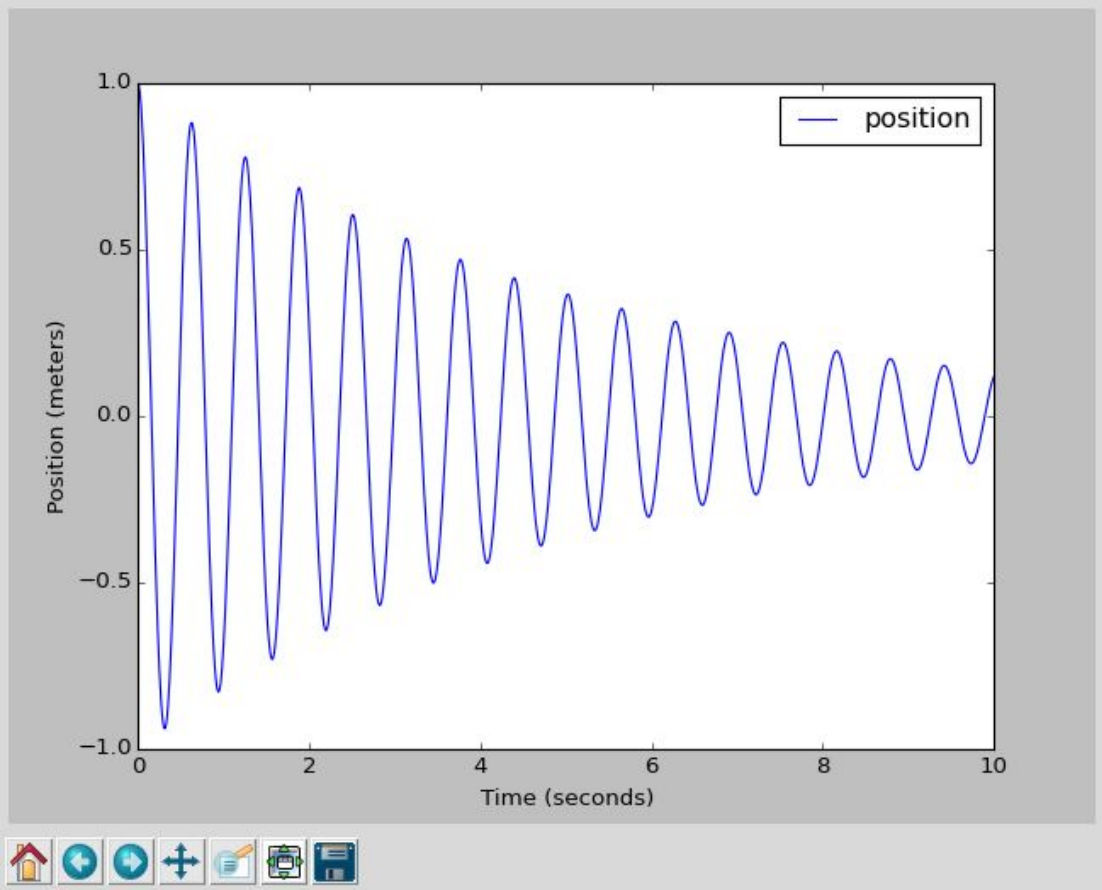
Controls 101
(Making robots dance)

Austin Schuh
Spartan Robotics (FRC Team 971)

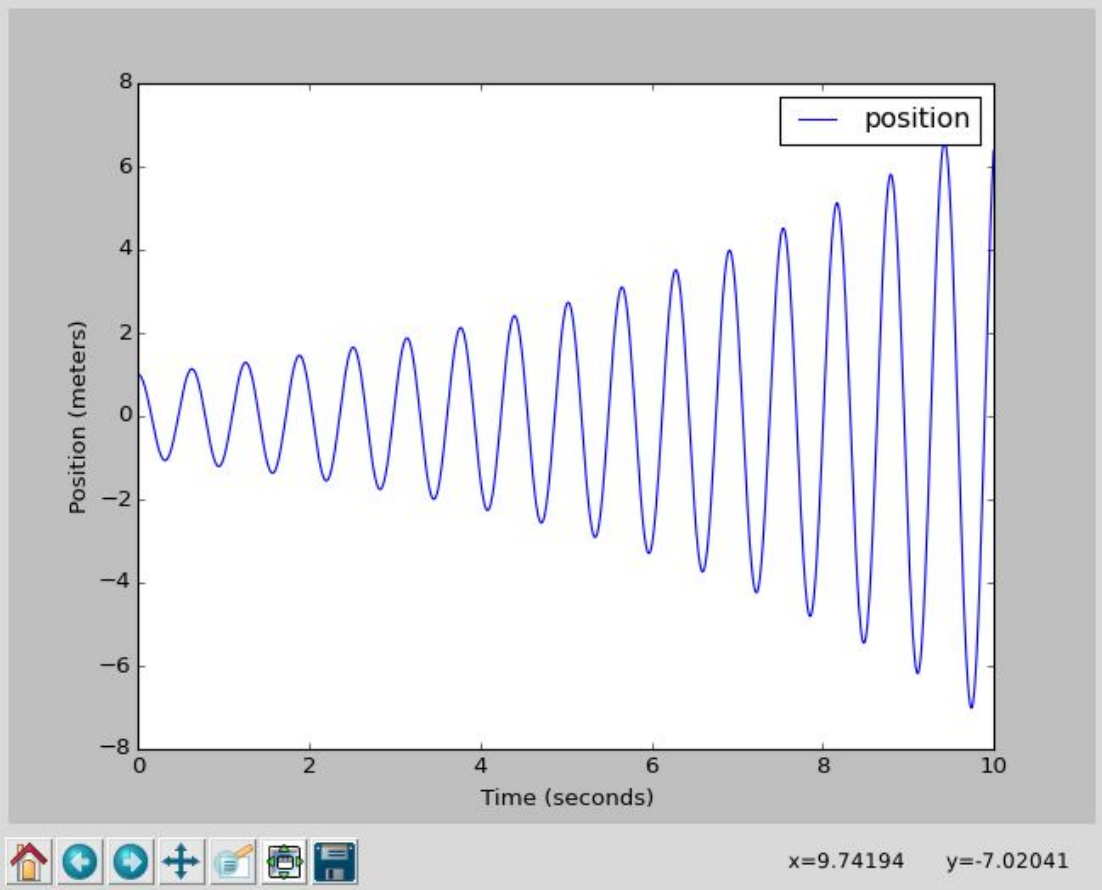
971
SPARTAN ROBOTICS

What is a control system?

