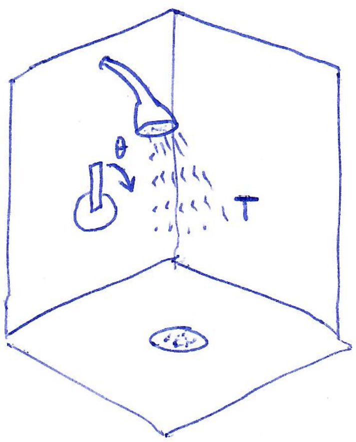
ME 4555 - Lecture 1 - Introduction

The class is called "system analysis & control".

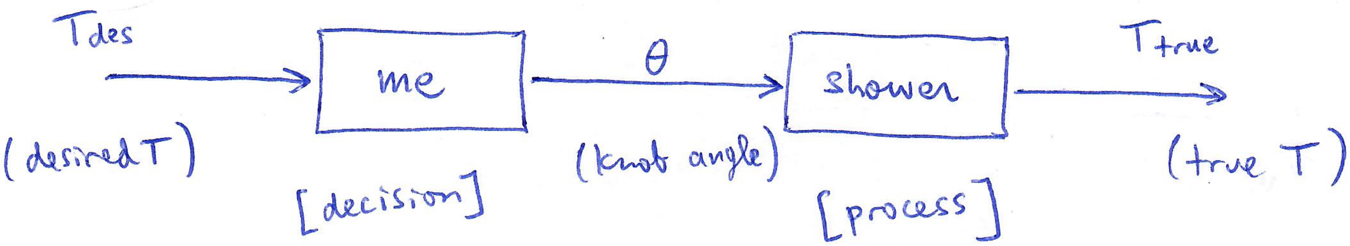
A "system" can be many different things, so we will see several different examples.

Ex. 1 : Taking a shower.



I prefer having the water temperature at T_{des} (desired temperature). The shower has a knob that controls the temperature. Let's call the angle of the knob "θ".

We can view this system as a causal chain of events; i.e. "cause-effect" or "input-output" pairs. We can write a diagram ("block diagram"):

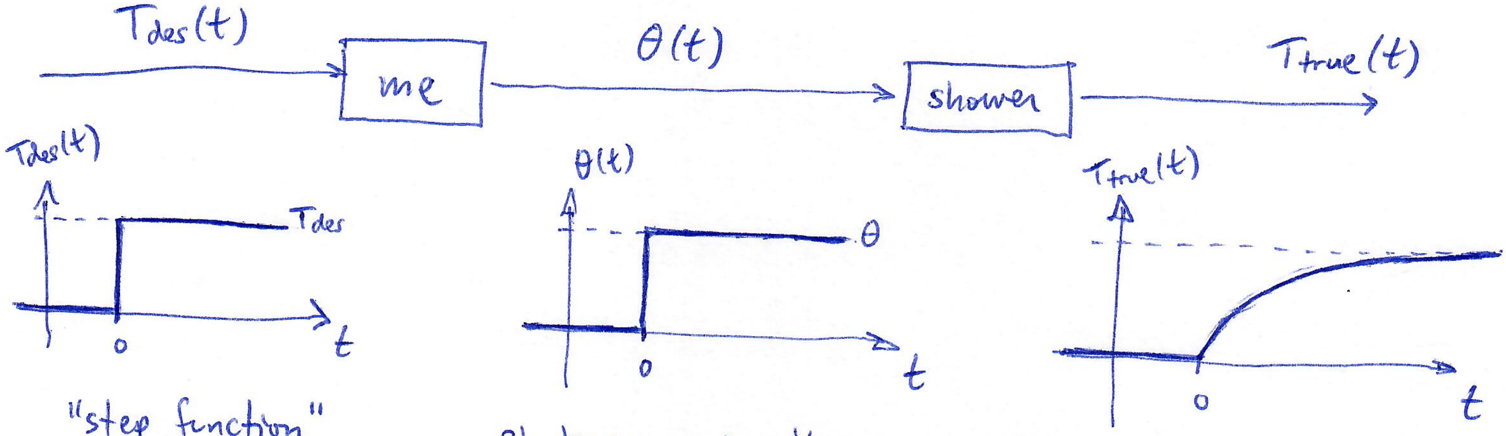


This chain makes sense because the arrows indicate cause-effect.

* T_{des} influences my decision on how I choose θ.
* θ affects the temperature of the shower T_{true}.

These quantities are functions of time.

