ENGR 3421:Robotics I

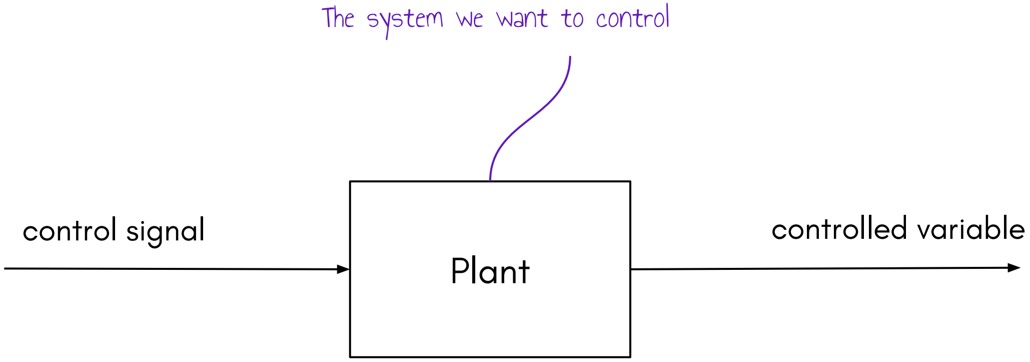
PID Control

10/28/2025

Outline

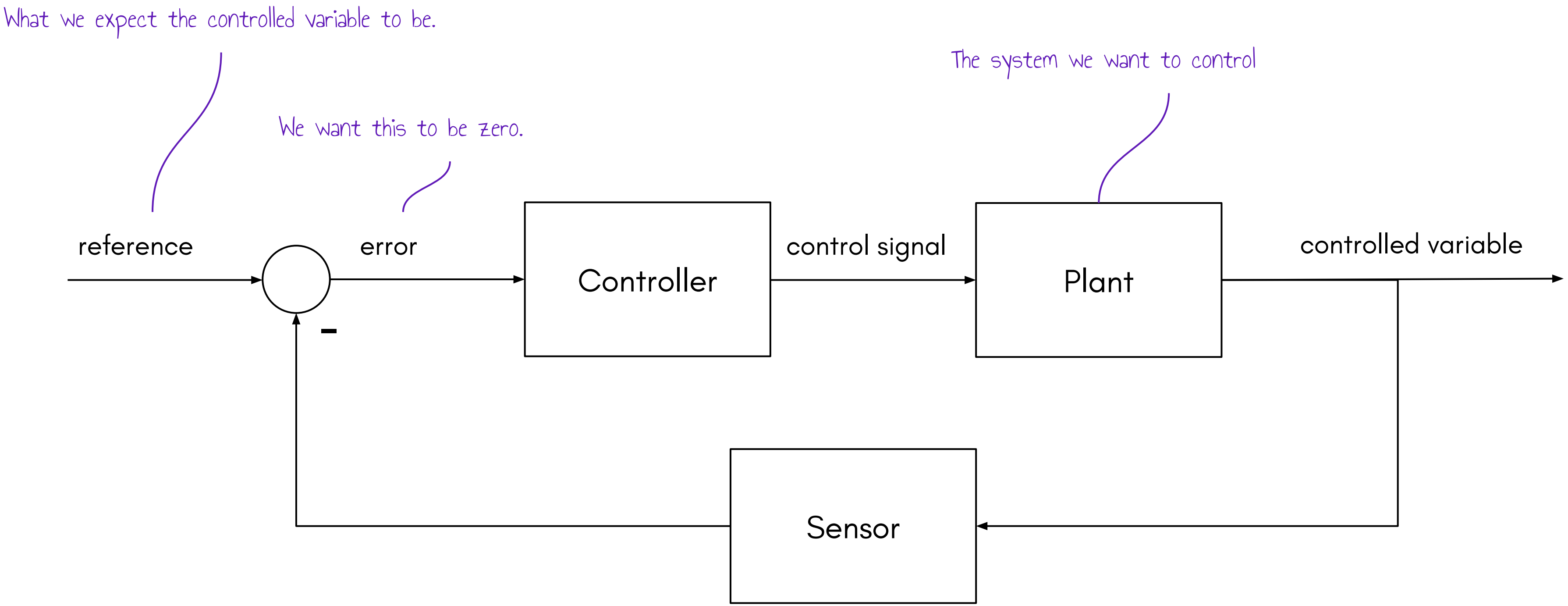
- Open-Loop Control vs. Closed-Loop Control
- PID Control
    - Proportional Gain
    - Integral Gain
    - Derivative Gain

