Systems Laboratory, Spring 2025

Damiano Varagnolo – CC-BY-4.0

Bureaucracy

Motivations

Why control systems?

https://www.youtube.com/watch?v=-7xvqQeoA8c

Systems laboratory:

Grading system

Exam?

- pre-written (multiple choice)
- written (multiple choice & open)
- oral (10 minutes each)

Pre-written Exam?

- 10 multiple choice questions extracted from a public database with solutions
- you pass if scoring at least 9 of them correctly
- if you know your stuff you won't have any problem in passing
- goal: discourage trying the exam for the sake of trying it

“How will I be assessed?”

check the rubrics in moodle!

Extra points?

- up to 1 for active participation (see below)
- up to 1 for helping others via creating / improving shareable material (code, questions, drawings, etc. See below)
- up to 2 for the Capstone Project (see below)

Classroom contract

Attendance?

- not mandatory (not even the labs)
- useful to learn
- what may be recorded will be recorded, and be made available asap

Physical or digital?

- hybrid is possible, but we cannot make it the default option (so, valid when being sick / issues with public transport / etc)
- we may move to zoom some of the lectures

Interactions with the teacher?

- as informal as possible
- standing reference group meetings
- one-on-one meetings via `damiano.varagnolo@unipd.it`
- in clasee, often we'll do peer instructions

Interactions among students?

- as collaborative as possible
- form study groups!
- peer instructions = great way of meeting new people

Peer instructions - what are they?

- purpose = be active
- algorithm = for each question:
  - first time, answer individually
  - then form groups, discuss, try to convince each other, but eventually answer individually
  - then I show the solution
  - after that you pose questions

Peer instructions - how to answer

- if attending physically: “1 - 2 - 3 - . . . ” with your fingers
- if attending digitally: “reactions” with zoom

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ready for a demo?

Question 1

Which of these effects:

- a: the height of the sun in the sky during the day
- b: the distance of the Earth from the sun
- c: how many hours the sun is up each day

are reasons for the seasons?

Potential answers:

I: a + b
II: a + c
III: b + c
IV: a + b + c
V: I do not know

Extra point for active participation?

Examples:

- be particularly proactive in answering questions
- asking questions that aid further understanding for the class
- any behavior that helps the class learn

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How to: Damiano will say "you, good point! One Maggy point to you!" and you shall send an email with subject "Maggy point to me!" to `damiano.varagnolo@unipd.it`.

4 Maggy points = 1 extra point at the exam (max 1, fractions up to 1 will count too)

Extra point for helping others?

Goal = creating / improving shareable material, like:

- code
- questions (in the `IFAC94.sty` format)
- drawings or plots

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How to: send things to Damiano (but let him know your plans, you'll get feedback!)

Example of material that helps learning

https://leastsquaresapp.onrender.com/

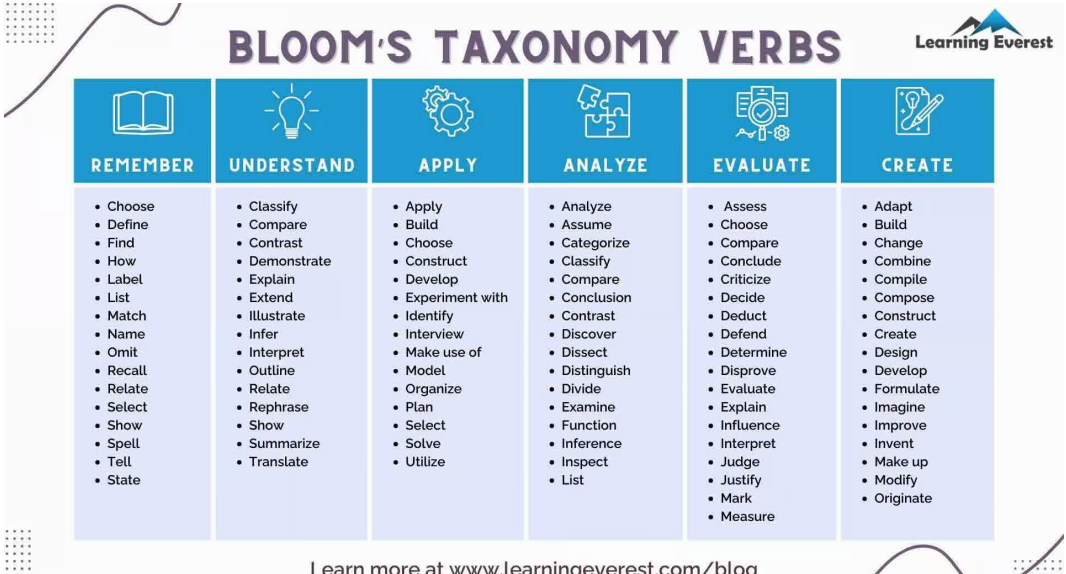
But where will the material be?

