EE3CL4 C01: Introduction to Linear Control Systems

Section 1: Introduction

Tim Davidson

McMaster University

Winter 2020

Outline

Why are you here?

You might be interested in:

- Athletic ability of drones
  https://www.youtube.com/watch?v=w2itwFJCgFQ
- Parkour-ing robots
  https://www.youtube.com/watch?v=fRj34o4hN4I
- Autonomous driving
  https://www.youtube.com/watch?v=cdgQpa1pUUE
- (Semi-)autonomous medicine
  - surgical robots
  - automated insulin pumps
  - industrial scale production of personalized medicines
- Integration of renewable energy sources into the grid
- Regulation of financial markets

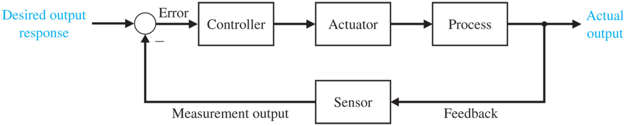
What is control engineering

- First we have to understand the behaviour of the process/plant/system that we want to control

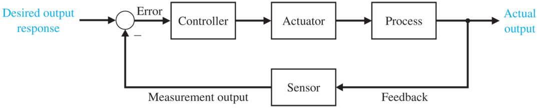
- Often, that involves constructing a math. model;
- this quantifies insight;
- may actually yield insight, too

What is control engineering II

- Then we use that understanding to design a secondary system that controls the behaviour of the process
- Typically, this takes the form of closed-loop (feedback) control



What is control engineering III



- **Secondary system:** sensors, actuators, electrical controller (or digital algorithm)
- **Sensors:** (noisy) conversion of physical conditions to electrical signals (or samples)
- **Actuators:** (imperfect) conversion of electrical signals (or digital commands) to physical actions
- **Controller:** processes measured signals according to what is known about the process; generates signals to drive actuators in order for the system to approximate some desired behaviour

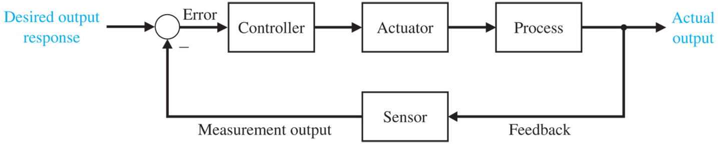
- Sensor and actuator selection are important; they change how the controller perceives and can influence the process,
- However, in this course we will focus on development of techniques that enable (analogue) controller design

Mathematical models

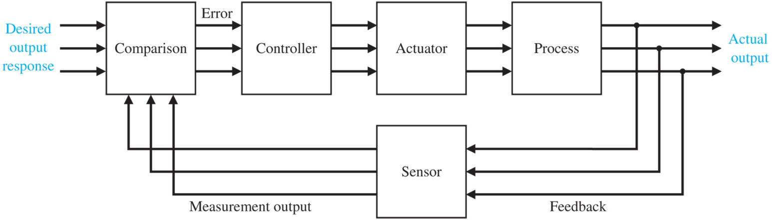
- In a wide range of applications, mathematical models facilitate the process of control system design
- Must balance accuracy against insight generated
- Similarly, controller design must balance performance against implementation complexity
- This course: process models and controllers will be linear
- Hence, tools available for insight: superposition, transfer function, Laplace

Single variable control

We will focus on systems in which a single output is to be controlled using a single command and measurements of that output:

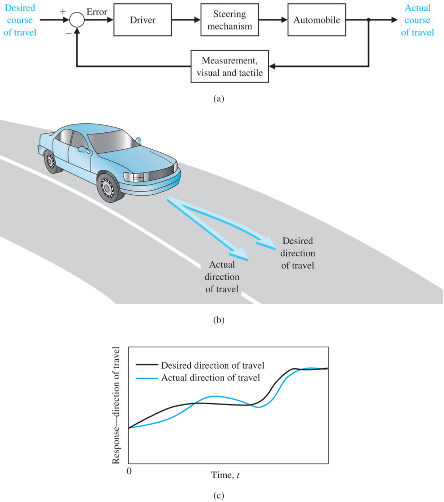


Multivariable control



Something for fourth year!

You driving a car



Doritos

- John MacGregor (Chem Eng):
  - Visual feedback control of flavours

What tools will we use?

