Introductory Lecture

Jens Kober Robert Babuška Sander Bregman

Integration Project Systems and Control (SC42035)
`http://www.dcsc.tudelft.nl/~sc42035`

Cognitive Robotics
3mE, Delft University of Technology, The Netherlands

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Lecture Outline

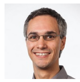
- Information about the course.
- Overview of laboratory setups.
- Important remarks concerning the project work.
- Forming groups and assignment of setups.

Integration Project Systems and Control

- Compulsory course for students following the M.Sc. program 'Systems and Control', elective for others
- 5 ECTS credits (140 hours) . . . on average 15 hours a week

Lecturers and Assistants

Lecturers: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Robert Babuška


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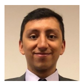
Jan-Willem van Wingerden

Assistants:


Nikolaos Moustakis


Alexandre Melo Pacheco


Jose Libardo Navia Vela

Goals of the Course

- Integrate knowledge gained in theoretical M.Sc. courses
  - modeling and system identification
  - filtering and state estimation
  - control design and performance evaluation
- Apply knowledge to laboratory setups
  - hands-on experience with the application of control theory
  - better understanding of theory – link to the physical world

"Teaching control without experiments is like music without sound."

- Learn to use MATLAB and Simulink effectively

Prerequisites

- Control Theory (SC42015)
- Filtering and Identification (SC42025)
- Modeling and Nonlinear Systems Theory (SC42060)
- Reasonable skills in MATLAB and Simulink

MATLAB and Simulink

- MATLAB basics (`plot`, `load`, `save`, M-files, etc.)
- Control toolbox:
  - LTI class (`ss`, `tf`, `zpk`)
  - time-domain and frequency analysis (`step`, `bode`)
  - control design tools (`place`, `acker`)
- Other toolboxes:
  - LTI System Identification Toolbox (available on BrightSpace)
  - found online
- Simulink
- Obtaining LTI models from Simulink (`trim`, `linmod`)

Control Design Methods

- Mechanistic modeling – Lagrange equations.
- Implementation of a model in Simulink.
- System identification and/or parameter estimation.

- Linearization and discretization of the model.
- Design of a linear observer for state estimation.
- Linear control design – at least two different methods.

- Evaluation and comparison of performance.
- System identification in closed loop – improve accuracy of the model (optional, though recommended).

Procedure

- form groups of two and choose your laboratory setup (today)
- sign up on BrightSpace (today)
- read the 'Course Information Sheet' and other docs
- familiarize yourself with the setup.

- derive and implement a mathematical model
- design suitable experiments, estimate parameters

- design controllers for the simulation model
- test and tune the controllers on the process
- evaluate the results, document in a report
- prepare a presentation

Contact with Lecturers

1. First intermediate discussion, week 3/4 of the quarter:
   - have a clear plan of what are going to do, first results
   - controllers you deem appropriate for 'your' setup
2. Second intermediate discussion, week 5/6/7 of the quarter:
   - discuss results achieved so far, problems encountered
   - your plan for the rest of the course
3. Presentation, week 10 of the quarter:
   - a short presentation – learn from each other
4. Final discussion, week 10/11 of the quarter:
   - discussion of results presented in your report

Assessment

- 40% Written report, one per group, deadline: Friday June 22, 2018 before 16:00
  - report on paper (2 copies, stapled) and electronically
  - MATLAB / Simulink files per e-mail
  - Maximum report length: 30 pages
- 20% Presentation of the results in a symposium: June 26 & 27, 2018
- 40% Discussions of the results with lecturers (oral exam)
- Lab activity