- everything in moodle
- be sure to check the handouts of the slides!

Overall approach on the course?

- focus on (relatively) few concepts
- on those, push for max conceptual understanding!
- very often, you will be pushed for a hands-on learning approach
- on other ILOs, you shall learn by yourself
- note: all cognitive aspects are important, from retrieval to creation

Again: this course will push for all the cognitive aspects there may be



Labs

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- not mandatory
- using both Matlab and python
- a hands-on occasion for learning

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Based on:

- physical system: `https://github.com/Hansolini/Take-home-Maglev-lab/`
- simulators in python notebooks (`https://jupyter.org/`) and/or Matlab & Simulink

When and where?

- on Fridays, but not all of them (i.e., first 3 weeks of the course “no”, then “one Friday yes, one Friday no”, but “last three Fridays yes”)
- we will need to do 2 turns (one in the morning, one in the afternoon)
- should be in Ue and Te

May I do the labs at home?

- yes, when working with simulators
- no, if working with Maggy and you don't have your own
- yes also if working with Maggy, if you have your own

How do I get Maggy?

interested in building one for your own?
absolutely feasible and relatively cheap

→ see the information in `https://github.com/Hansolini/Take-home-Maglev-lab/tree/main/physical_system/hardware`
(and anyway tell Damiano if so - ordering together means better prices)

Shall I prepare some reports on the labs?

- no, but you are encouraged to answer the questions you'll find in the various lab assignments

Which ILOs are associated to the labs?

(more detailed ILOs when we will actually do the labs!)

- demonstrate an ability to debug and troubleshoot control issues systematically
- collaborate effectively within a team to conduct experiments and document findings
- reflect on the challenges of real-world control implementation, including non-idealities like sensor noise, delays, and saturation

May we use AI tools?

- yes please!
- especially use it to check your knowledge level

Suggestion

install python & a LaTeX compiler asap

Capstone project

How do I get these 2 extra points you were mentioning before?

- goal: make Maggy do some new things, and document the process
- assessment: the more clear the documentation and the fancier the new trick (or algorithm), the better
- can be a group work; the bigger the group the fancier stuff you shall develop

Examples of project

- make the magnet levitate with Maggy placed vertically
- implement some more advanced noise filtering technique
- get a recursive system identification filter work
- ...

Feel free to propose!

When shall I start doing the project?

- wait at least 1 month before starting even thinking at it!

Will I get help implementing the project?

- yes, only though on the concepts and not on the coding - and for a limited amount of time!

How shall the report of the Capstone project be?

no requirements, only one indication:
think at how to simplify the life for a
developer that picks up your project

Why do we do this in this way?

you shall learn how to learn new things by yourself

How can I self-assess myself?

How may I self-assess how ready I am for the exam?

For each of the questions in the slides and in the pre-oral test, besides knowing how to answer it, are you able to:

- define mathematically all the content units in the statement of the question?
- Make drawings that explain what these content units mean?
- Explain which role these content units play in the "control engineer workflow"?
- Make examples of automatic control situations where these content units would play some role?
- Explain which kind of mistakes one may do if a control engineer has not understood / heard about these content units? (This may not apply to all the content units in the course)
- Explain how these content units connects with the other ones in the course?

How can I increase my metacognition?

