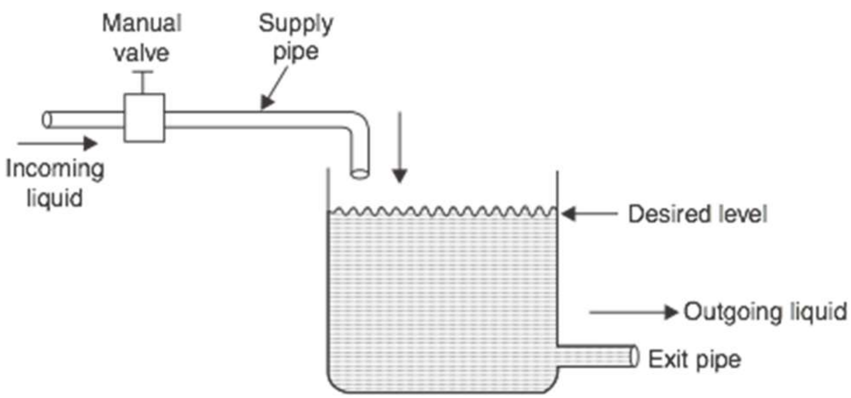


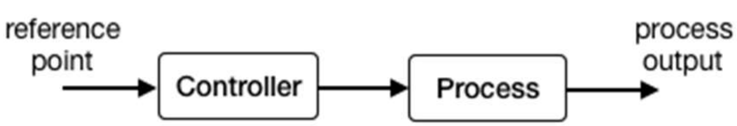
- After a toilet is flushed, the water tank must be refilled to a desired level r
- This is done with a simple control system using a valve controlled by a floating ball



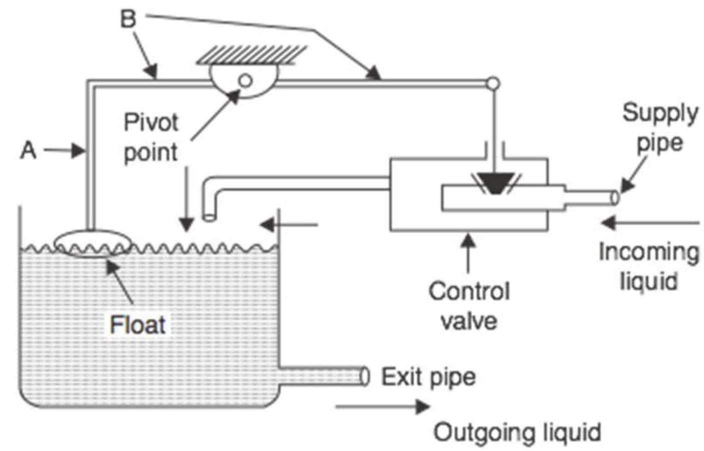
Open-loop vs closed-loop control

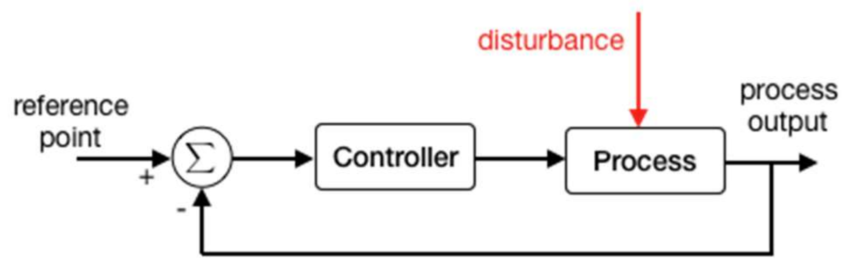
Open-loop control
(feedforward control)





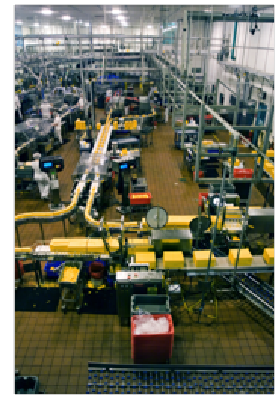
Closed-loop control
(feedback control)





Application areas of control & automation

- Automotive, Aeronautics & aerospace engineering
- Process control (chemical, pharmaceutical, …)
- Environmental systems
- Manufacturing
- Robotics
- Supply chains
- Financial engineering
- Telecommunications
- Power electronics
- Power networks
- …



Segway Human Transporter

The Segway™ Human Transporter (HT) is the first self-balancing, electric-powered transportation device.

Dynamic stabilization enables Segway HT to work seamlessly with the body's movements.

Gyroscopes and tilt *sensors* in Segway HT monitor a user's center of gravity at about *100 times a second*. When a person leans slightly forward, Segway HT moves forward. When leaning back, Segway HT moves back.

Balancing a mini Segway-like robot

A project for understanding the process of:
How to design a (modern) control system?

- Understand the **automation problem**:
  - *Which variables can we control?*
  - *What are the output variables?*
  - *What should we measure?*
  - *What are the disturbances?*
- Derive a simplified **mathematical model**
- Obtain a reliable **simulation model**
- Synthesize the **control algorithm**
- **Test** in simulations, **validate** on the real system (robot)

Summary of the course

Content of the course

- **From control:**
  Representations of dynamical systems (transfer functions, state-space representation), simple modeling of a dynamical system (process), the control problem, negative feedback, poles, zeros, stability, controllability, observability, PID controller, state controllers, frequency domain techniques.

- **From automation:**
  This course will address the problem of how to design simple automation systems that include feedback. It includes basic structures and functions of automation systems. Sensors and automation networks. Automation programming (PLC).

Learning outcomes

- **From control:** The student
  - understands the principles and analysis methods of dynamical systems
  - can design controllers by different methods and verify the operation of the closed loop system by analytical means and through simulation

- **From automation:** The student
  - understands the hardware and software architectures of automation systems
  - can use automation programming languages of PLCs
  - designs methods and patterns learned with hands on experience

Preliminaries

- **Prerequisites:**
  MATLAB, Signals and Systems, Differential calculus, Basics of computer programming, Boolean algebra, Matrix Algebra

- **Assessment methods and criteria:**
  Quiz problems, homework assignments, final examination.

- **Courses where this course is a prerequisite:**
  - Digital and Optimal Control (ELEC-E8101)
  - Automation Systems Synthesis and Analysis (ELEC-E8110)
  - Distributed and Intelligent Automation Systems (ELEC-E8102), but practically we accepted there students without prerequisites.