Modelling and control summaries

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Introduction to feedback 1 - introduction

KEY SKILLS: Why do we need feedback? What is feedback? What is the impact of adding feedback? Are there good and bad feedbacks? Analysis of feedback loops.

OPEN LOOP CONTROL (this means no feedback and no measurement)

Imagine you need to get your car to 60mph, but you are not allowed to see the speedometer or hear the engine revs. How would you do it?

In all likelihood you call on experience and memory and estimate the foot pedal position required to reach the desired speed.

1. Estimate steady-state gain G(0).
2. Implement u = [1/G(0)]*60.

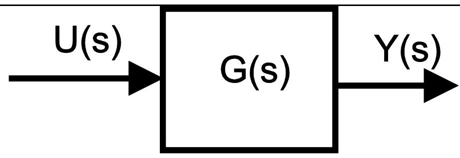
Will this work?

SUMMARY: Clearly the actual G(0) will be different due to modelling errors, road conditions, slopes, winds and so on and therefore the actual speed will be far different from 60mph. Open-loop control fails due to lack of measurement/observation.

Open-loop control assumes that G(s) is known exactly and hence one can achieve the desired R(s) by selecting U(s):

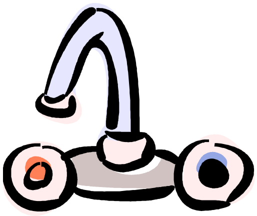
$$U(s) = G_m^{-1}R(s) \quad \Rightarrow \quad Y(s) = G(s)G_m^{-1}R(s)$$

As $G \neq G_m$ clearly $Y \neq R$. **Open-loop fails!**



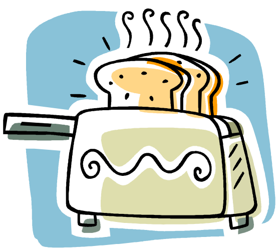
HUMAN PROCEDURES FOR ENSURING THE CORRECT STEADY-STATE OUTPUT

How do you control the temperature in a shower?



1. Estimate the required cold/hot balance and run for 10s.
2. Monitor and increase cold/hot if required.
3. Monitor for 10s and adjust again if required.
4. Keep iterating until happy.
5. In general the adjustments get smaller each time as we get closer to the required temperature – that is the **adjustments are in proportion to the temperature error**.

How do we ensure toast is correct?



1. Under estimate the required toasting time.
2. Monitor bread and increase time if required.
3. Keep iterating until happy.

In general the time adjustments get smaller each time as we get closer to the required browning – that is the **adjustments are in proportion to the browning error**.

<table>
<tr><td colspan="2">SUMMARY OBSERVATIONS</td></tr>
<tr><td>1. Open-loop usually fails because there is no observation of the actual system.
2. Therefore no check as to whether the desired outcome has been achieved.
3. No information which could be used to inform a change in the control input.
Any modelling information is likely to be approximate leading to inevitable deviations from the desired target.</td><td>1. Remove a cake after precisely 2 min without checking.
2. Drive a car with your eyes closed using a predetermined set of steering wheel and accelerator positions
3. Estimate shower tap positions and leave.</td></tr>
<tr><td colspan="2">Open-loop can rarely be used in practice because for most manufacturing, processes, devices and so forth there are specific requirements on the behaviour. (i) Voltages into a house need to be close to 240v; (ii) Air/fuel ratios in a car engine must be precise to ensure efficient running; (iii) Angle of attack in turbines and aeroplane wings is chosen to gift lift and avoid stall. Etc.</td></tr>
<tr><td colspan="2">Open-loop control fails for many reasons.
1. Incorrect estimate of gain/system model G(s). [Often denoted parameter uncertainty]
2. No awareness of varying external conditions such as wind, temperature, etc.. [Often denoted as disturbances]
3. Due to inevitable errors, some measurement and input correction is essential to ensure the output reaches the desired value.</td></tr>
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REMARK: Humans manage to control the world effectively precisely because we incorporate an effective measurement → correction system in an iterative loop.

1. Measure the actual output.
2. Modify the input according to some rule.
3. Measure again and keep iterating.

The efficacy of this control system is closely linked to the rule base we use for modifying the input and it is this concept and the need to ensure an effective rule which motivates the study of feedback control systems.