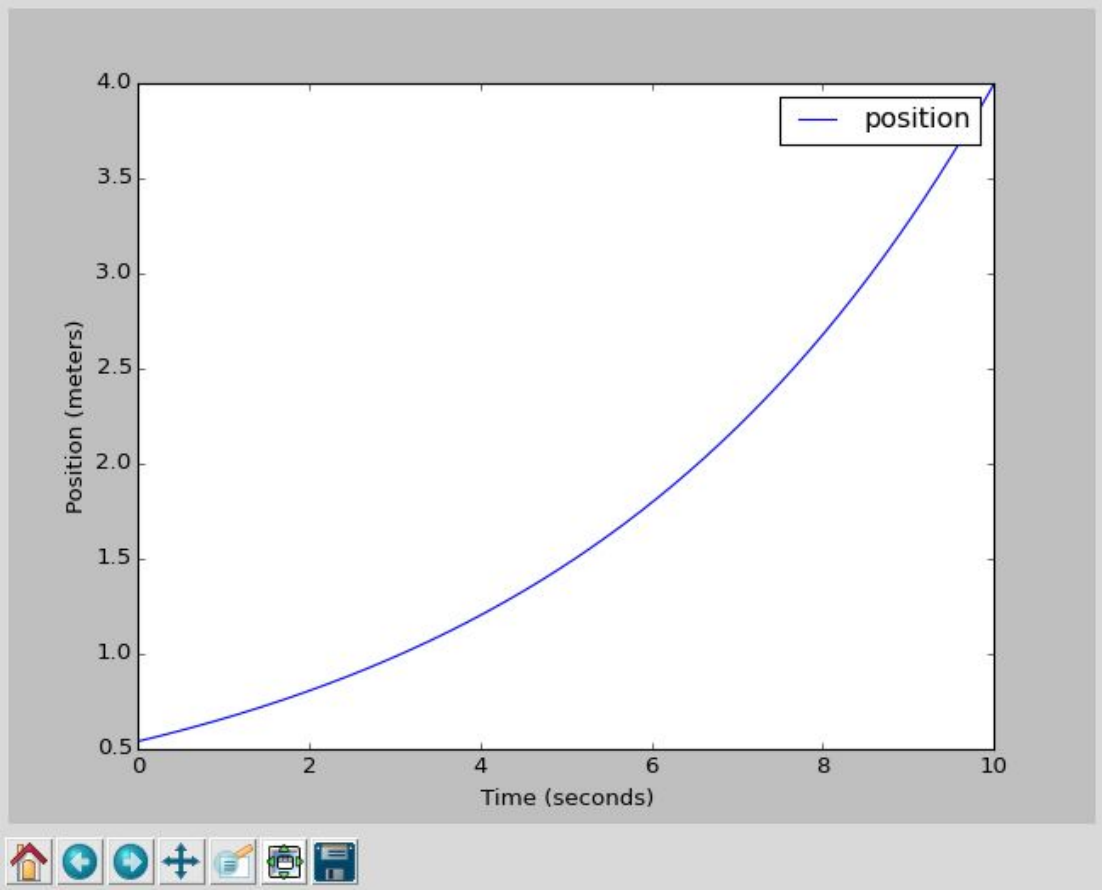
- A control system modifies your system dynamics to make them stable



