Control is Everywhere

- The modern world is driven by control systems
- Modern engineers must understand control systems for all disciplines

Covid-19 and Control Engineering

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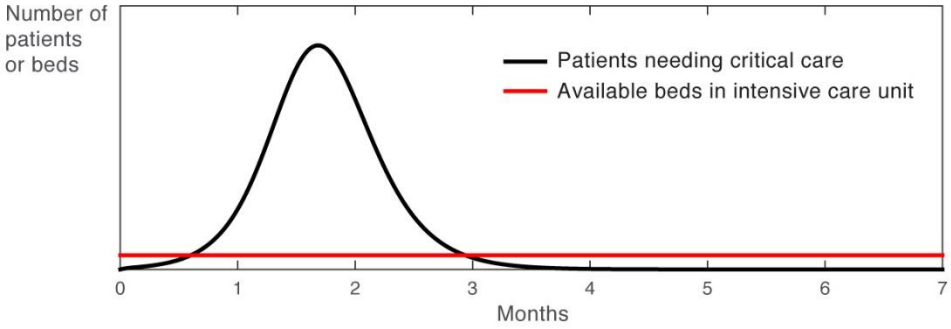
17 Jul 2020 | 11:00 GMT

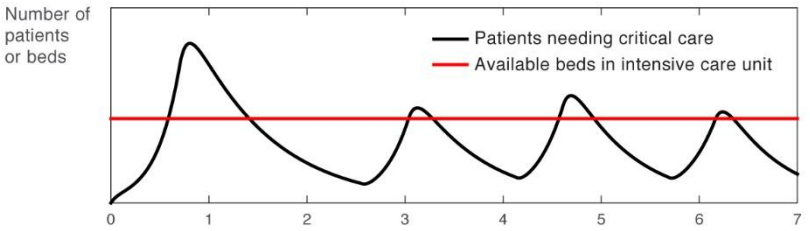
How Control Theory Can Help Us Control COVID-19

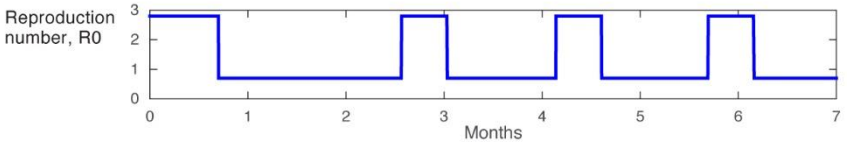
Using feedback, a standard tool in control engineering, we can manage our response to the novel coronavirus pandemic for maximum survival while containing the damage to our economies

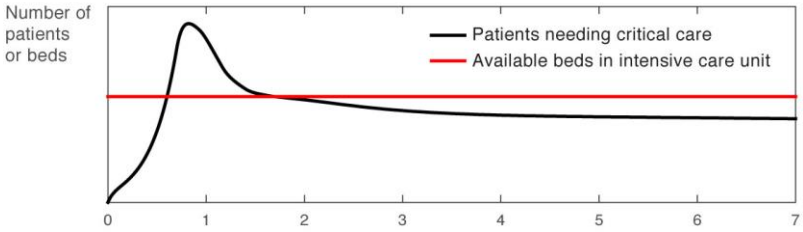
By **Greg Stewart, Klaske van Heusden and Guy A. Dumont**

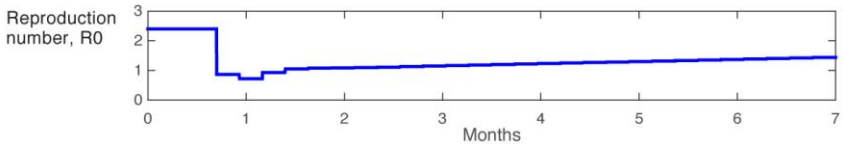
https://spectrum.ieee.org/biomedical/diagnostics/how-control-theory-can-help-control-covid19











Control systems are responsible for determining the appropriate system response to measurements from the environment.

Open-loop Control

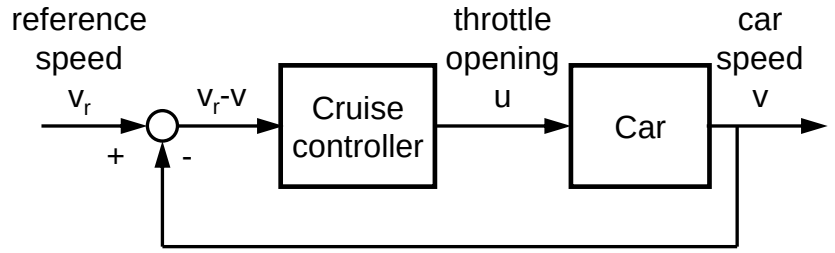
- Controllers generally attempt to drive a *plant* to a desired *state*
- Open-loop controller
  - Changes the output from the controller based on a **model** of the plant
  - Only used to control simple systems with known dynamics
  - Does not account for disturbances