- go through the “self-assessment sections” in the various slides in groups, using the handouts to check the correct questions
- make ChatGPT or alike interrogate you
- use FaceIt to get/generate new questions, and think at whether the concept map of the course is clear or not

The FaceIt portal

https://faceittools.com/

Course structure

In a nutshell

- continuous time modelling
- discretization
- stability
- filtering
- system identification
- control design
- Capstone Project

Note: course objectives $\mapsto$ course structure

objective: get the Intended Learning Outcomes

(Macro) Intended Learning Outcomes

Learning Outcomes: Continuous-Time Modeling

- **LO1:** analyze the behavior of continuous-time systems using ODEs, phase portraits, and state-space representations under varying initial conditions and inputs
- **LO2:** compute and interpret the impulse and forced responses of LTI systems based on the principles of superposition
- **LO3:** apply linearization techniques to approximate nonlinear dynamic systems near equilibrium points and understand the limitations of the operation

Learning Outcomes: Stability Analysis

- **LO4:** evaluate the stability properties of equilibria in continuous and discrete-time systems using graphical criteria in the general case, and numerical criteria for the LTI systems case
- **LO5:** assess BIBO (bounded-input, bounded-output) stability of input-output relations for LTI systems using graphical criteria

Learning Outcomes: Discrete-Time Modeling

- **LO6:** as LO1, LO2, LO3 but for discrete time systems
- **LO7:** discretize continuous-time systems using sampling techniques
- **LO8:** list and discuss the limitations that sampling has as an operation, plus which problems a practitioner may encounter when discretizing a continuous time system

Learning Outcomes: Filtering and Data Processing

- **LO9:** compare different definitions of noise reduction efficiency, and select the most appropriate one depending on the situation at hand
- **LO10:** recognize which signal smoothing needs a specific measurement system may have, and design and apply suitable types of filters for the situations encountered during the course

Learning Outcomes: System Identification

- **LO11:** apply least squares estimation techniques to identify the parameters of dynamic models from sampled data
- **LO12:** recognize potential overfitting and underfitting problems by looking at the performance of the estimator on different parts of the dataset
- **LO13:** implement simple regularization techniques to robustify the system identification process

Learning Outcomes: Control Algorithms

- **LO14:** design simple PID and MPC controllers for LTI systems and tune them towards meeting specified performance criteria
- **LO15:** compare the effectiveness of PID and MPC control strategies under varying operating conditions

Learning Outcomes: Capstone Project

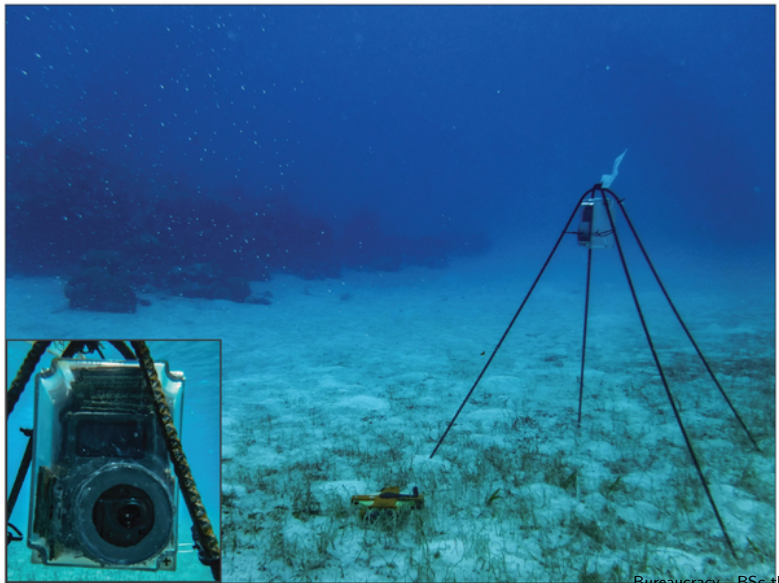
- **LO16:** develop and implement a control solution for the maglev system, integrating modeling, stability analysis, filtering, identification, and control techniques

BSc theses and internship projects

Macroproject 1: autodocking

Macroproject 2: Sonsub

Macroproject 3: marine wildlife monitoring



Macroproject 4: marine eDNA collection

Macroproject 5: learning analytics on FaceIt

Macroproject 6: female sexual rehab