Open-Loop Control



Lever angle	Tap	Water level
Bioelectrical signal	Leg, foot	Stride length
Heater current, tumbling speed	Dryer	Humidity

Closed-Loop/Feedback Control



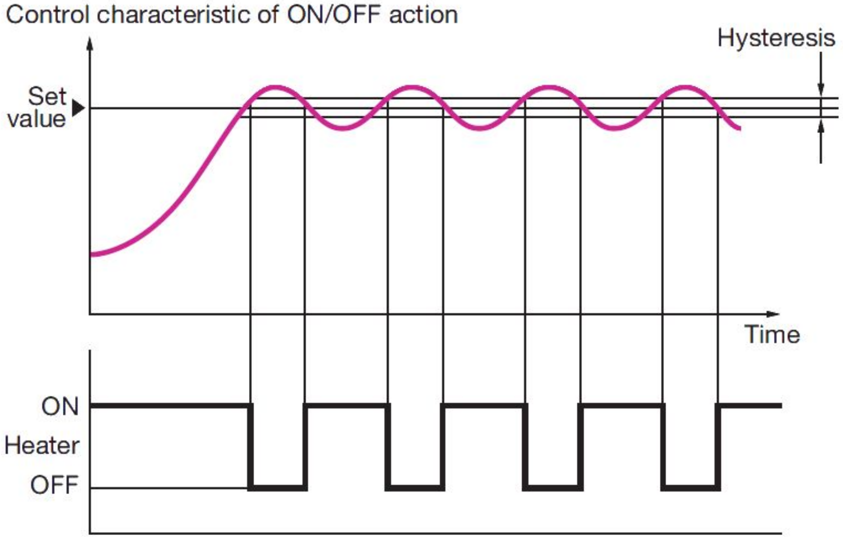
Some Control Scenarios

- A furnace trying to warm a room.
- A robotic arm trying to reach to a certain pose.
- A valve trying to control water flow..
- A cart trying to arrive to a destination point.
- A quadcopter trying to balance itself.
- A motor trying to reach desired speed.

Control Goals

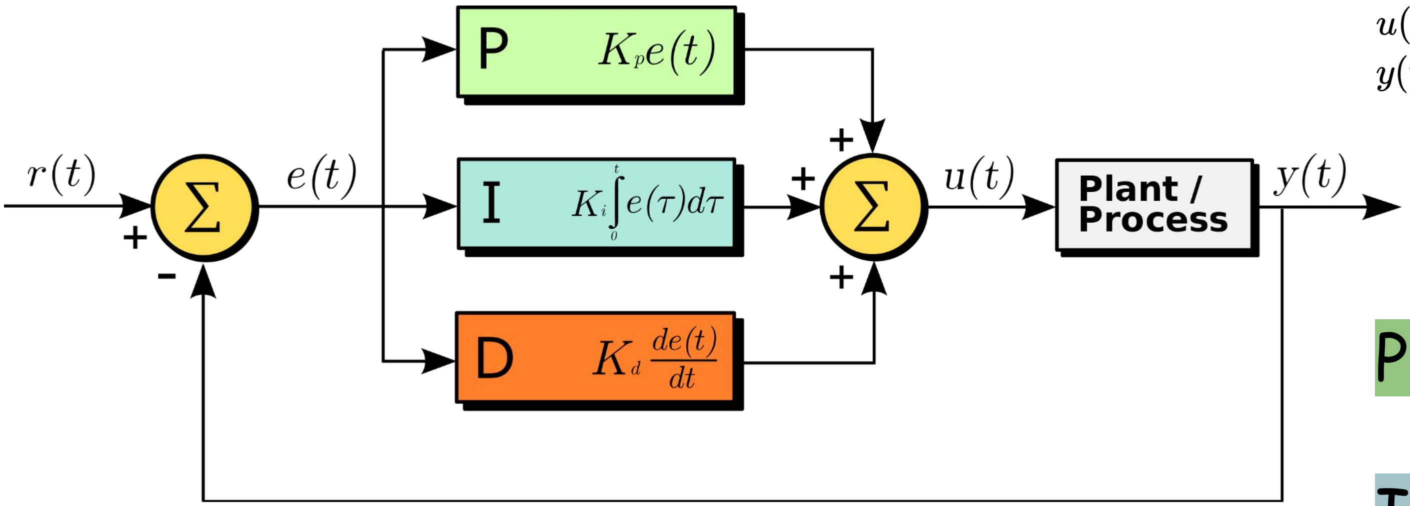
- Quick response.
- Stable at the reference.