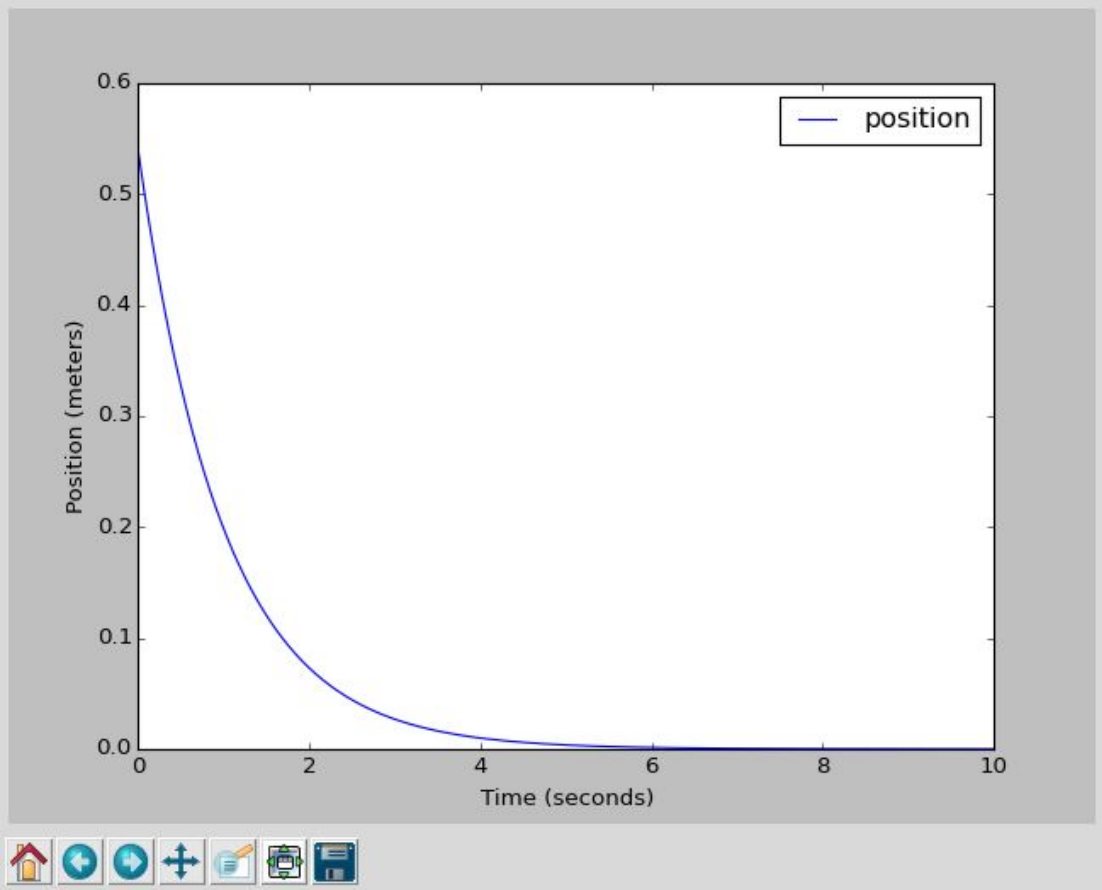
971
SPARTAN ROBOTICS



971
SPARTAN ROBOTICS



971
SPARTAN ROBOTICS



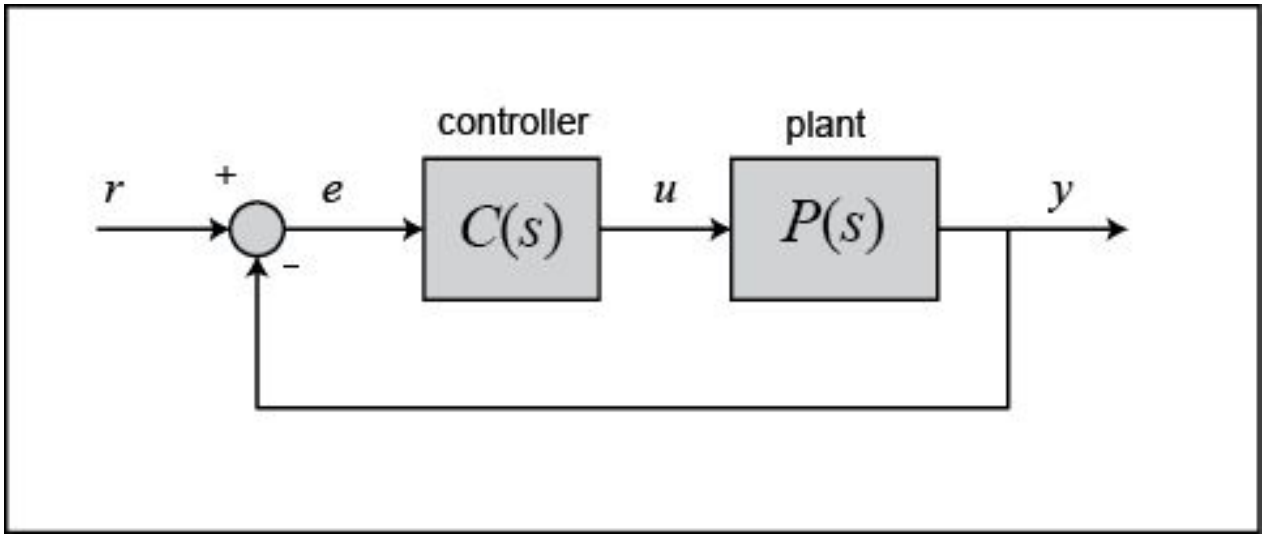
971
SPARTAN ROBOTICS

What is stability?

- A system is stable if it converges to 0

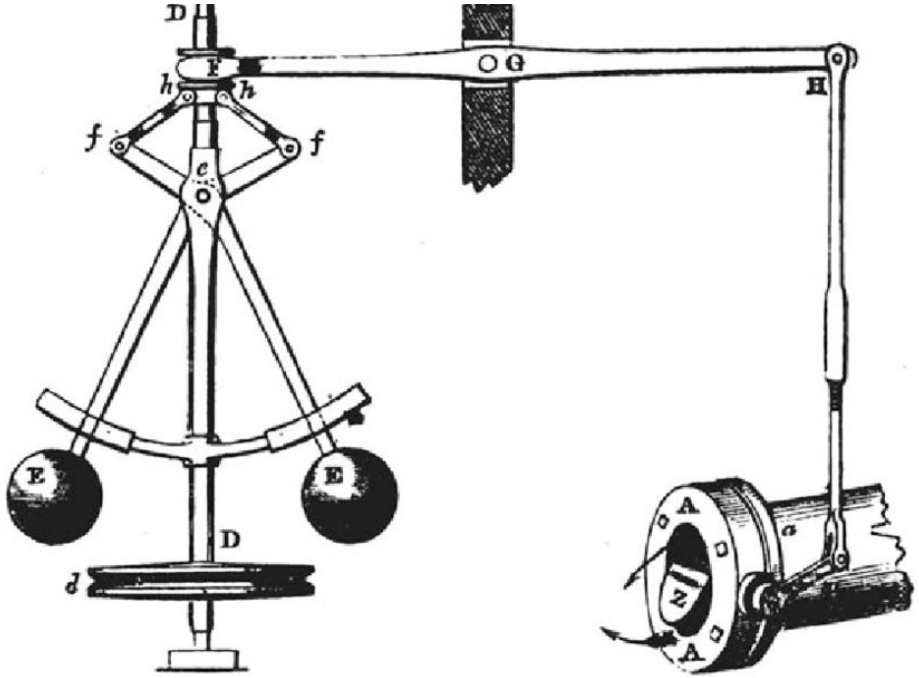
971
SPARTAN ROBOTICS

Terminology



971
SPARTAN ROBOTICS

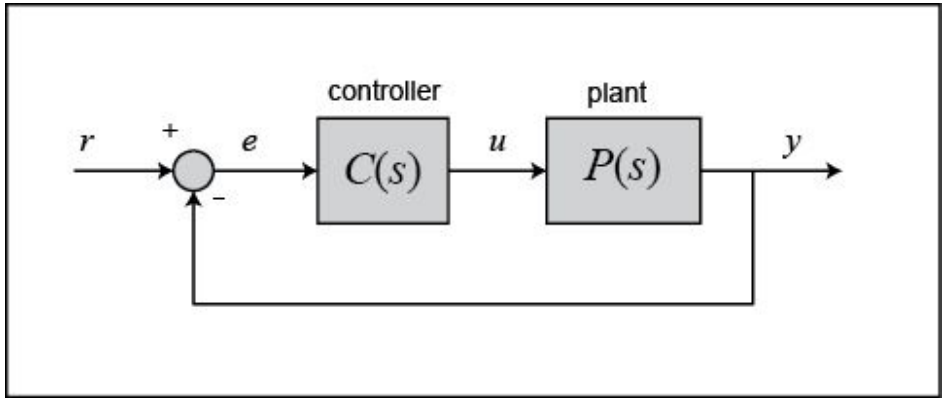
Watt's centrifigual governor for a steam engine