A more realistic version might look like this:



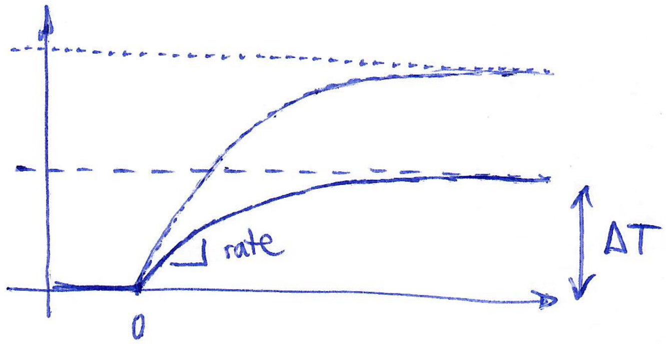
"step function"

Strategy: go directly to the appropriate angle and then stay there.

actual temperature is slow to respond. (why?)

What if I want to get to T_{des} more quickly... Is it possible?

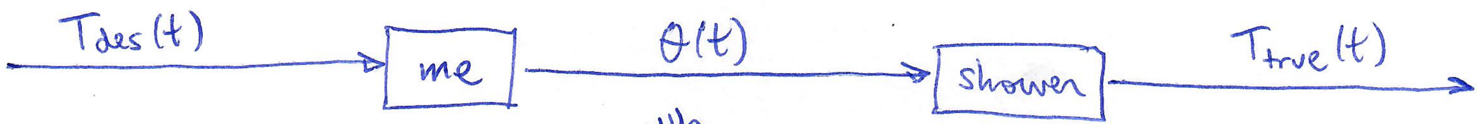
Yes! To see why, we need to understand why the temperature responds the way that it does. One explanation is that the pipes are cold, so they cool the water before it comes out of the shower head. Eventually, the pipes warm up. If the rate of cooling is proportional to the difference in temperatures (Newton's Law of cooling) we would expect fast change at first, as is observed. This is a model (based on physics) of what is happening. If this model is accurate, then larger differences will cause more rapid changes...

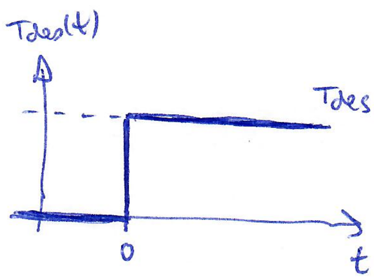


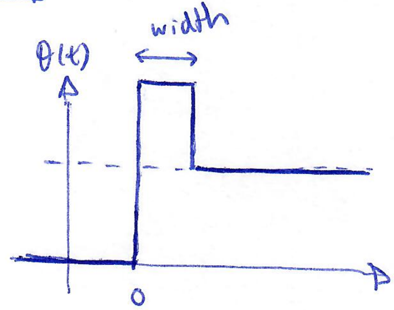
ΔT drives the rate!

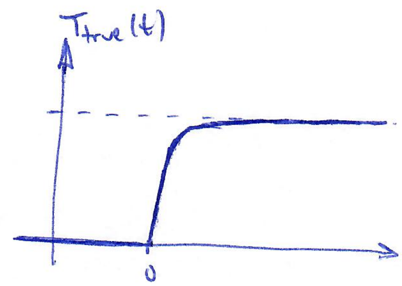
more ΔT = faster rate.

solution that achieves faster response:









smarter strategy: overshoot the true angle for a short time.

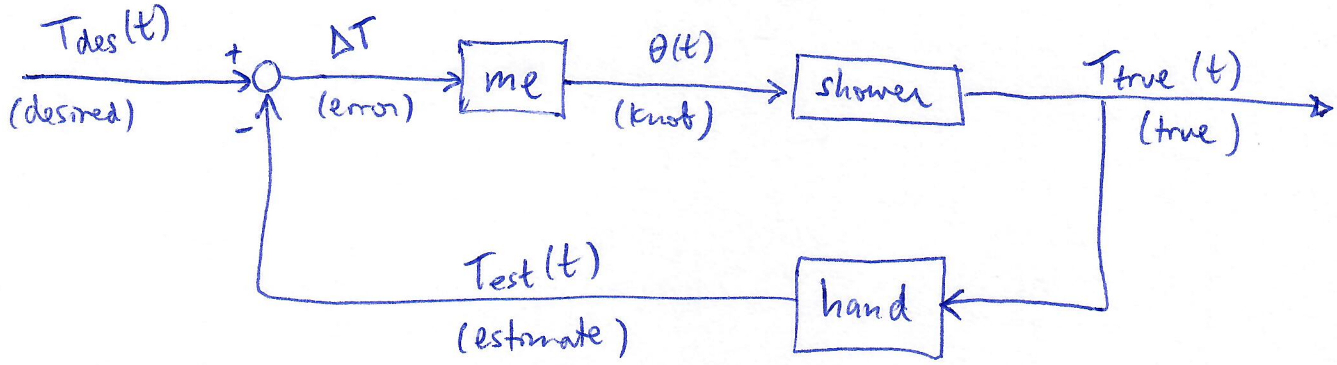
actual temperature responds faster!

This is called "open-loop" control. What is the danger?