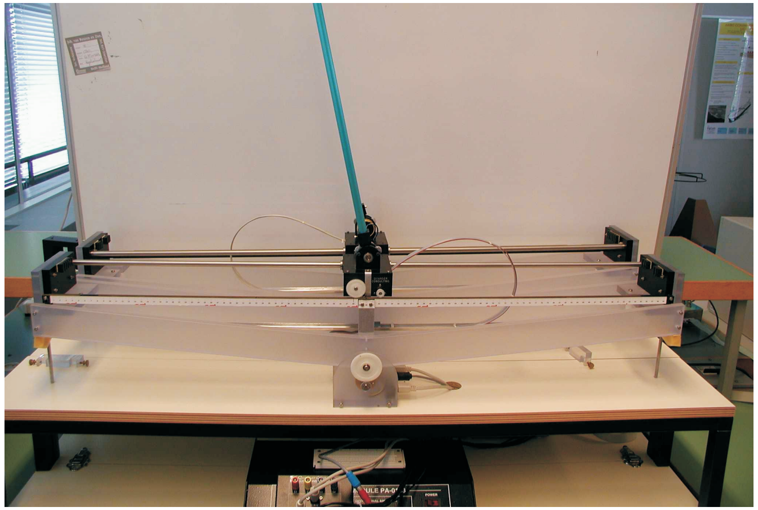
Course Materials

- Books, lecture notes, etc., of theoretical courses
- Documents for download available on the Web:
  `www.dcsc.tudelft.nl/~sc42035`
  `brightspace.tudelft.nl`
- On-line resources:
  - Library (`library.tudelft.nl`)
  - IEEE Xplore (`ieeexplore.ieee.org`)
  - Elsevier Science Direct (`sciencedirect.com`)
  - IFAC (`www.ifac-control.org`)
- MATLAB/Simulink software

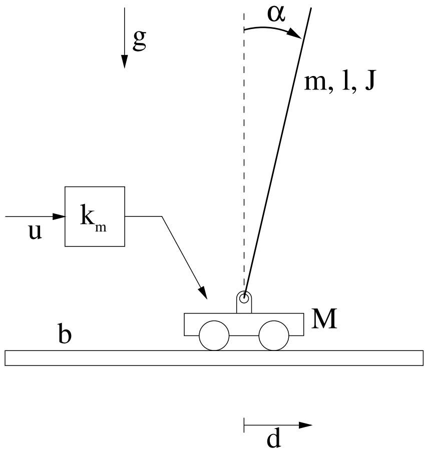
Where to Run MATLAB

- DCSC laboratory.
- Other computers at the faculty.
- At your home PC: download MATLAB via `software.tudelft.nl`.

