6.302 Feedback Systems

Recitation 1: Closed-loop vs. Open-loop Systems

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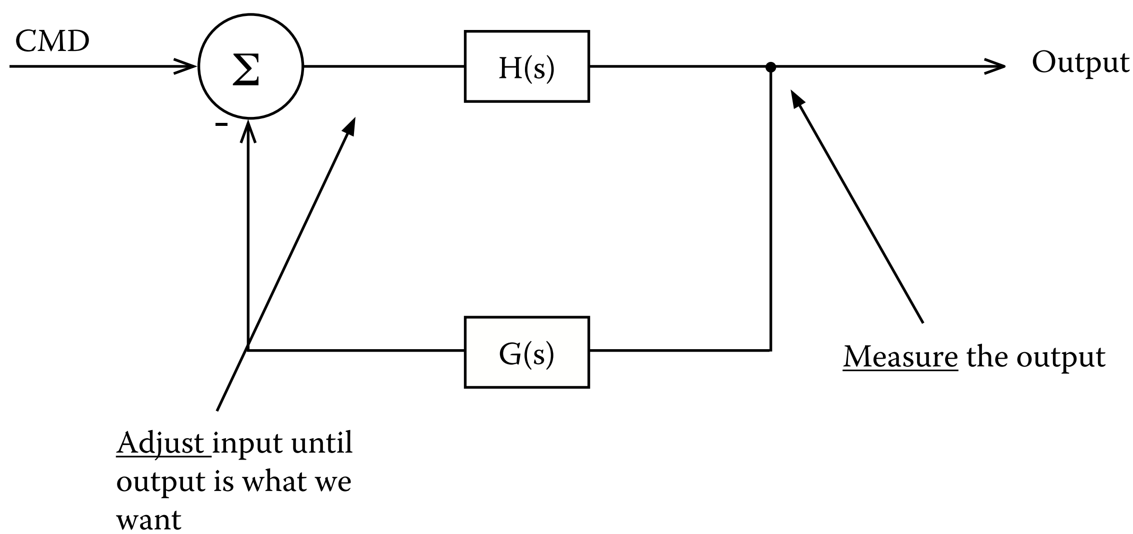
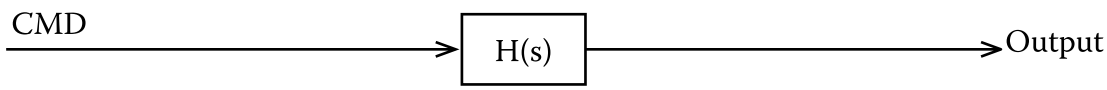
Handouts: Course syllabus, etc. to be given out in lecture.

Discussion: Conceptually, what are we building into a system when we "close a feedback loop around it?"



This is in contrast to an open-loop system:



Here, we choose the command input based on foreknowledge of H(s) in order to get the desired output.

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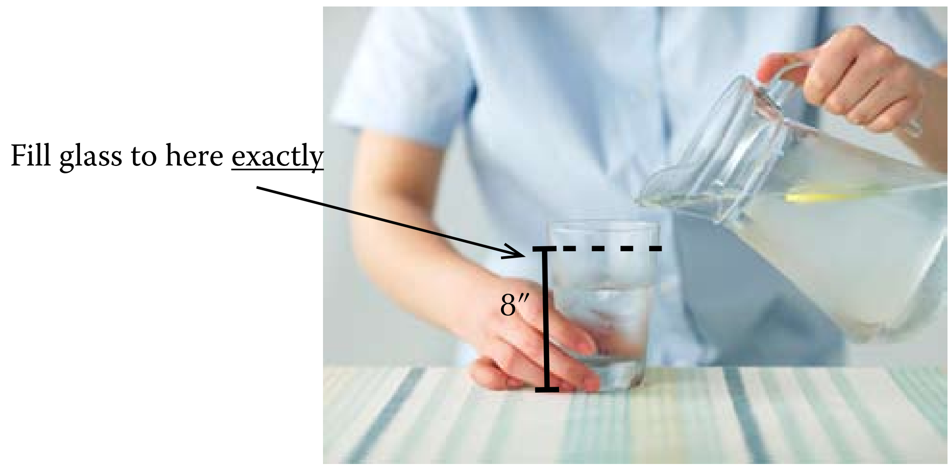
Now, a few examples to illustrate the difference between closed-loop and open loop behavior.

EXAMPLE 1: Filling a glass with water.



Open-loop: Know ahead of time your average flow rate when you pour, and the detailed geometry of the glass. Then, using a stopwatch, you <u>close your eyes</u> and pour according to your calculations.

⇒ What problems does this approach have?

Closed-loop: What we always do. We pour water, constantly monitoring progress, until we reach our goal. Then we stop. No matter what combination of flow rate, glass size, pitcher geometry, etc., we get the job done.

NOTICE, as the term goes on, similarities between filling a glass and "real" feedback systems:

- At the start, you pour fast, and slow down as you reach goal.
- The more accurate you want to be, the longer time it takes...