971
SPARTAN ROBOTICS

PID

- u(n) is our control input
- e(n) is our error

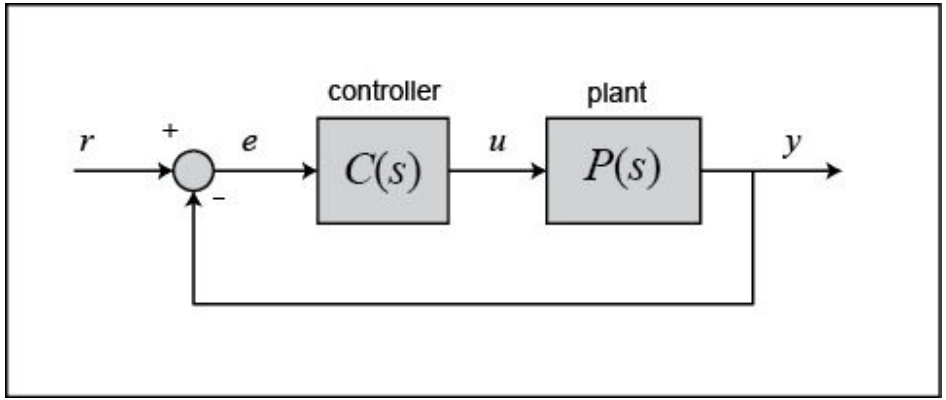


$$u(n) = K_p e(n)$$

971
SPARTAN ROBOTICS

PID

- u(n) is our control input
- e(n) is our error

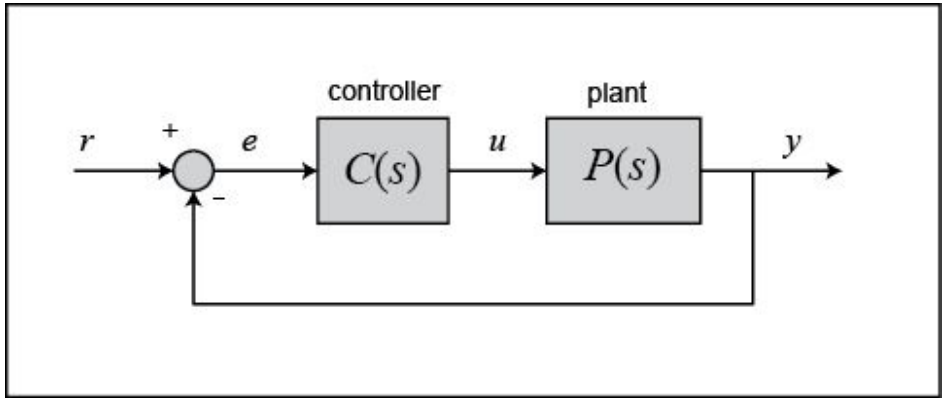


$$u(n) = K_p e(n) + K_d \frac{e(n) - e(n-1)}{\Delta t}$$

971
SPARTAN ROBOTICS

PID

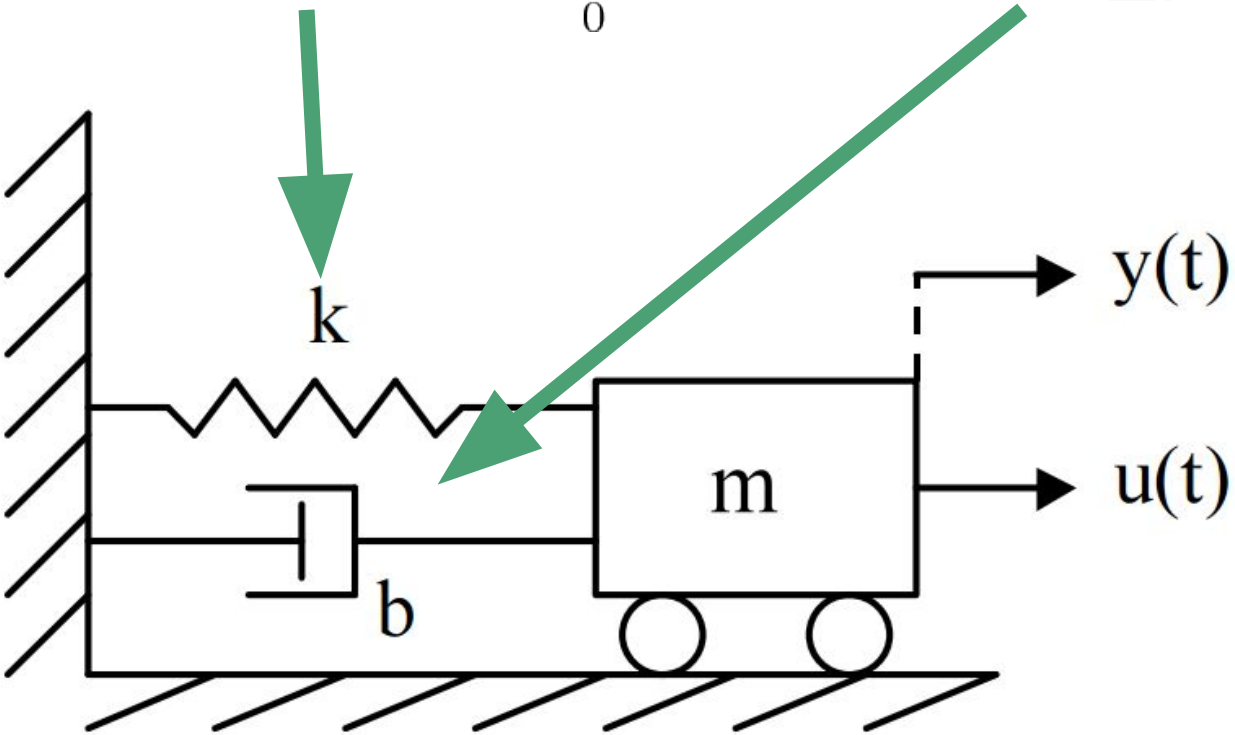
- u(n) is our control input
- e(n) is our error