Closed-loop (Feedback) Control

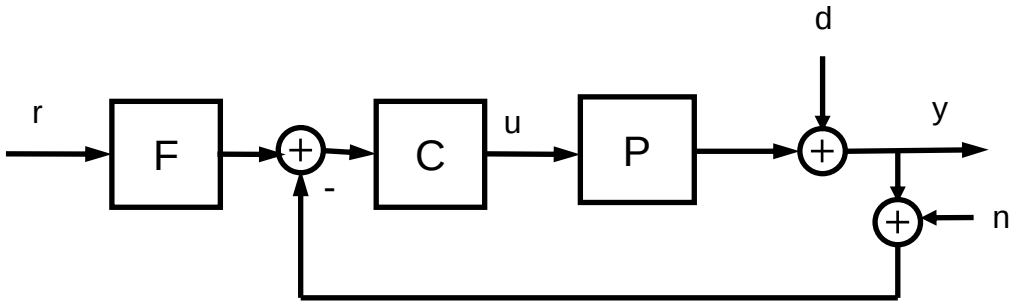
- Changes the output from the controller based on the **measured state** of the plant
- Able to **compensate** for both changes in command and **disturbances** to the system
- Most common modern approach to control

Feedback Control System

- P: the plant
- C: the controller
- F: a prefilter (for command response shaping)



- y: controlled variable
- r: command (or reference) signal
- u: control signal



- d: disturbance signal
- n: measurement noise

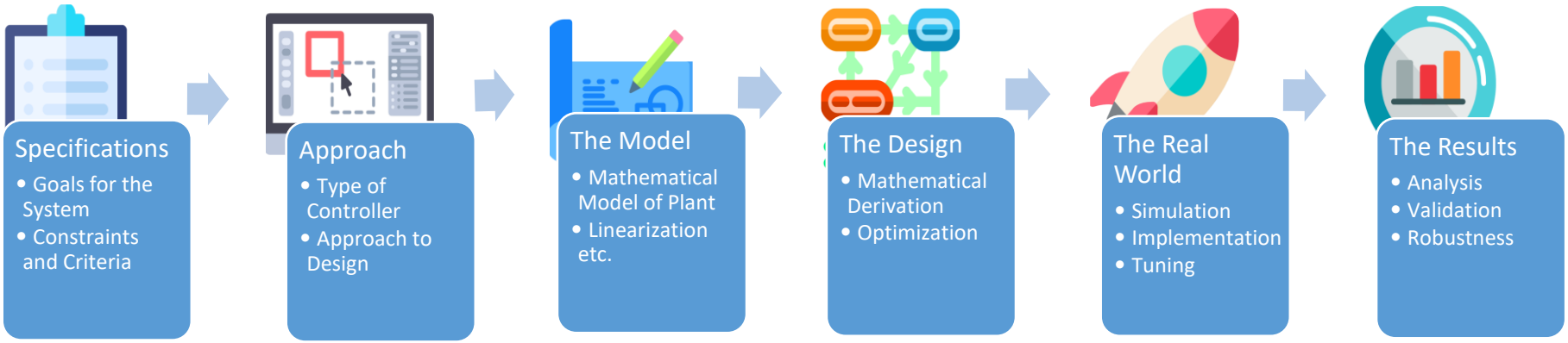
Control Design

- The design process begins with WHAT you want the plant to do, and what controller makes sense based on the properties of the system.