Bang-Bang Control



- On/Off control is simple.
- Set a reasonable hysteresis gap.
- Sudden high current/heating/expansion leads to wear-and-tear effect.

PID Controller



$r(t)$: *reference*
$e(t)$: *error*
$u(t)$: *control signal*
$y(t)$: *controlled variable*

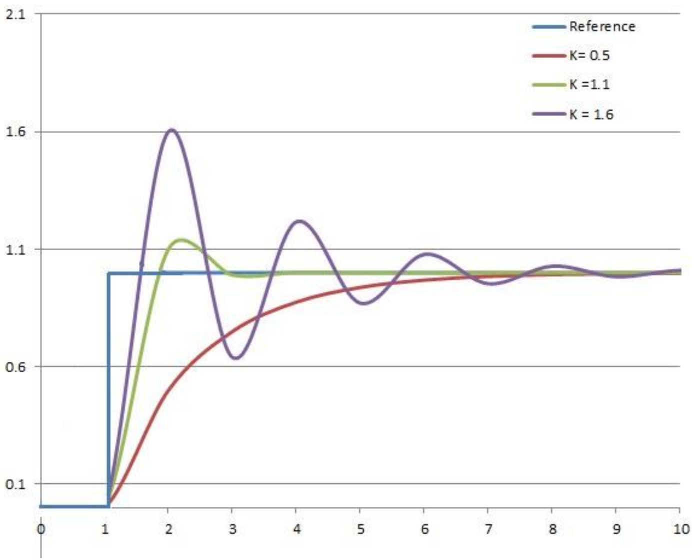
$$u(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{de(t)}{dt}$$