$$u(n) = K_p e(n) + K_i \sum_{0}^{n} e(n) + K_d \frac{e(n) - e(n-1)}{\Delta t}$$

971
SPARTAN ROBOTICS

$$u(n) = K_p e(n) + K_i \sum_{0}^{n} e(n) + K_d \frac{e(n) - e(n-1)}{\Delta t}$$

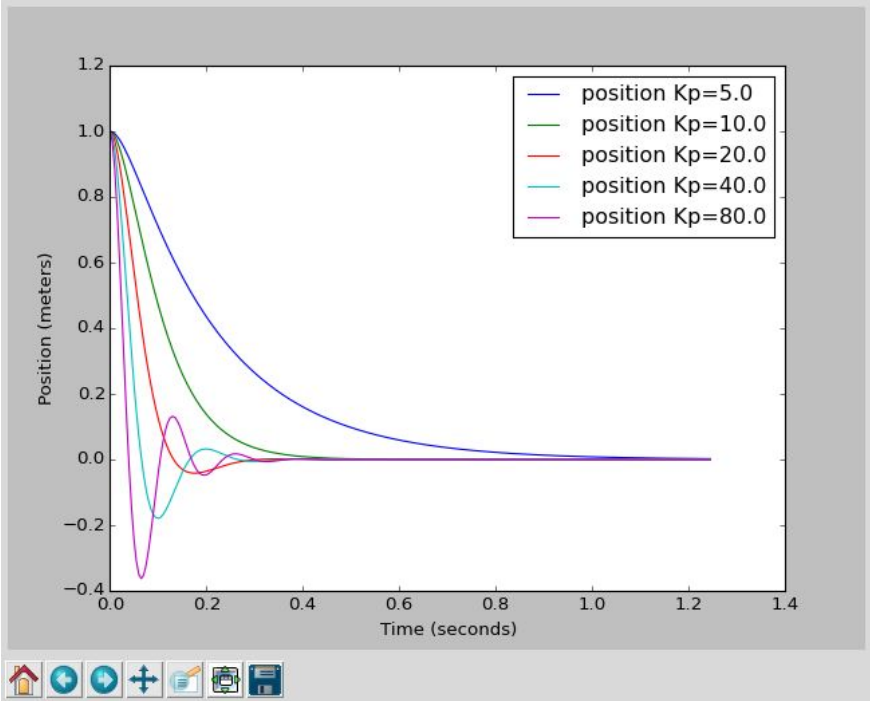


971
SPARTAN ROBOTICS

What does changing Kp do?

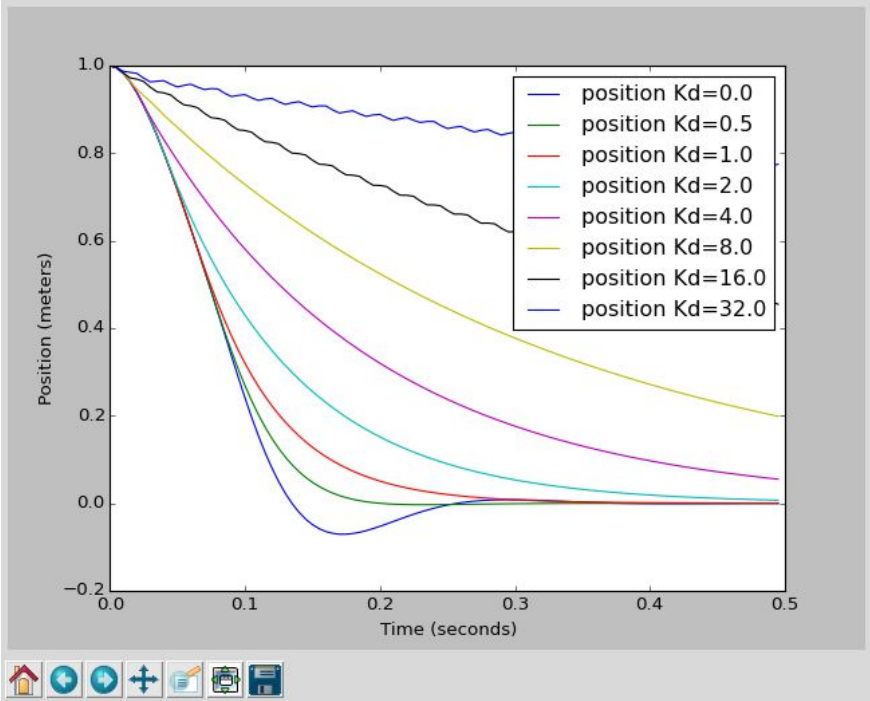
971
SPARTAN ROBOTICS

What does changing Kp do (Kd = 0) ?



971 SPARTAN ROBOTICS

What does changing Kd do (Kp = 30) ?