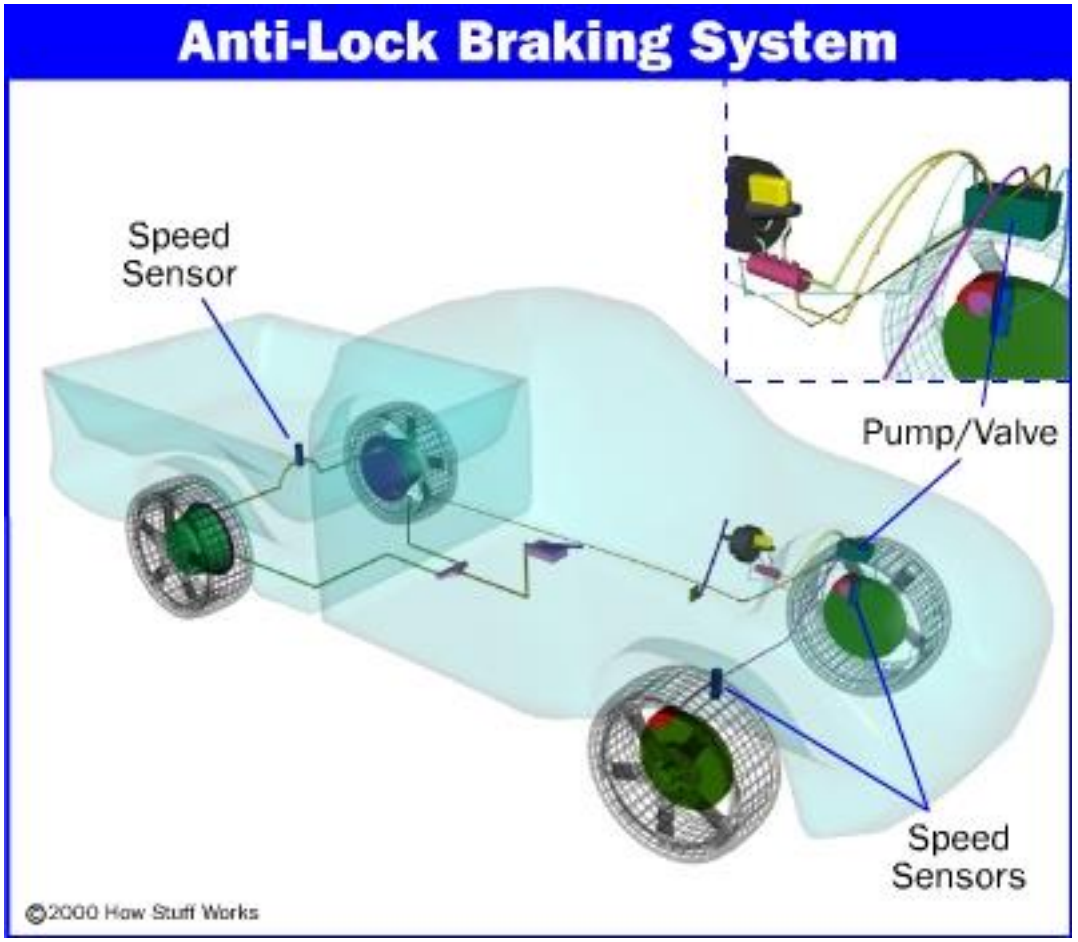
- You then **design** the controller **mathematically** based on a **system model** if possible, and test the proposed controller **using a simulation**.

- Finally, you **implement** the controller on the **actual system** and **tune** in order to achieve the desired response.

