Control

CSC752: Autonomous Robotic Systems

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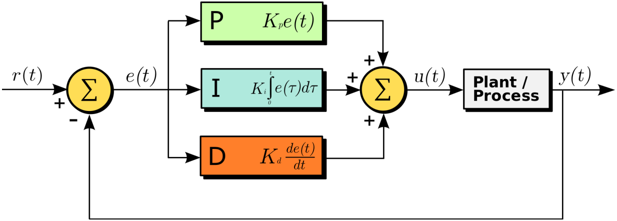
Outline

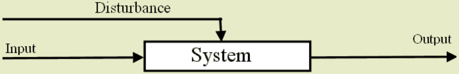
1. Control system
2. PID controller



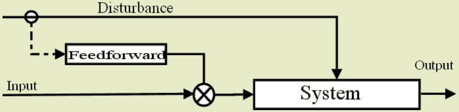
Source: Arturo Urquizo

Controller

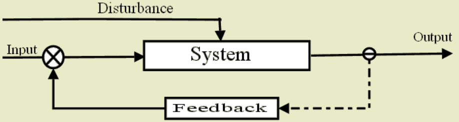
- Open loop:



- Feed-forward:

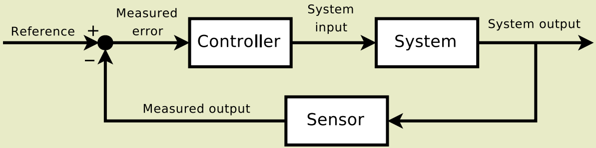


- Closed loop / feedback:



Images from http://en.wikipedia.org/wiki/Feed-forward

Controller



- Controller → Actuator → Effect → Feedback
- Measurable output: process variable (PV) = y(t)
- Reference: setpoint (SP) = r(t)
- System input: manipulated variable (MV)
- Error $e_t = r_t - y_t$

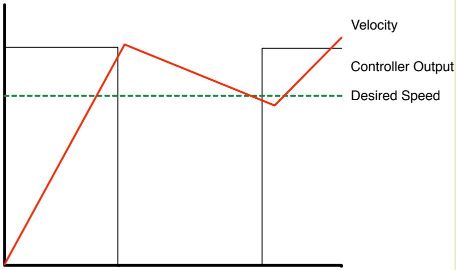
Examples for feedback control

Feedback controller can be used to regulate e.g. temperature, pressure, flow rate, speed ...

- Refrigerator
- Oven temperature
- Car velocity
- ...

Example: Car velocity control

- Controller for the speed of a car.
- Simple on-off design:

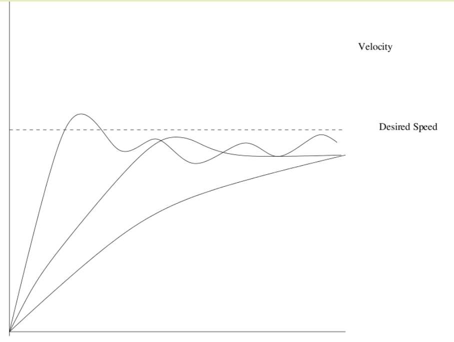


- Hysteresis to avoid unbounded oscillations.

Following slides based on material from http://www4.cs.umanitoba.ca/ jacky/Teaching/Courses/

Example: Car velocity control - Proportional control

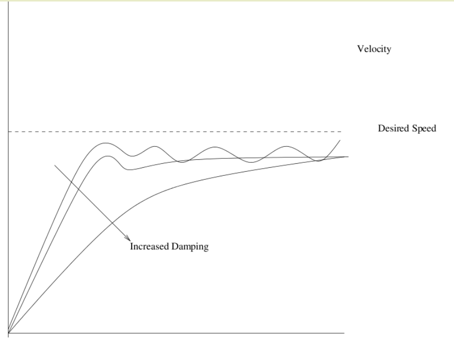
- Controller sets throttle proportional to the output.
- $u(t) = MV(t) = K_P e(t)$, where K_P is the controller gain.



- In the end $PV \neq SP$, since MV is 0 is for the error 0.

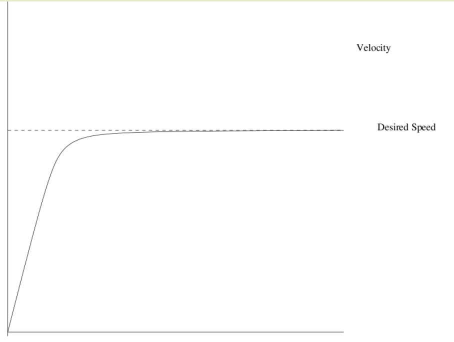
Example: Car velocity control - Derivative control

- Derivative term avoids oscillations of high gains.
- $u(t) = K_P e(t) + K_D \frac{d\ e(t)}{dt}$



Example: Car velocity control - Integral control

- Integral term avoids the steady state error.
- $u(t) = K_P e(t) + K_I \int_0^t e(t)dt + K_D \frac{d\ e(t)}{dt}$



PID controller

- PID controller / three term controller

$$u(t) = K_P e(t) + K_I \int_0^t e(t)dt + K_D \frac{d\ e(t)}{dt}$$

- Effects of increasing the gains K_P, K_I and K_D

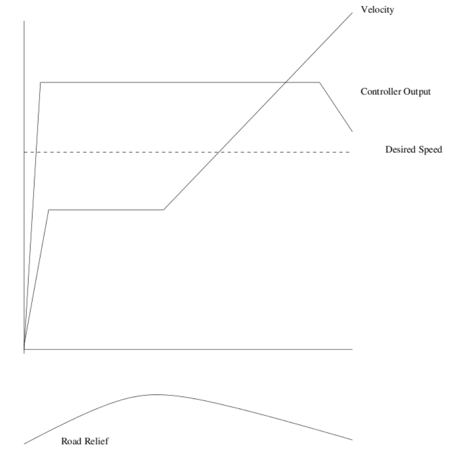
Parameter	Rise time	Overshoot	Settling time	Steady state error
K_P	Decrease	Increase	Small change	Decrease
K_I	Decrease	Increase	Increase	Eliminate
K_D	Small change	Decrease	Decrease	Small change

- Trade off between response time and stability.

Problem with PID controllers

- Integral wind-up
- Physical limits of the actuator let the integral term accumulate a high error.
- What if the controller tries to drive faster than the maximum velocity of the car?
- The error never reaches 0 and the integral term continues to increase.
- Once the speed is reduced, the integral term will still increase the speed.

Example: Car velocity control - Integral wind-up



- Solution: Max/min values for the integral. Stop summation on saturation.

RoboCup examples

A humanoid robot can use controllers for several tasks:

- Move joint to a given angle.
  - Desired joint angle, controller sets voltage, motor moves joint, current joint angle is measured.
- Balancing (inverted pendulum).
  - Desired torso angle, controller sets walk command, walk motion moves robot, torso angle is measured.
- Walk to position.
  - Desired position, controller sets walk command, walk motion moves robot, robot position is measured.
- ...

Acknowledgement

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The slides for this lecture have been prepared by Andreas Seekircher.