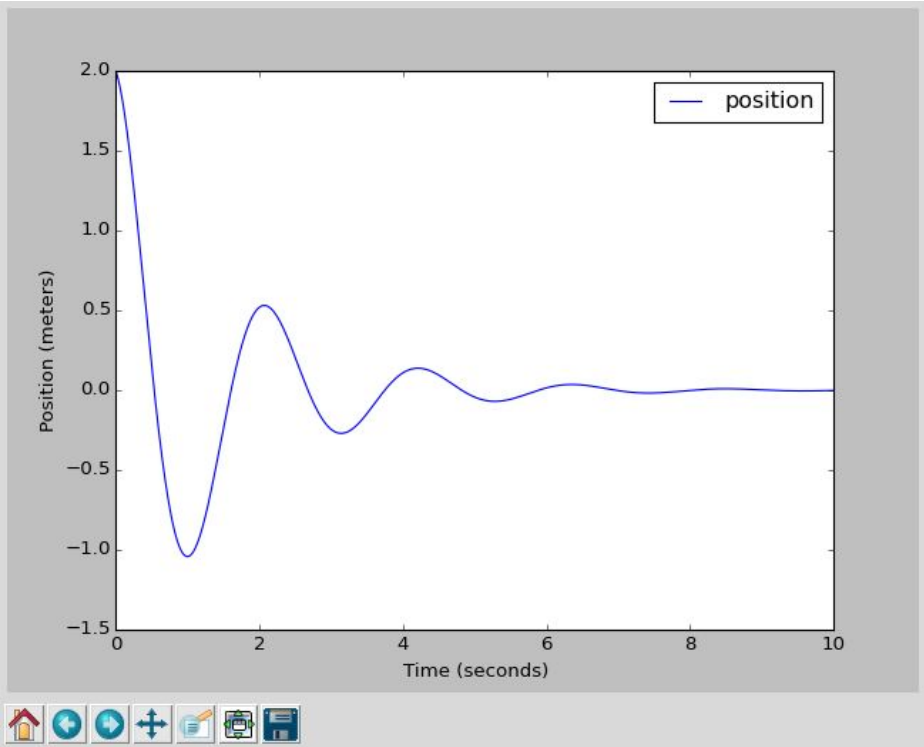


971 SPARTAN ROBOTICS

Damping ratio

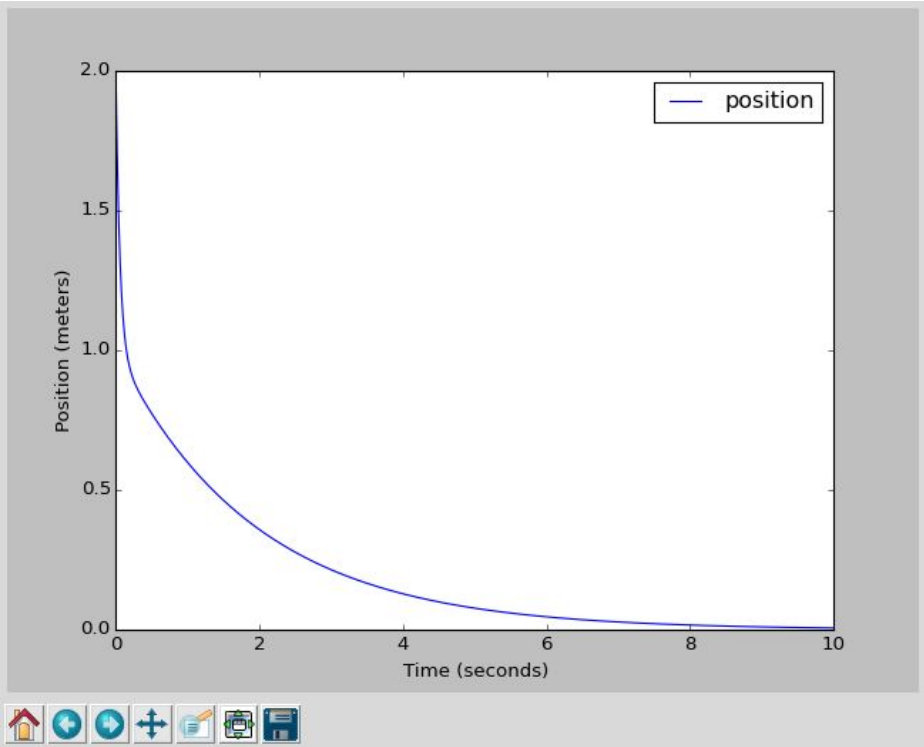
971
SPARTAN ROBOTICS

Underdamped



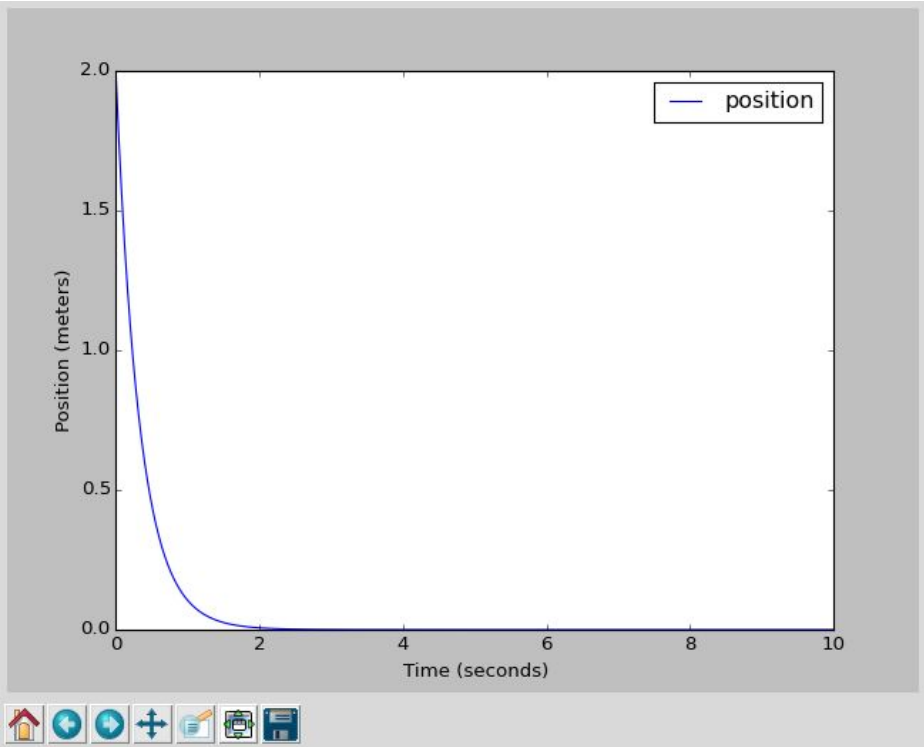
971
SPARTAN ROBOTICS

Overdamped



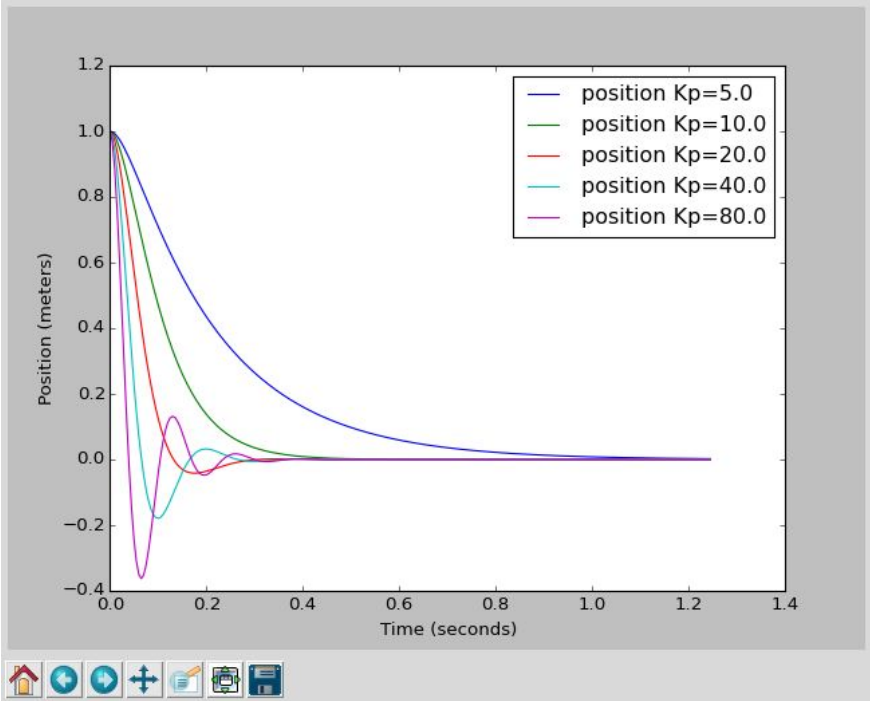
971 SPARTAN ROBOTICS

Critically Damped



971
SPARTAN ROBOTICS

Which is underdamped, overdamped?