Inverted Pendulum

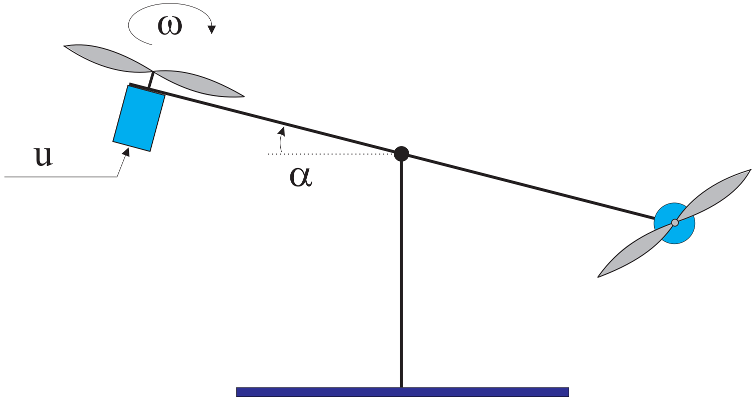


Inverted Pendulum

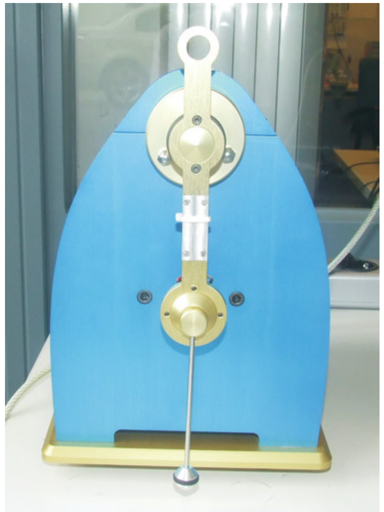


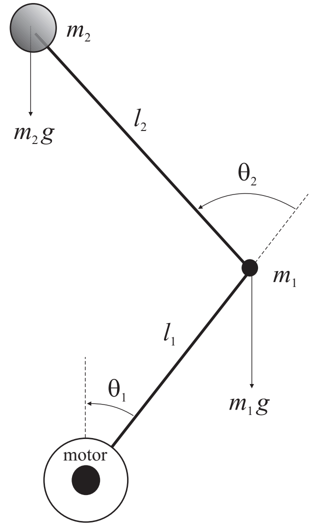
Helicopter

Helicopter



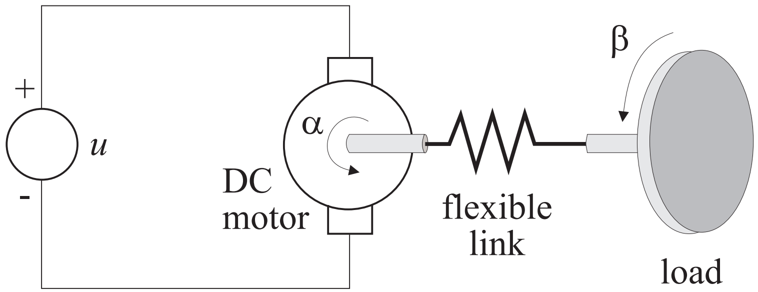
Rotational Pendulum





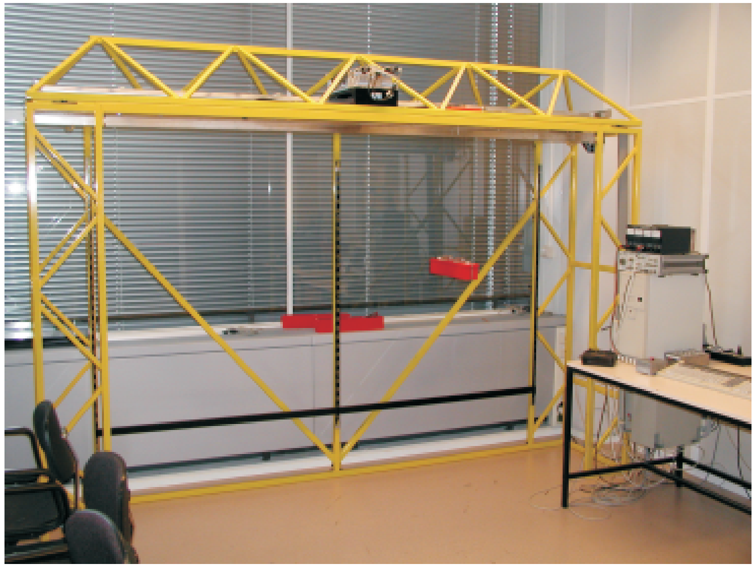
Flexible Link System

Flexible Link System

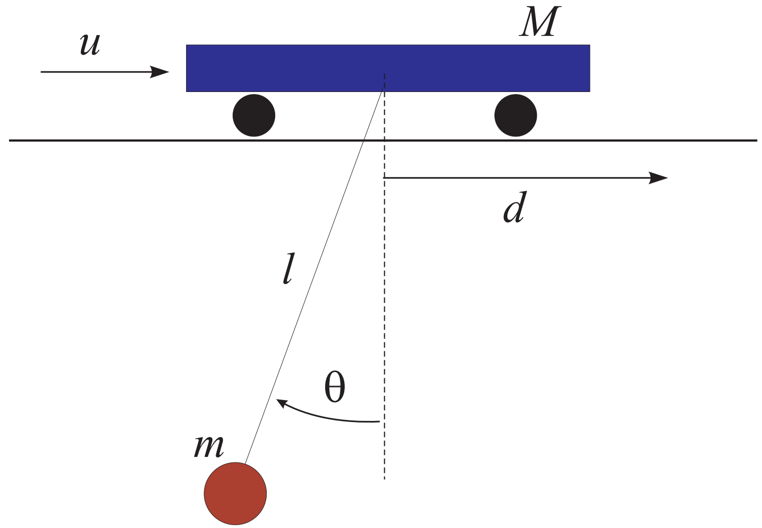


Abstraction of many real-world systems, such as robot arms, motors with gears, etc.