P: present

I: past

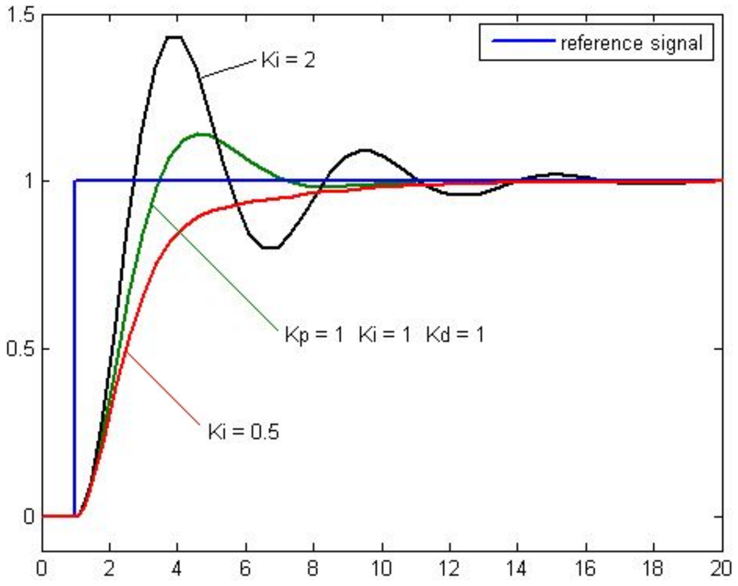
D: future

Proportional Gain



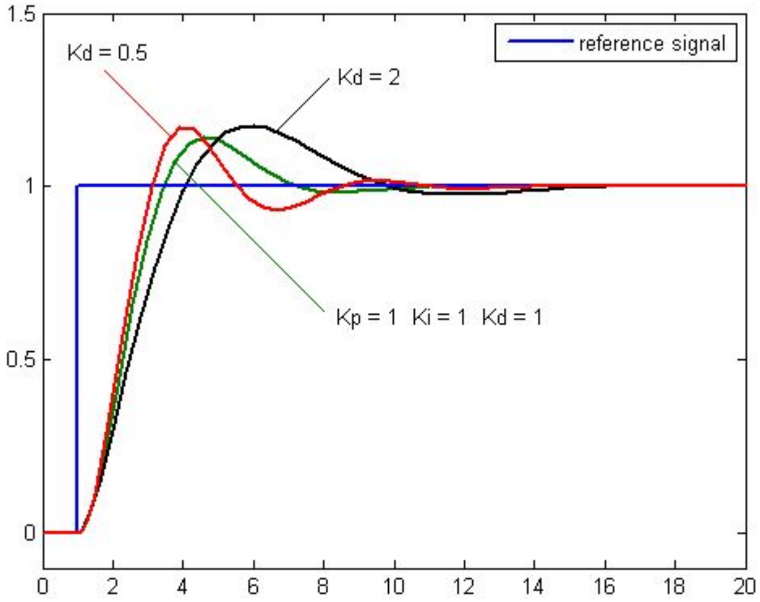
- Proportional gain is simple and can work out of the box in practice.
- Large Kp may cause oscillation.
- Output will have an offset from the set point if a non-zero input is required at that point.

Integral Gain



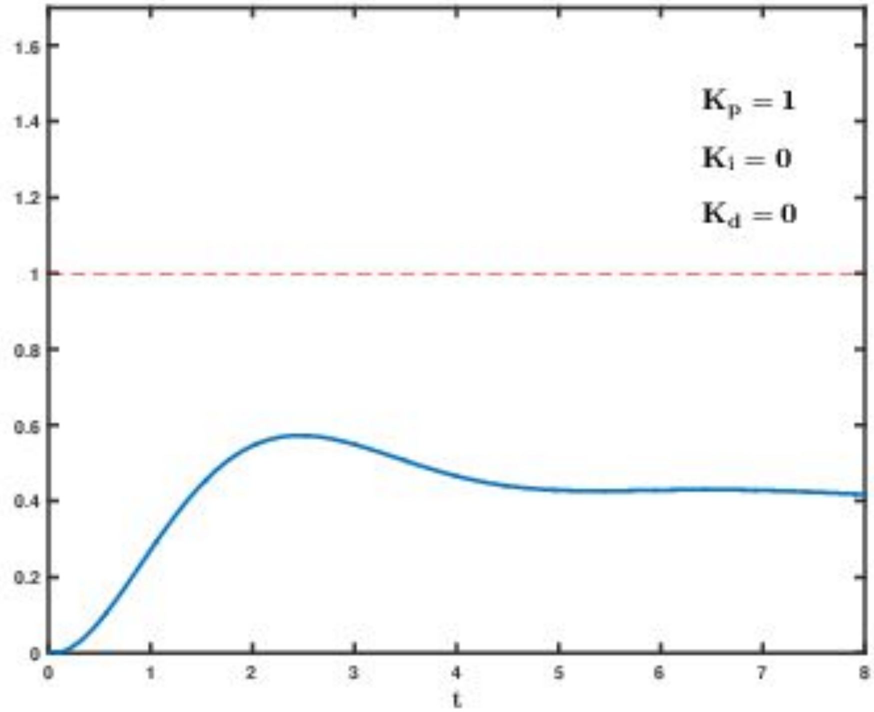
- Compare to Kp, Ki is usually a smaller factor.
- Need a reasonable error buffer size.
- You don't want to save errors at the beginning, set a threshold for Ki to kick in.
- Set point/reference may drastically changes, make sure to clean up the error buffer after that.

Derivative Gain



- Usually, Kp and Ki will do the job.
- Kd can help to stabilize the outcome.
- Set a time interval to calculate derivatives, the error exact one time step before could be noisy.

PID Putting together



Study Resources

- Matlab Tech Talks
- DC Motor PID Speed Control
- Examples