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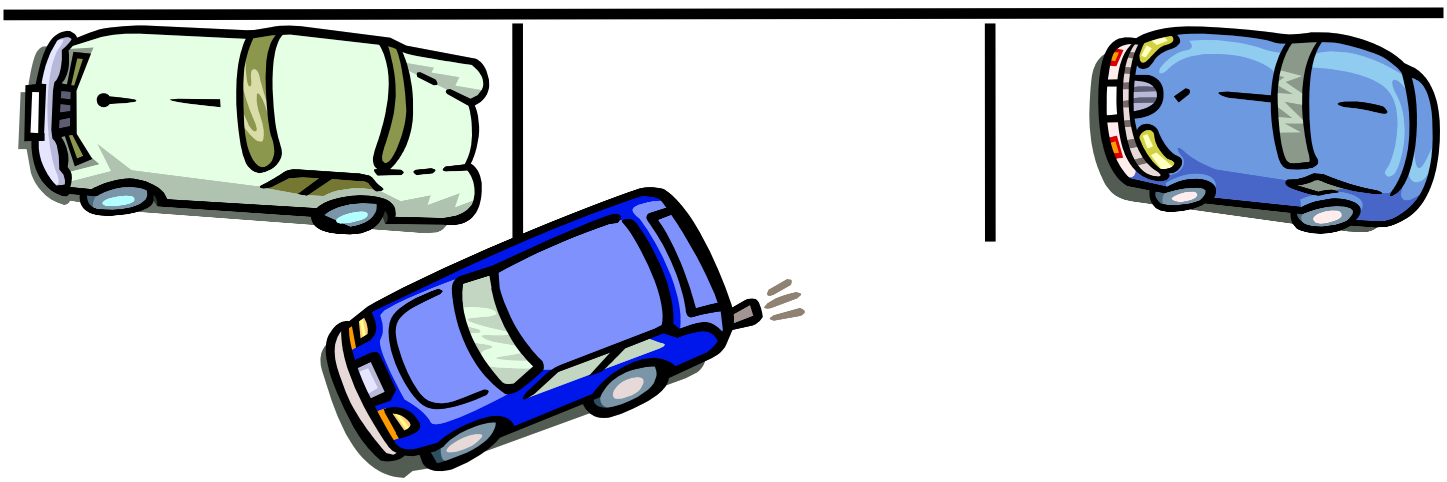
EXAMPLE 2: Learning how to parallel park.



Open-loop: Park according to a pre-determined recipe. For example,

1. Pull parallel to car in front of your space
2. Reverse until front of door lines up with rear bumper of the car ahead.
3. Give steering wheel 3/4 turn to the right.
4. Continue reverse until...

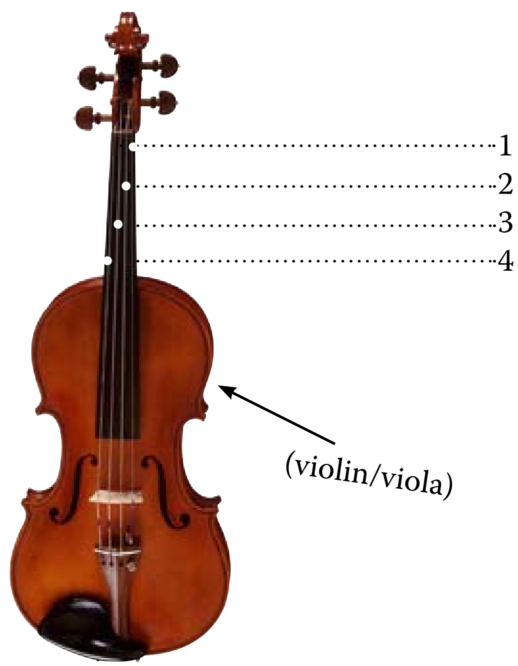
What problems does this approach have?

Closed loop:

- Know a set of general principles.
- Trust your eyes to guide yourself in.
- Practice.

Parallel parking is just one example of how we rely on feedback for driving.

EXAMPLE 3: Playing a musical instrument.



Open-loop:

- Calibrate by finding, say, F# on the D string with second finger, then mark that spot somehow.
- Repeat with all the notes, placing markings all over the fingerboard.
- When finished, no need for the player to listen! Just place finger on the marked spot, and you're in tune!

[This doesn't work. William Primrose, perhaps the greatest violist who ever lived, struggled to play when he lost his hearing. Eventually it ended his career.]

Closed-loop:

- Use your ears, sense of touch.
- Practice.
- Practice some more.

EXAMPLE 4: Gymnastics

Women's vault in Sydney Olympics (2000) was 5cm too low. It was a fiasco! Gymnasts were badly botching their vaults, for the most part (some were fine).

Shows that the vault is, to a certain degree, an "open-loop" event. The gymnasts rely on a great deal of precision in the dimensions of the apparatus to allow them to execute sophisticated vaults.

A closing word on these examples: the kind of feedback described here, executed by the human mind and body, is <u>far</u>, <u>far</u> more sophisticated than the machines and systems we will talk about in class. These examples are here to help you remember what all the math we will do is about.

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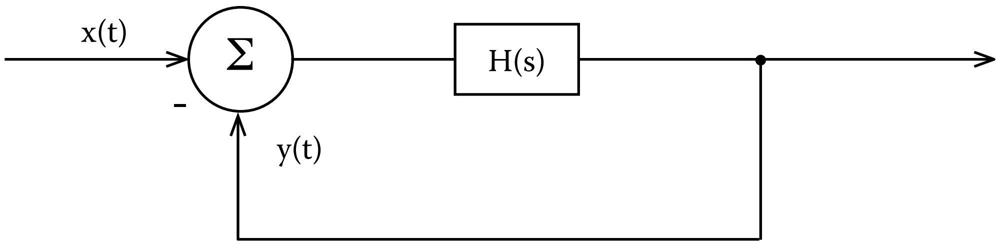
Main factor that complicated feedback system design: DELAY

Classical diagram:



It says: "Compare output with desired input, and adjust until they are the same."

But there is always delay through H(s), so we are never comparing x and y at exactly corresponding moments in time. Doesn't this complicate things? YES!! And we'll be thinking about it all term. Things like phase margin, gain-bandwidth products, conditional stability...all these things are a mathematical manifestation of delay.