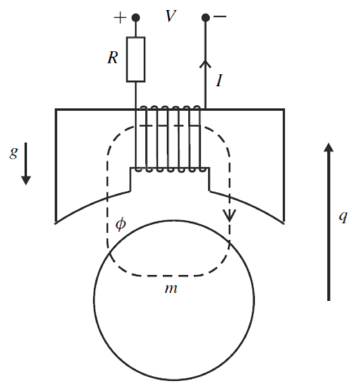
Gantry Crane



Gantry Crane



Magnetic Levitation System

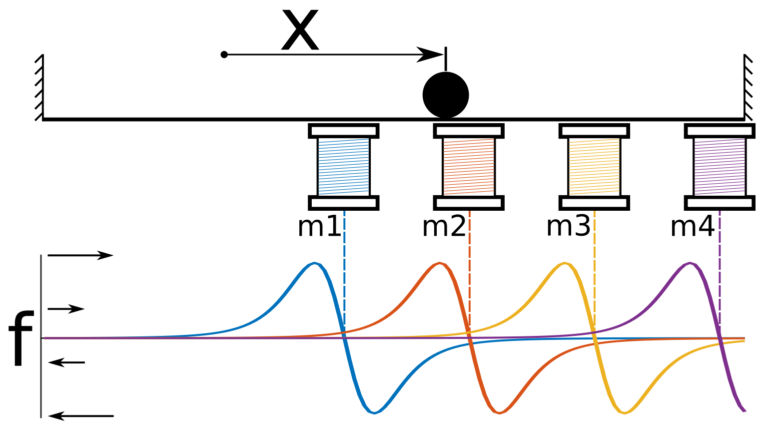


Qube Servo and Rotary Pendulum

Magnetic Manipulation (Magman)

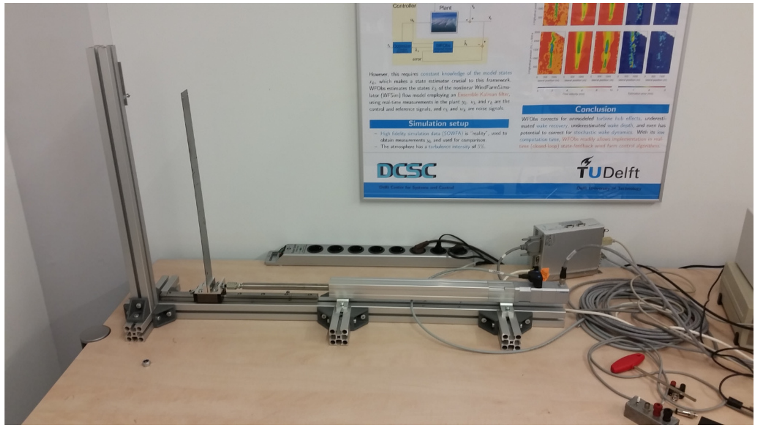
Do not stare in the laser!

Magnetic Manipulation (Magman)



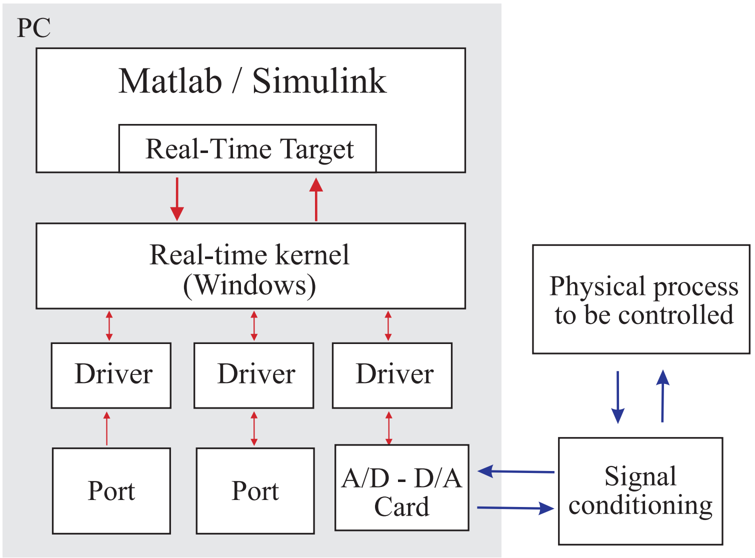
Ball and Beam

Linear Actuator with Flexible Load

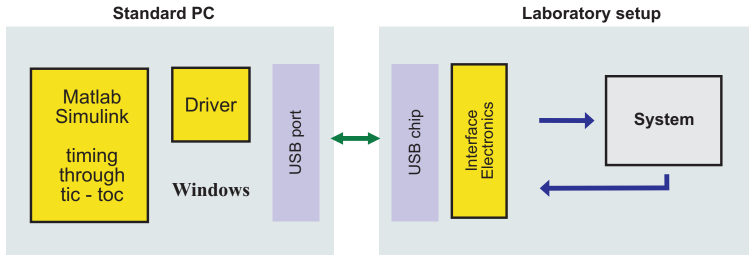


Do not stare in the laser!