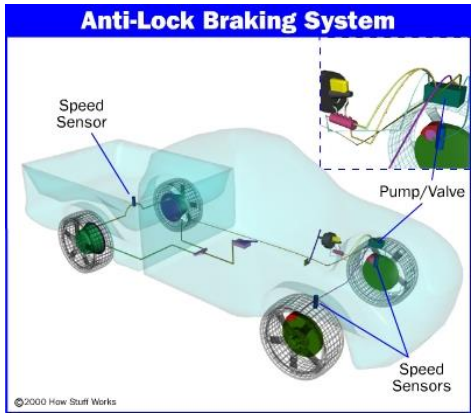
Control Design

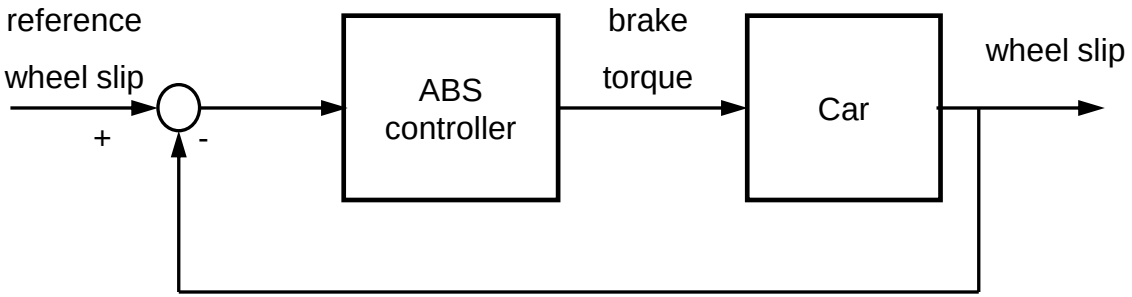


Anti-lock Brakes (ABS) control system



ABS control system





ABS control system

ABS control system

ABS control system

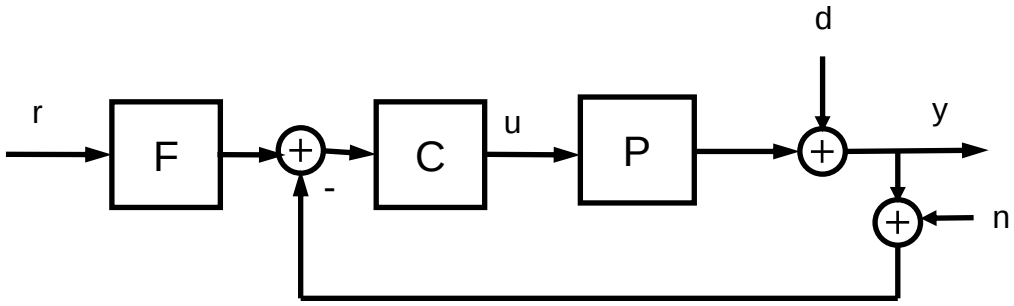
Design Issues

Targets

- Good command response
- Closed-loop stability
- Disturbance attenuation
- Robustness - despite plant changes the feedback system should maintain
  - stability
  - performance

