EECS 192: Mechatronics Design Lab
Discussion 10: Control Responses & Tuning

GSI: Justin Yim

3 & 4 Apr 2019 (Week 10)

- Dynamical Systems Review
- Control Response
- Summary
Dynamical Systems Review
The car’s behavior is described by **state variables** (e.g. position, velocity)

- Actuators accept **inputs** and sensors read **outputs** (e.g. PWM, camera line)
Dynamical Systems

- The car’s behavior is described by **state variables** (e.g. position, velocity)
- Actuators accept **inputs** and sensors read **outputs** (e.g. PWM, camera line)

\[
\begin{align*}
\dot{y}_a &= \frac{-V^2}{L} \delta(t) - V\dot{\delta}(t) \\
x(t) &= \{y_a, \dot{y}_a\}
\end{align*}
\]
Dynamical Systems

- The car’s behavior is described by **state variables** (e.g. position, velocity)
- Actuators accept **inputs** and sensors read **outputs** (e.g. PWM, camera line)
- It should follow a **reference** (lateral displacement & track, velocity & setpoint)
Dynamical Systems

- The car’s behavior is described by **state variables** (e.g. position, velocity)
- Actuators accept **inputs** and sensors read **outputs** (e.g. PWM, camera line)
- It should follow a **reference** (lateral displacement & track, velocity & setpoint)
- Our controller feeds **inputs** to the system to achieve this (servo angle, motor PWM)
It is often nice to work with **Linear Time-Invariant Systems**

\[
\begin{align*}
\dot{x}(t) &= Ax(t) + Bu(t) \\
y(t) &= Cx(t) + Du(t)
\end{align*}
\]

When systems are nonlinear, we can create linear approximations about operating points

(what is \(\ddot{y} = -\frac{V^2}{L}\delta(t) - V\dot{\delta}(t)\)?)

Keep in mind the approximations get worse as we get further from our operating point
Control Tuning

- We’d like to tune our controller to keep the car close to the track while it runs as fast as possible.
- How do we systematically examine how it’s doing?

What to do about my crazy car?
We’d like to tune our controller to keep the car close to the track while it runs as fast as possible.

How do we systematically examine how it’s doing?
  - Frequency response
  - Impulse response
  - Step response

What to do about my crazy car?
Control Response
Impulse response is very useful for analyzing the system.
Responses

- Impulse response is very useful for analyzing the system
  - Time trace after Dirac delta input
  - Time-domain equivalent to Laplace domain transfer function
Responses

- Impulse response is very useful for analyzing the system
  - Time trace after Dirac delta input
  - Time-domain equivalent to Laplace domain transfer function
  - But we can’t give our car an infinite input (and if we could we wouldn’t want to)
Impulse response is very useful for analyzing the system
- Time trace after Dirac delta input
- Time-domain equivalent to Laplace domain transfer function
- But we can't give our car an infinite input (and if we could we wouldn't want to)

Instead, we often use step responses
We can use the step response to tell how we should adjust PID gains

**General tips:**
- Often easiest to begin with only proportional feedback, then add other terms later
- Higher gains improve tracking, but ...
- Extremely high gains cause jittering and shaking (or even instability)
- Time delay causes instability
Step Response

Note the steering saturation. Is the linear approximation good?

P is too high
Step Response

- Note the steering saturation. Is the linear approximation good?
Step Response

- Note the steering saturation. Is the linear approximation good?
- \( P \) is too high
Step Response

Note the jittery steering input, P is 1/2 of before, but D is too high.
Step Response

- Note the jittery steering input
- P 1/2 of before, but D is too high
Step Response

![Step Response Graph]

- Time (s)
- Lateral Displacement (cm)
- Steering

Looking better

P 3/4 of original, D 1/3 of earlier
Looking better

P 3/4 of original, D 1/3 of earlier
Save telemetry data!

Look at step responses and control signals