- the width must be perfectly chosen.
- the shower may respond differently on different days (e.g. might depend on outdoor temp, or if someone else showered recently.)
- what if we don't even know how to pick θ?

Solution: we could test the temperature to see how close we are to what we want!

"closed-loop control": use measurement feedback:



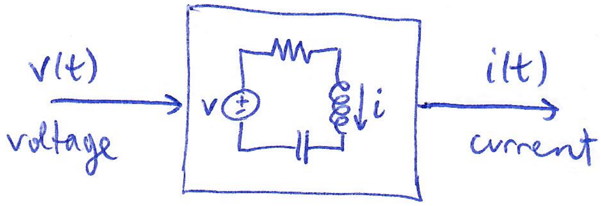
The "me" is now acting on the error (difference between desired and true temperature). Essentially:

- if temperature is too hot, turn it down.
- if temperature is too cold, turn it up.

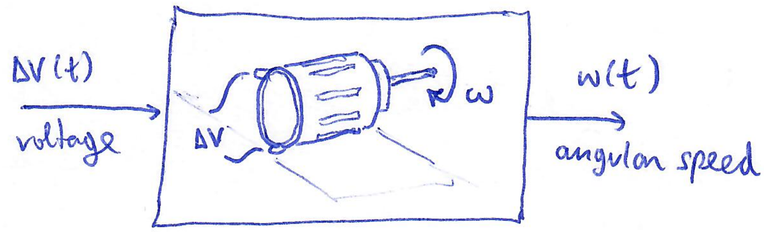
What can go wrong here?

- sign flipped (which way is up?)
- too agressive with adjustments (keep overshooting)

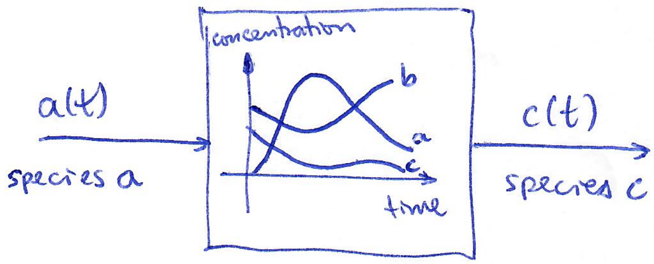
Ex. 2 many other examples of processes we might want to control:



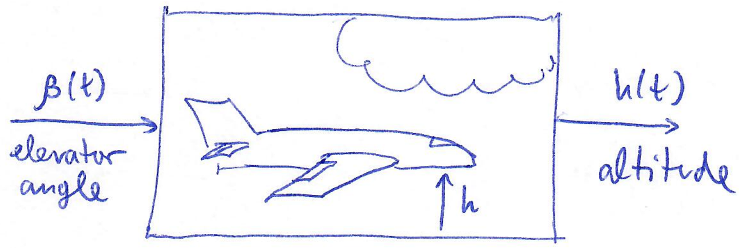
electrical circuit



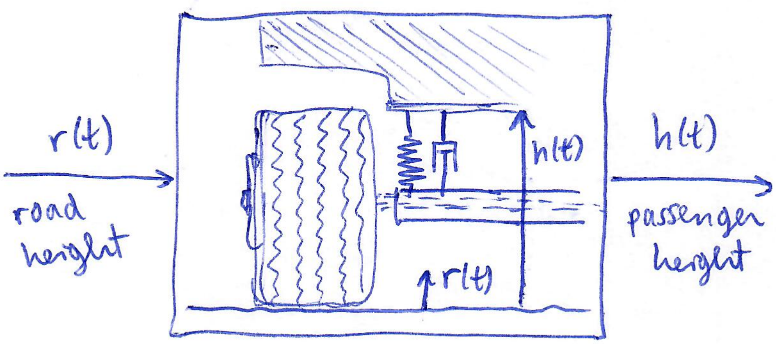
electromechanical system (e.g. motor)



chemical reaction



aerospace engineering



automobile suspension.

Control systems also occur in fields outside mechanical engineering:

- homeostasis in the human body (blood sugar or temperature regulation)
- social networks (e.g. how opinions propagate)
- the stock market
- climate science, ecology.

"System analysis & control".

Three big topics in this class.

1) <u>Modeling</u>: - use physics to build a mathematical model that relates the inputs to the outputs.
   - we will see examples of: mechanical, electrical, hydraulic, thermal, ... systems. Physical laws include: Newton, Ohm, Hooke, and more.

2) <u>Analysis</u>: - use model to predict and/or simulate the dynamic response of a system.
   - Develop a language to describe desirable/undesirable performance of a system.
   - Use both mathematical analysis as well as numerical (e.g. Matlab) approaches.

3) <u>Control</u>: - learn how to <u>change</u> the dynamic response by using feedback control
   - learn about trade-offs, what is actually possible?
   - use both mathematical analysis as well as numerical tools (e.g. Matlab) for design.