Limitations

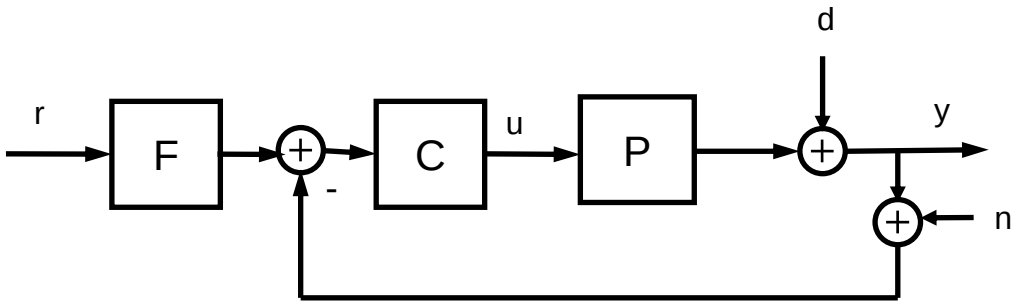
- Plant capacity
- Measurement noise



Summary

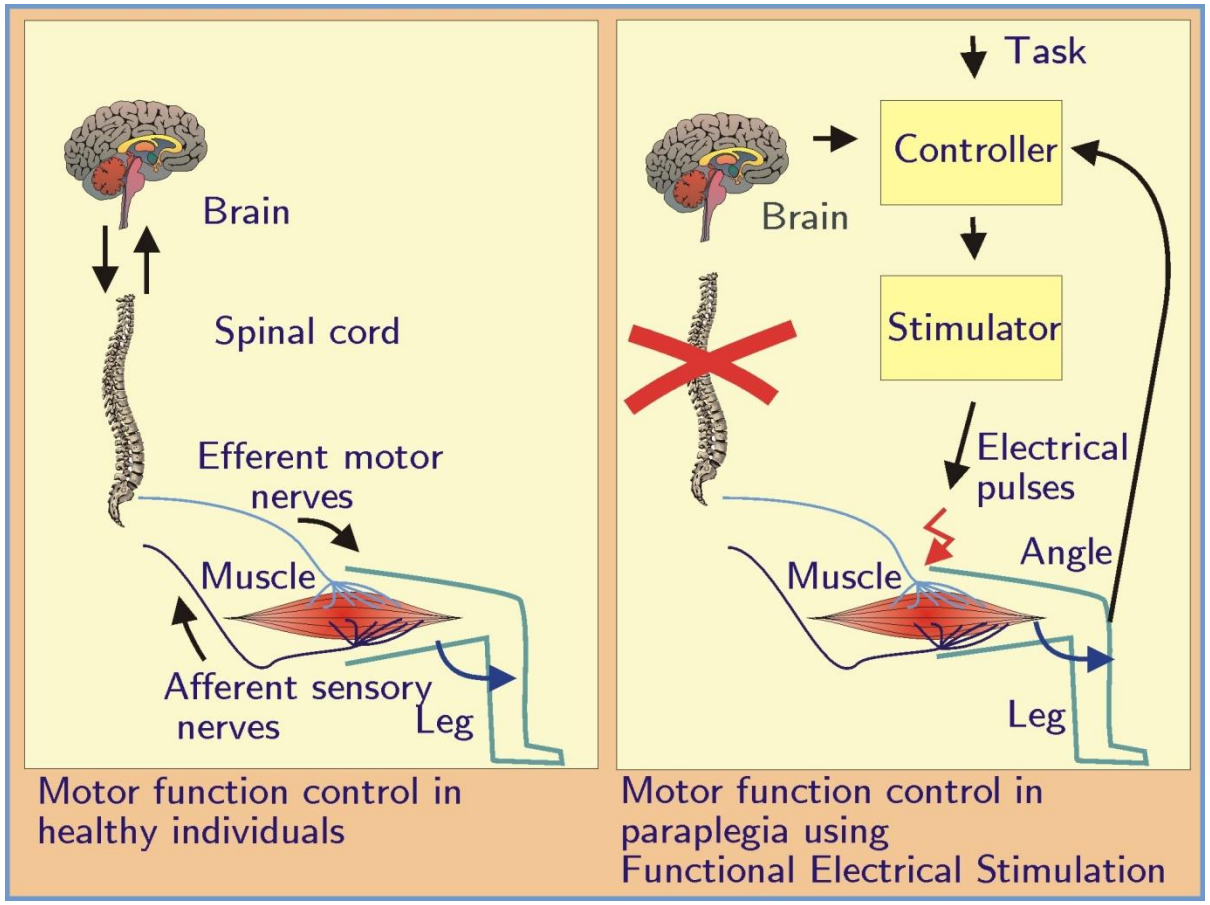
Themes

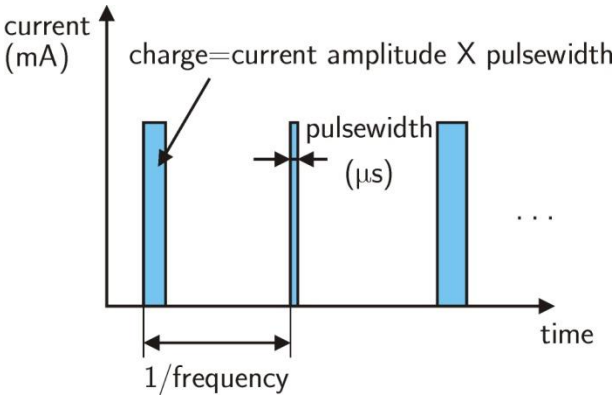
- Feedback control
- Stability
- Robustness
- Performance
  - Frequency response
  - Loop shaping



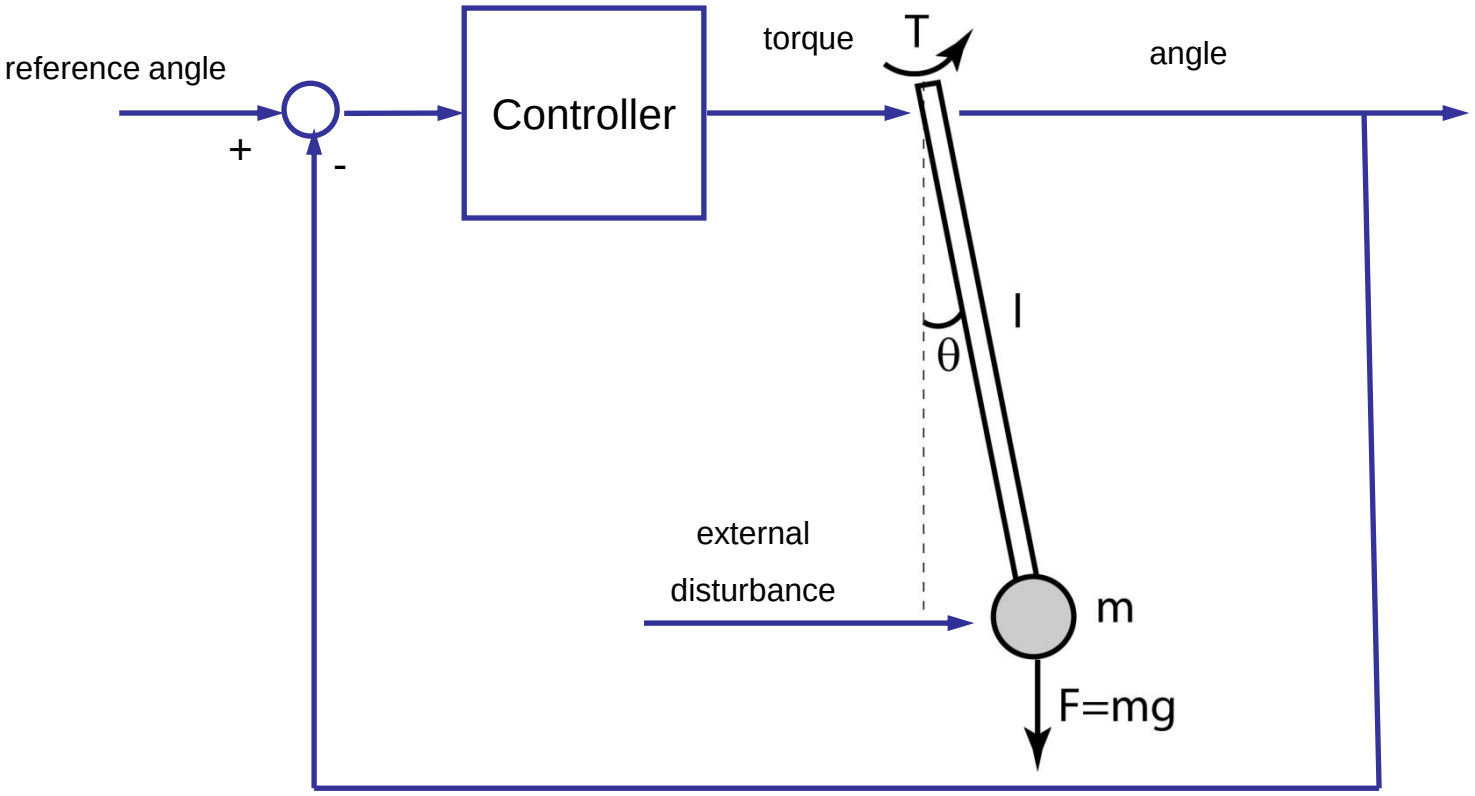
Using electrical muscle stimulation for knee-joint control in spinal cord injury