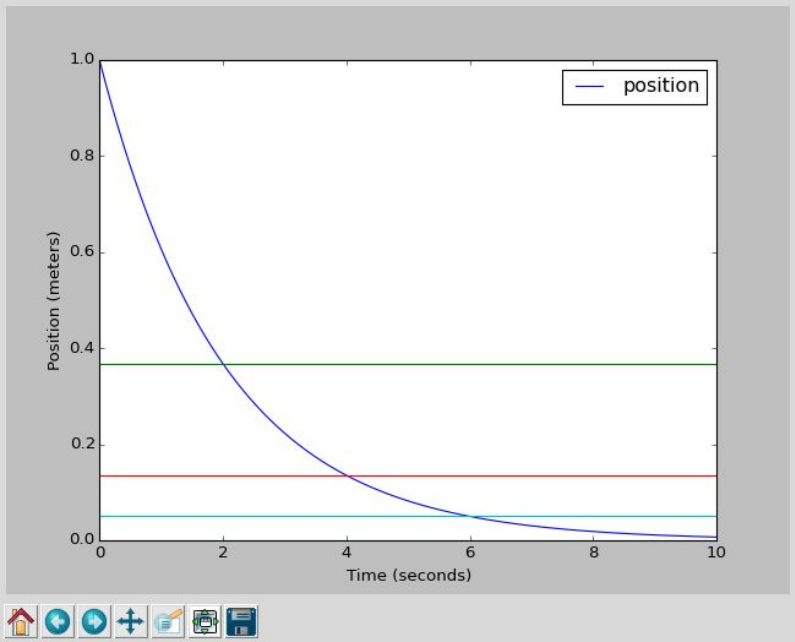
971 SPARTAN ROBOTICS

When to use integral?

- Try without it first. Just ask for a couple cm higher
- Hard to tune
- 971 doesn’t use integral unless we have to
- Only use it if your system can’t tolerate any error

More terminology

- Time constant
- Poles
- f(t) = e^(-0.5 t)



971 SPARTAN ROBOTICS

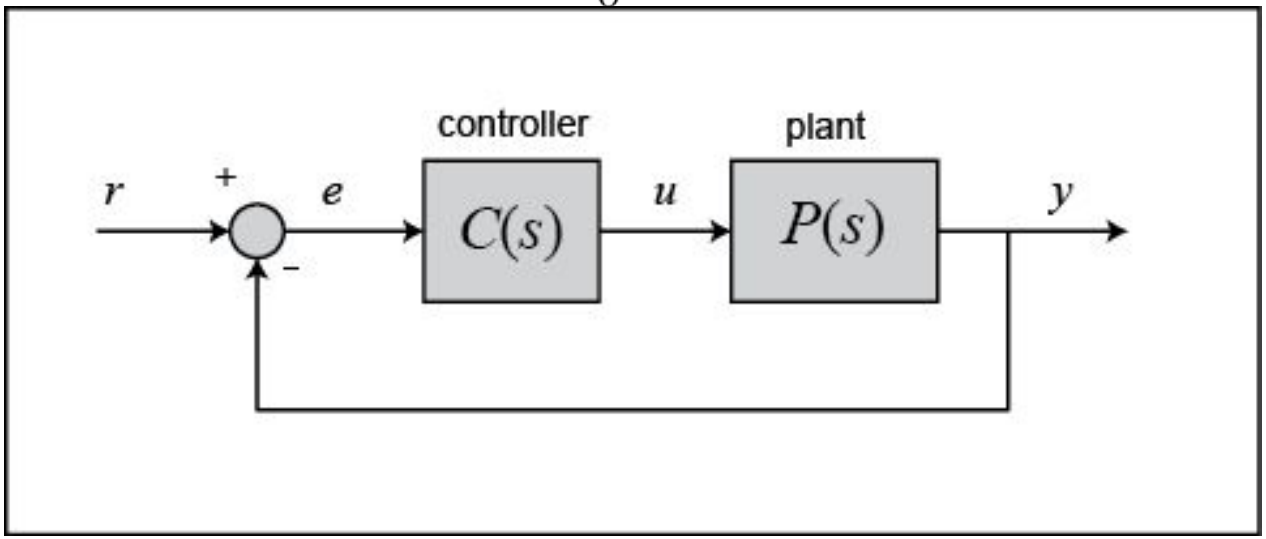
Debugging control systems

- Smart Dashboard
- CSV file and import into Excel
- High speed video from your phone

971 SPARTAN ROBOTICS

Design your software with controls in mind

$$u(n) = K_p e(n) + K_i \sum_{0}^{n} e(n) + K_d \frac{e(n) - e(n-1)}{\Delta t}$$



971
SPARTAN ROBOTICS

Build a robot you can control

- Controls is hard
- Pistons are easier to control if you have them
- Do you need all the terms?
- Do you need a control loop?
- Try it in the off-season first
    - Control your drivetrain! Hard to break

971
SPARTAN ROBOTICS

What makes something hard to control?

971
SPARTAN ROBOTICS

Poor sensors

- Can control within +- 10 “counts”
- Calculate what precision your sensors will give you before you start

971
SPARTAN ROBOTICS

Sensor choice: Potentiometer

- ADC has 12 bits -> 4096 counts.
  - ~400 positions
  - 4m elevator -> good for 1 cm
- Noisy, so derivative term will be poor
+ Easy to code, no zeroing required

Note: buy a nice one if you need it to be accurate.
Wirewound, precision pot

971 SPARTAN ROBOTICS

Sensor choice: Potentiometer + Mag encoder

+ Encoder has 12 bits -> 4096 counts per revolution
+ Encoder can give you accurate absolute position in a revolution
+ More positions, so more precision
+ Not noisy
- Hard to code, need to use pot at startup to figure out which revolution
+ Startup calibration doesn't require movement