- Newtonian mechanics, linear and rotational (Phys 1D03)
- Basic electromagnetism (Phys 1E03, EE 2CJ4)
- Electric circuit analysis (EE 2CI5, EE 2CJ4, EE 2EI5)
- Step response of first and second order systems (Math 2ZO3, EE 2CI5, EE 2CJ4)
- Laplace transforms (Math 2ZO3, EE 2CJ4, EE 3TP3)
- Transfer functions (EE 2CJ4, EE 3TP3)
- Bode diagrams (EE 2CJ4)
- Structured problem solving methods (EE 2CI5, EE 2CJ4, EE 2EI5, EE 3TP3, . . .)

Contact details for C01

- Tim Davidson
  ITB–A111A
  Ext. 27352
  davidson@mcmaster.ca, “EE3CL4” in subject line
- Public web site
  http://www.ece.mcmaster.ca/~davidson/EE3CL4
  includes some additional resources that you may find interesting
- Avenue to Learn site:
  - For submission of pre-labs and lab reports,
  - For interim mark distribution
  - Some distribution of material, such as ECHO360 recordings of lectures; some announcements
- A formal course outline appears on the web site and on Avenue

Marking scheme

- Laboratory reports: 30%
- Midterm test: 25% (no simplified MSAFs)
  Monday 2 March 2020, 6:30pm, 90 mins
- Final examination: 45%

- Students must personally complete all laboratories and all laboratory reports in order to be eligible for a final grade
- Formally deferred tests & exams may be conducted orally
- Remarking requests will require documentation

- On tests & exams, expect to see problems that you have not seen before

The number one FAQ

- How should I study for this course ?
- The advice I used to give:
  - Be active in lectures
  - Participate in tutorials
  - Take advantage of the labs
  - Prepare summaries of concepts in your own words
  - Do half of the assigned problems under examination conditions
  - In exams, explain your methodology
- Arguably a better question:

  How do I learn concepts that will enable me to be creative enough that I can enrich the lives of people in my community through control system design?

How to learn

- But what do I know about learning?
- Who should we ask?
- Perhaps some cognitive psychologists
- The work of Henry Roediger and Mark McDaniel strikes a chord with me (*Make it Stick*)

Learning: common short-term tactics

- Re-reading notes and text, including highlighting
- Massed practice: single-minded repetition of a new skill
- Cramming

- Emphasis: stuffing information into long-term memory
- Feels comfortable; especially familiarity with the text
- May provide the "illusion of mastery"
- May enable you to look at the solution of a problem and think "yeah, I could do that if it comes up on the test"
- What if what comes up in your job (or on the test) is a little bit different?

Learning: strategies for durable learning

- Emphasis: retrieving information from long-term memory
- Encourages the brain to invest energy in changing the structure of its network
- Facilitates generalization of knowledge;
  i.e., application outside our previous experience

- How can we encourage the brain to invest energy in durable learning?

- Spaced and interleaved recall:
  try to remember only once you have started to forget!
- Uncomfortable: really takes effort;
  sometimes you won't be able to remember!
- Experimental evidence suggests that for a large fraction of students it is worth it in the long run

Learning: tactics for durable learning

- Retrieval practice:
  - short summaries (half-page) of a concept in own words; try to teach someone else
  - self-quizes: practice problems under exam conditions
- Space out retrieval practice. Try to remember material:
  - at the end of that day
  - after having a full night's sleep
  - a week later
- Interleave retrieval practice
  - Perhaps do only an hour at a time on one course, or an hour at a time on one topic within a course

Learning: more tactics for durable learning

- Elaboration:
  - Explore connections between aspects of material
  - Explain ideas in own words, visualization or metaphor
- Association:
  - Connect the new material to previously acquired knowledge
- Generation:
  - try to solve problems (just) before the material is covered in class; helps build associations
- Reflection:
  - Summarize each week in own words ($\sim$ 1 page)
  - Summarize larger components towards the end; make these summaries cumulative
- Calibration:
  - Test how you are going; yes, really test yourself out
  - Evaluate the outcomes; address weaknesses

My goals

- I will be trying to introduce these tactics into the classroom
- There will be interleaving of concepts
- May be a bit different from what you have experienced
- I hope that they will be effective in the long run