Functional Electrical Stimulation (FES)

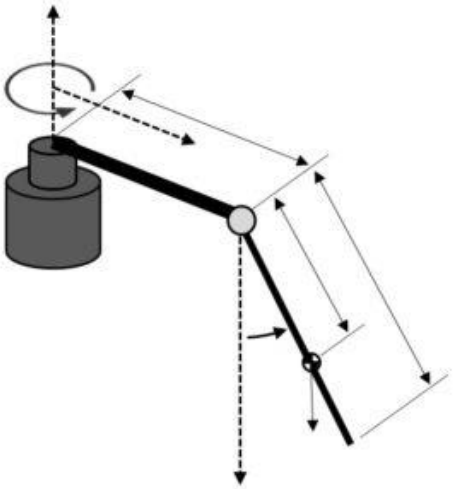




Pendulum Control System



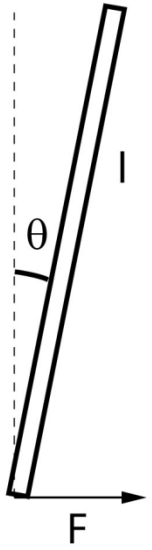
Pendulum control system: Crane control



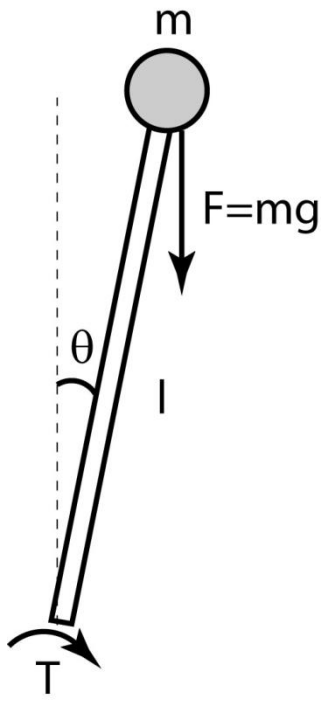
Balancing – inverted pendulum (unstable!)

