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System Modeling & Control

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Module VII
Controllers

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Lesson - 35

Controllers

Introduction

Suppose you have a system that needs to be controlled

Your software gives commands, the system responds to it

- Turn x degrees to the right
- Move forward 15 wheel rotations

Can you always trust your commands will be executed accurately?

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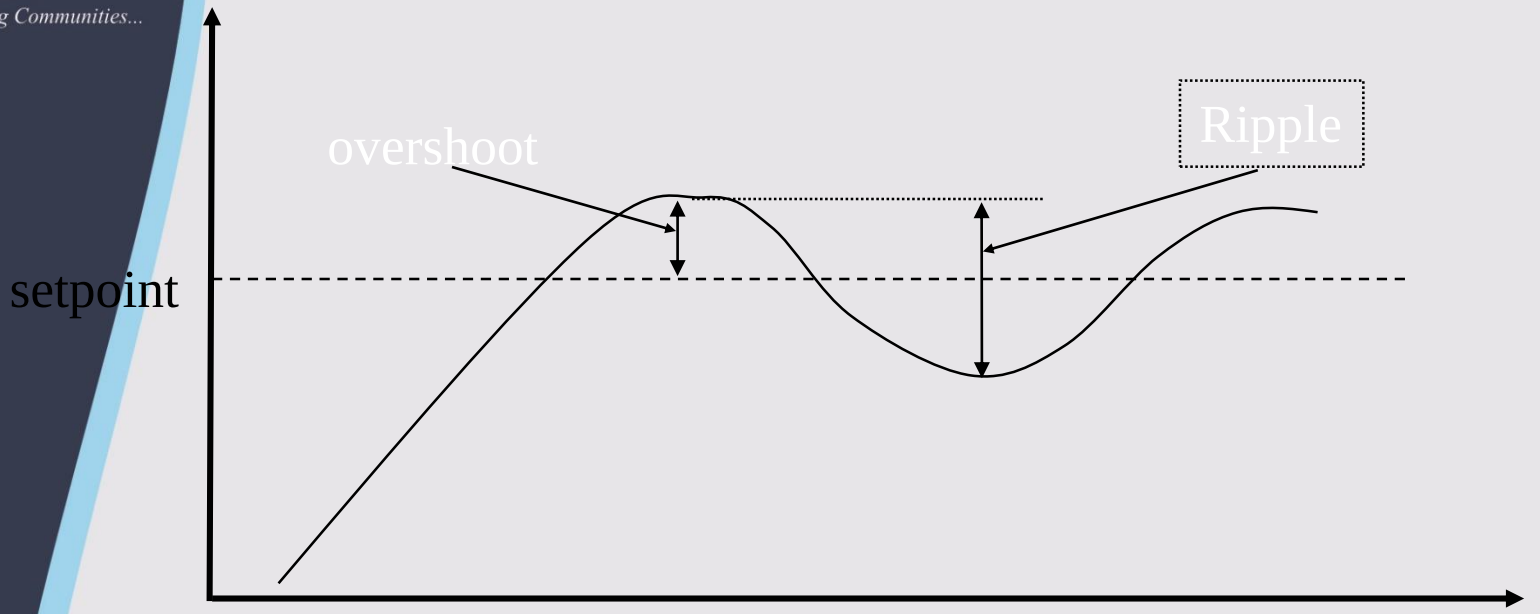
Problem example



Increase the quantity until you get to the setpoint

Temperature, angle, speed, etc

If too much, reduce the quantity, until the setpoint

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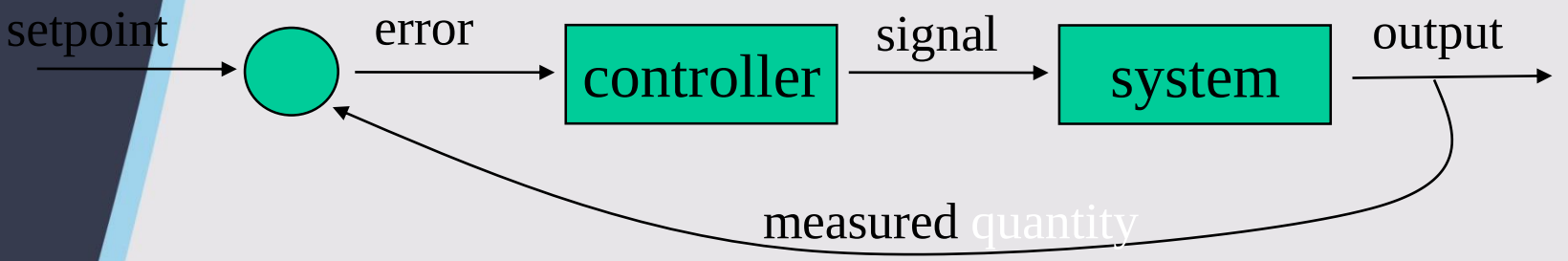
Closed loop controller



- closed loop because it has feedback
- output is measured at a certain frequency
- signal is generated at a certain frequency
- which frequency is not smaller?

On-off control

For some systems, on-off signaling is sufficient

For example, a thermostat, when the heater is either on or off, and early cruise-control systems

- Could do airflow or speed control also
- More modern systems do it

Depending on the frequency of control, overhead of on-off, etc, this could cause overshoots and undershoots (ripples)

- Oscillation is a common behavior in control systems
- Need to avoid it at all costs… well, almost all costs

Proportional control

- Good alternative to on-off control: more “control” ☺
- Signal becomes proportional to the error
  - *P (setpoint – output)*
  - Example, car speed for cruise control
- Need to find out value of constant P
  - Tuning the controller is a **hard** job
  - If P is too high, what happens?
  - If P is too low, what happens?
- Typically a prop cntrl decreases response time (quickly gets to the setpoint) but increases overshoot

Adding derivative control

To avoid (or reduce) overshoot/ripple, take into account how fast are you approaching the setpoint

- If very fast, overshoot may be forthcoming: reduce the signal recommended by the proportional controller
- If very slow, may never get to setpoint: increase the signal
- In general: *D (current measure – previous measure)*

PD controllers are slower than P, but less oscillation, **smaller** overshoot/ripple

Integral control

- There may still be error in the PD controller
  - For example, the output is close to setpoint
    - P is very small and so is the error, discretization of signal will provide no change in the P controller
    - D controller will not change signal, unless there is change in output
- Take the sum of the errors over time, even if they're small, they'll eventually add up
  - I * sum_over_time (setpoint — output)
- Again the main problem is the value of I
- Can we let sum grow to infinity?

Summary

Different types of controllers

PID hardest task is tuning

Controller	Response time	Overshoot	Error
On-off	Smallest	Highest	Large
Proportional	Small	Large	Small
Integral	Decreases	Increases	Zero
Derivative	Increases	Decreases	Small change

Tips for Designing a PID Controller

1. Obtain an open-loop response and determine what needs to be improved
2. Add a proportional control to improve the rise time
3. Add a derivative control to improve the overshoot
4. Add an integral control to eliminate the steady-state error
5. Adjust each of Kp, Ki, and Kd until you obtain a desired overall response.

Lastly, please keep in mind that you do not need to implement all three controllers (proportional, derivative, and integral) into a single system, if not necessary. For example, if a PI controller gives a good enough response (like the above example), then you don't need to implement derivative controller to the system.

Keep the controller as simple as possible.