Windows Real-Time Target



DCSC USB Interface



Possibly more sampling period jitter in the beginning of experiment – in case of suspicion, discard a few initial samples.

Real-time Simulink Templates

- Work under Matlab / Simulink
- Each setup has a Simulink template
- Directories:

  D:\Opstellingen\Pendulum1
  D:\Opstellingen\Pendulum2
  . . .
  D:\Opstellingen\Helicopter
- Files:

  ...template.mdl (Simulink file)
  hwinit.m (Matlab script – SW/HW definitions)
- Make a copy to your own directory, remove read-only attribute

More About the Templates

- Create your own files through menu: File / Save As ...
- Scopes are configured to export data to Matlab workspace
- You may change the name through the 'Parameters' icon
- Save data in workspace by the command line command:
  save filename
  (for off-line identification and model validation, presentation and report)
- To export data you can also use the 'To Workspace' or 'To File' blocks

Procedure

- Switch off the setup's electronics box, may reboot the computer (not absolutely necessary)
- Start Matlab, change to your working directory
- Open your real-time Simulink file (first time in the lab: open the template)
- Switch on the setup's electronics box (with pendulum and wedge: first move the cart by hand to the rightmost position and hold it there while switching the box on)
- Define in Matlab workspace the sampling time, e.g.: $h = 0.1$
- Start experimenting (small amplitude input signals first).

Do NOT use white noise or high-frequency waveforms as excitation signals!

Running Real-time Experiments

- Define suitable duration of experiment through the menu: Simulation / Simulation Parameters / Stop time
- Do not change the simulation method
- Start simulation by pressing Ctrl-T
- Do not click the mouse or drag windows around during experiment

If the computer hangs . . .

- first switch off the setup's electronics box, then restart computer

If only Matlab terminates . . .

- start Matlab again (do not restart the computer)

Questions and Answers

- Can we have more than two intermediate meetings?
  Yes, that is possible, you must take the initiative, though. It is best to meet in the lab, at the setup. Mind that the number of students is large and that the lecturers can only allocate part their time to the course
- Can we get examples of how to identify systems, design controllers, etc.?
  No, we do not provide examples on purpose. Figure out yourself or find examples in the literature. If you get stuck, we will be happy to help.
- Is the report a simple "logbook" of what we have done or are we expected to write a high-standard technical report?
  It is the latter. Pay attention to all aspects of technical writing: structure, content, form, language, etc.

Questions and Answers

- Will I get a higher grade if I do more than what is expected?
  Not necessarily. Although we stimulate initiative and creativity, weigh carefully how much you are going to do and report; the report is limited in length! If you are unsure about what to include, consult the lecturers.
- What is the purpose of the oral exam (final discussion)?
  It is an opportunity for the lecturers to ask questions about your report, assess the contribution of individual group members and give you feedback. You should be able to defend the results presented in the report.
- Are certain methods and tools imposed, such as the use of nonlinear optimization to fine-tune parameters of the model?
  No, nothing is imposed. Note that specifically in the modeling phase of the project, the purpose is to obtain a model that is good enough for control design, and not necessarily the exact values of the physical parameters.

Lab Discipline

- Last person who is leaving the lab makes sure the door is closed.
- No food or drinks in the lab! Do not leave any trash, papers, money, etc., behind.
- Before applying a feedback controller for the first time, reduce its overall gain to a very small value, e.g., multiply the control signal by 0.1, and test the sign of the loop (i.e., make sure you are using negative feedback!).
- If you find the setup broken or if it breaks during your experiments, inform the lecturers or the assistant immediately.

Form Groups and Choose Setups

- Please, form groups of two, if you have no done so yet.
- Go to `http://www.dcsc.tudelft.nl/~sc42035/setups/`, fill in your student numbers (the two students in the group), sort setups according to your preference and save.
- We will provide tables for you to plan the dates and times for your appointments and for the presentation.

Do not worry, if you do not get your favorite setup, you will have fun anyway!