Segway

Balancing a stick

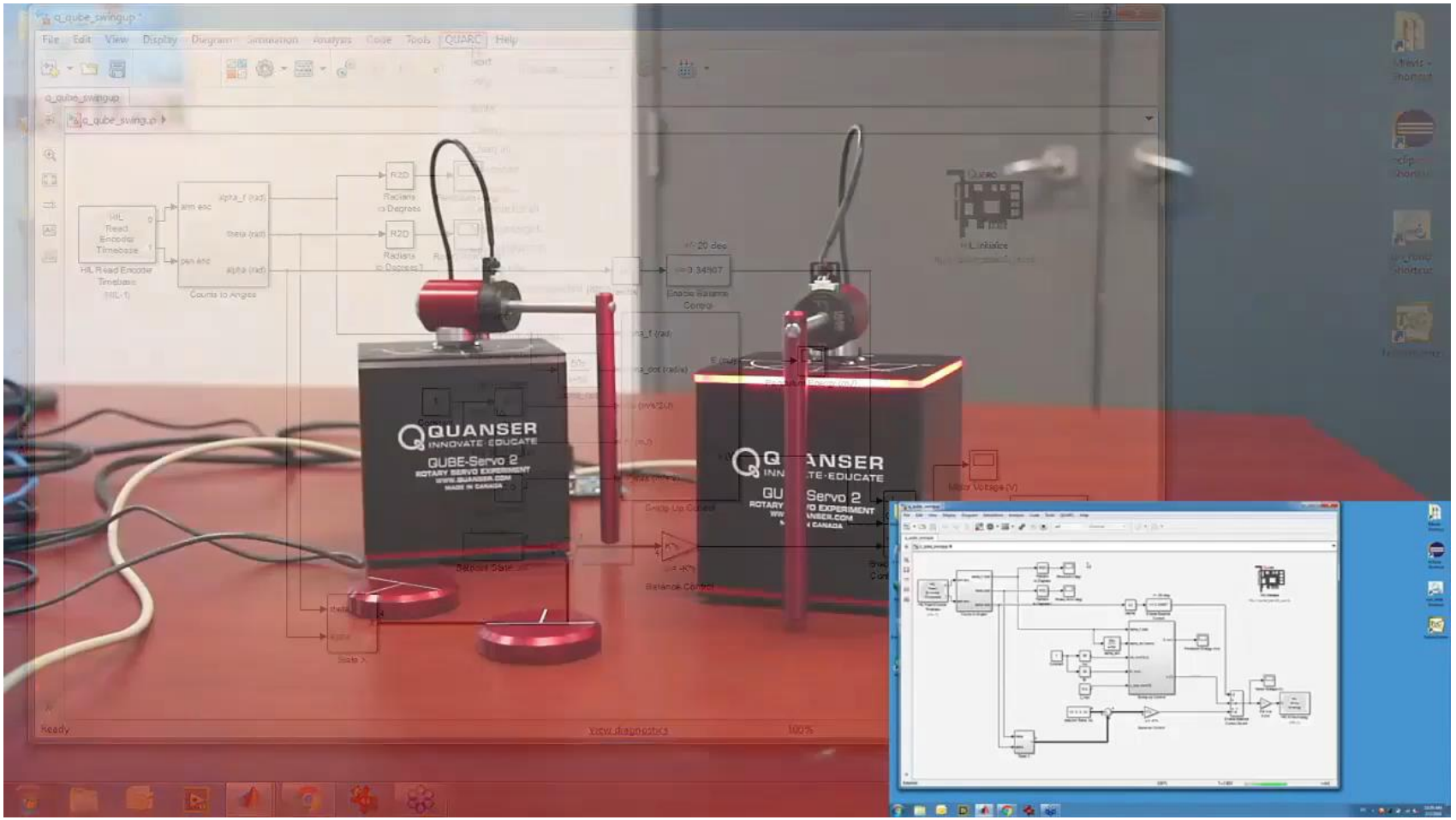


Inverted pendulum



Rotary inverted pendulum

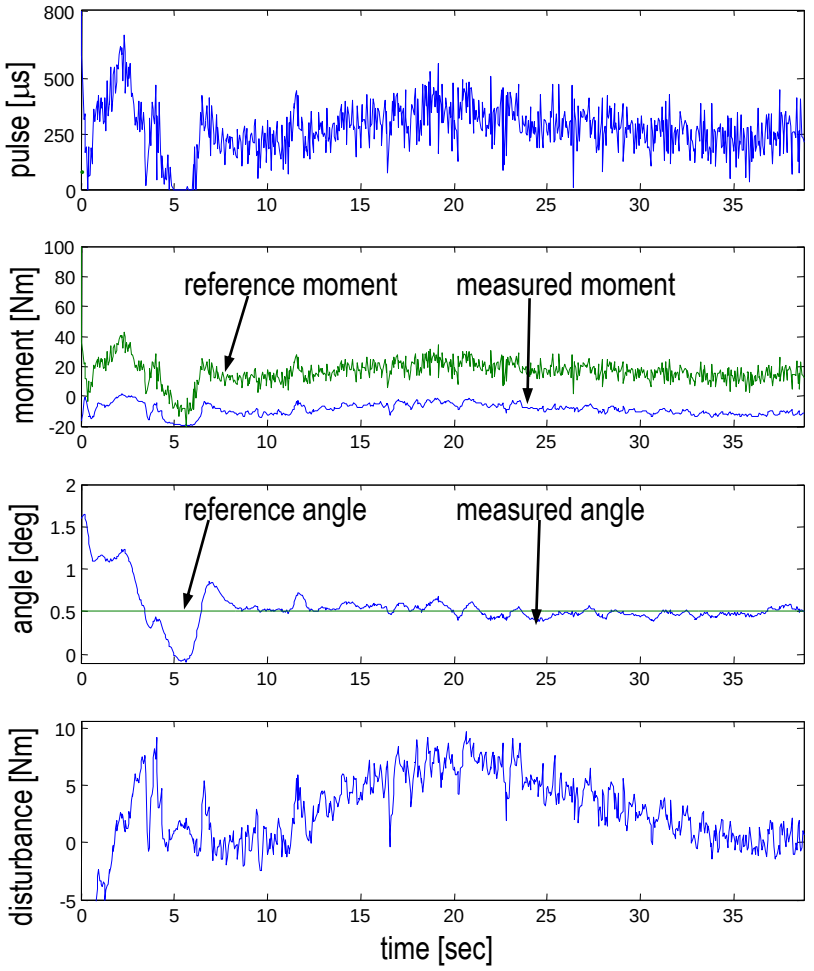
“Balancing a stick”



