Contents map

developed content units	taxonomy levels
feedforward	u1, e1
feedback	u1, e1
model based control	u1, e1
model free control	u1, e1

prerequisite content units	taxonomy levels
RR	u1, e1

Main ILO of sub-module "what is control"

Interpret automatic control as an opportune operation on the dynamics of a system

Example: speed control



main parameters:

- *m* mass of the car
- *b* friction coefficient
- g gravity coefficient

A sufficiently accurate model for the purpose



A sufficiently accurate model for the purpose



from Newton laws: $m\ddot{x} = -b\dot{x} + u - mg\sin(d)$

from Euler backwards discretization: $x^{++} = a_1x^+ + a_0x + u + f(d)$

A sufficiently accurate model for the purpose



from Newton laws: $m\ddot{x} = -b\dot{x} + u - mg\sin(d)$

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control objective: minimize |y[k] - r[k]| with r[k] = wished speed

Feedforward control: "I think I know which d[k] will happen, and I compensate for that"



Open loop / feedforward control: "I think I know which d[k] will happen, and I compensate for that"

u[k] = something that compensates that $\widehat{d}[k]$

problem: if $\hat{d} - d$ is big, then we expect y - r to be big too, and we won't be able to note this!

Note that open loop \neq feedforward

Open loop:



Feedforward:



Open loop / feedforward control is so simple and naïve that no system in the world uses it

Potential answers:

I: true

- II: false
- III: I do not know

Feedback control: "I measure something, and depending on what I measure I take a decision"



(= designing a controller, i.e., in this case designing a function that maps the signal e into the signal u)

Main dichotomy on how to build a feedback controller

- model free (e.g., PIDs)
- model based (e.g., MPCs)

Crash-slide on PIDs



implicit assumption: we can measure y[k]! (see also https://www.youtube.com/watch?v=UROhOmjaHp0!)

PID for the speed control task



${\sf Question}\ 2$

A PID is guaranteed to work well

- I: yes, always
- II: no, never
- III: no, it depends on how well tuned it is
- IV: I do not know





















A MPC is guaranteed to work well

- I: yes, always
- II: no, never
- III: no, it depends on how good the model is
- IV: I do not know

Is MPC guaranteed to work better than PID?

- I: yes, always
- II: no, never
- III: no, it actually depends on the situation
- IV: I do not know

Is closed loop control guaranteed to work better than open loop control?

- I: yes, always
- II: no, never
- III: no, it actually depends on the situation
- IV: I do not know

But eventually, what is control?

an algorithm to compute u[k] starting from the available information



A final note: in practice it is a good choice to combine both feedback and feedforward actions



Summarizing

Interpret automatic control as an opportune operation on the dynamics of a system

- think at what feedforward and feedback mean
- think at the fact that essentially they are ways of computing u, and that that u
 enters the dynamics of the system

Most important python code for this sub-module

Note: going through everything here would take months - just be aware of their existence and start playing with them

- https://python-control.readthedocs.io/en/0.10.1/
- https://pypi.org/project/simple-pid/
- https://www.do-mpc.com/en/latest/

Self-assessment material

Which of the following is a key disadvantage of open-loop control compared to closed-loop control?

- I: It requires more computational resources.
- II: It cannot correct for disturbances or system variations.
- III: It is slower to respond to changes.
- IV: It is more expensive to implement.
- V: I do not know.

What is the primary purpose of the integral term (K_i) in a PID controller?

- I: To amplify the current error.
- II: To eliminate steady-state error by summing past errors.
- III: To predict future errors based on the current trend.
- IV: To reduce the sensitivity to noise.
- V: I do not know.

What is a key advantage of Model Predictive Control (MPC) over PID control?

- I: It requires less computational power.
- II: It is easier to tune.
- III: It can handle constraints and optimize future behavior.
- IV: It is always more stable.
- V: I do not know.

In a combined feedforward and feedback control system, what is the role of the feedforward component?

- I: To correct for errors after they occur.
- II: To compensate for known disturbances before they affect the system.
- III: To measure the system output and adjust the control action.
- IV: To reduce the computational load of the feedback controller.
- V: I do not know.

What is the main goal of automatic control in the context of system dynamics?

- I: To increase the complexity of the system.
- II: To manipulate the system's dynamics to achieve a desired behavior.
- III: To eliminate all disturbances from the system.
- IV: To reduce the need for sensors and actuators.
- V: I do not know.

Recap of sub-module "what is control"

- designing a controller means designing an algorithm that transforms information into decision
- there are several types of controllers, each with pros and cons
- taking decisions (i.e., actuating *u*) means modifying the dynamics of the system

- what is control 8

?