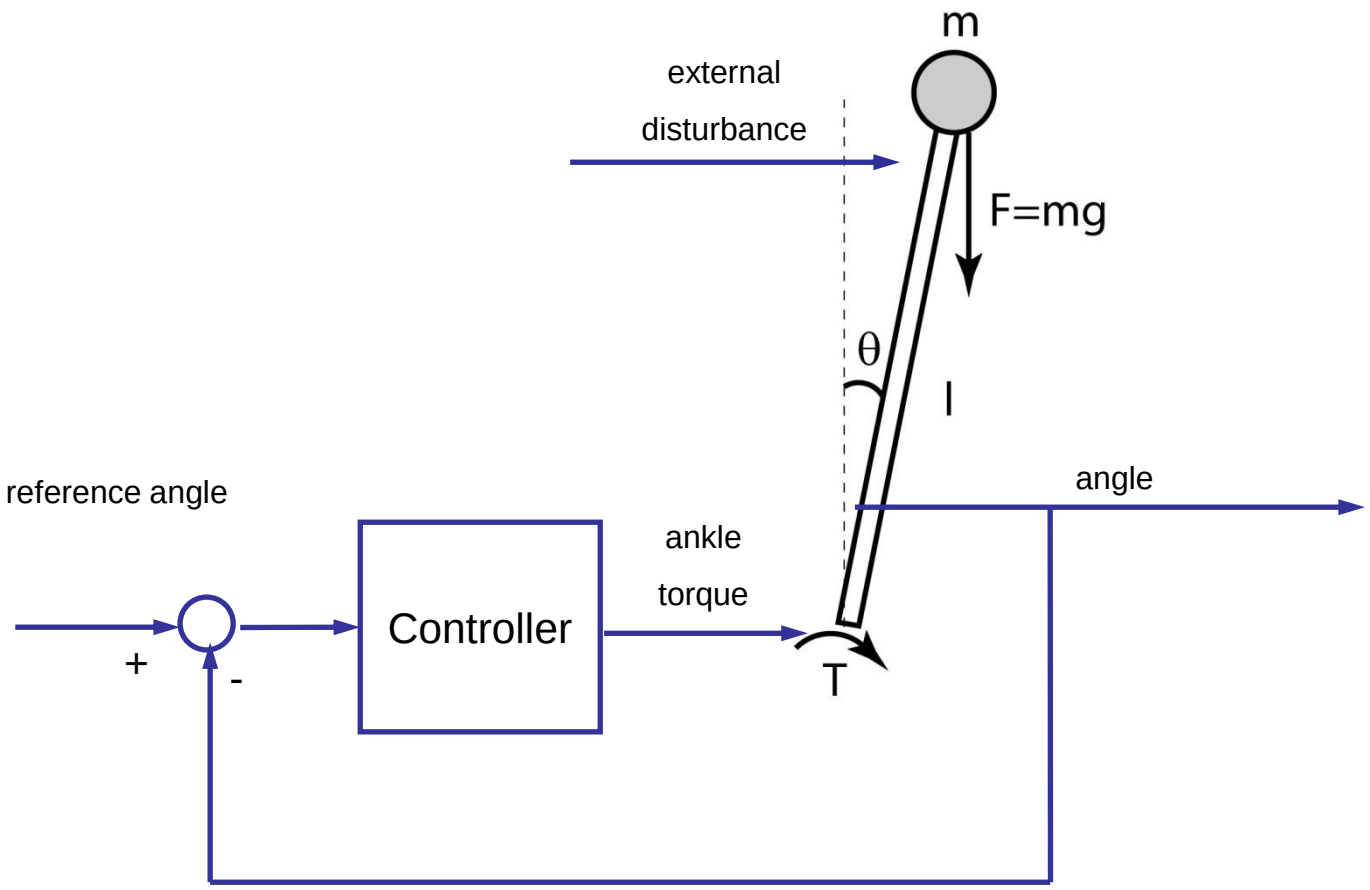
Control of Unsupported Standing

quiet standing with disturbance

Complete spinal cord injury



Balance Control System



a different kind of an inverted pendulum…

What's next?

- **Revision:** Time domain, state space and transfer function representations
  - 2^{nd} order model of a pendulum
  - Open / closed loop control

- **Part I - Classic Control:** Frequency domain analysis of feedback system
  - **Concepts**:
    - ✓ **Sensitivity** of control systems
    - ✓ **Stability** and **robustness**
    - ✓ **Design goals**
  - **Controller design**:
    - ✓ PID, root locus, pole placement,

- **Part II - Modern Control:** State space design
  - State feedback control
  - Observer design