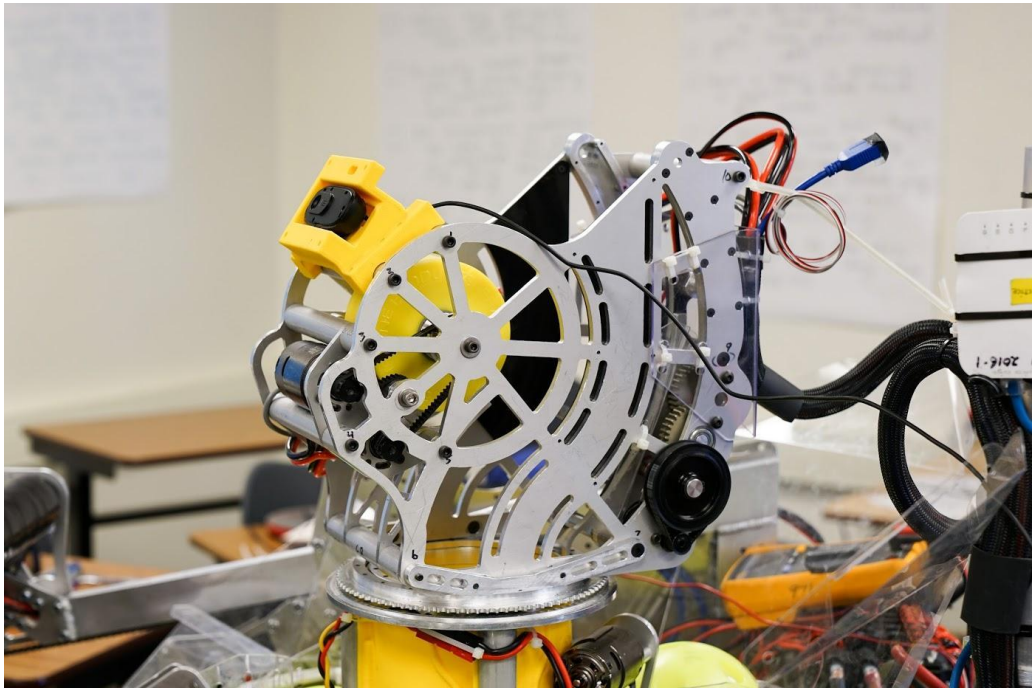
971 SPARTAN ROBOTICS

Sensor choice: Encoder + limit switch

+ Precise. Can get high counts
+ Not noisy
+ Easy to program (See my TDD workshop)
- Requires motion at startup to zero

971
SPARTAN ROBOTICS

Fast response time



971
SPARTAN ROBOTICS

971
SPARTAN ROBOTICS

Changing dynamics

971
SPARTAN ROBOTICS

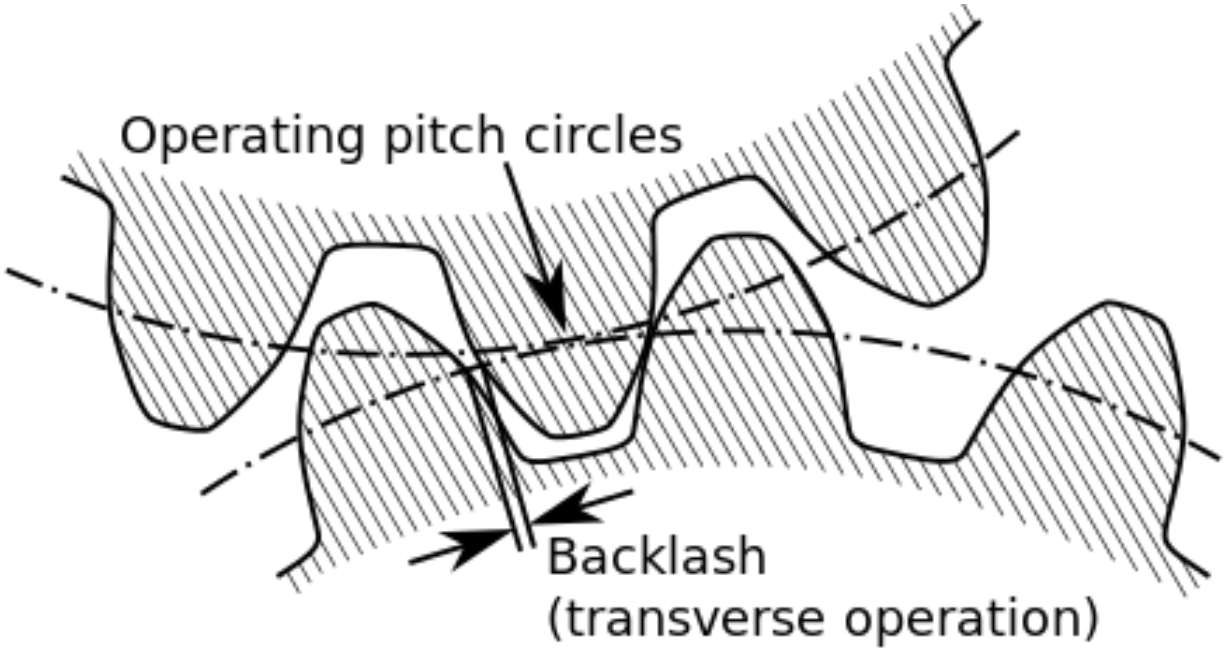

CHEZY CC CHAMPS

Changing dynamics

- Tune for the average
- Test with all variations
- Slow time constant

971
SPARTAN ROBOTICS

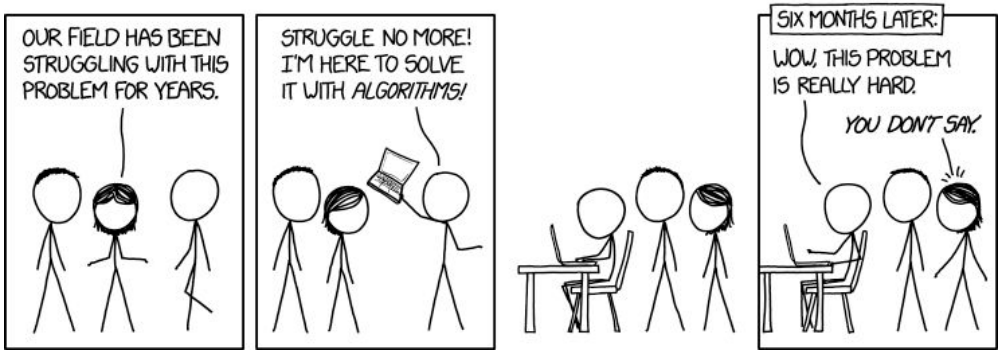
Backlash



971
SPARTAN ROBOTICS

Precision

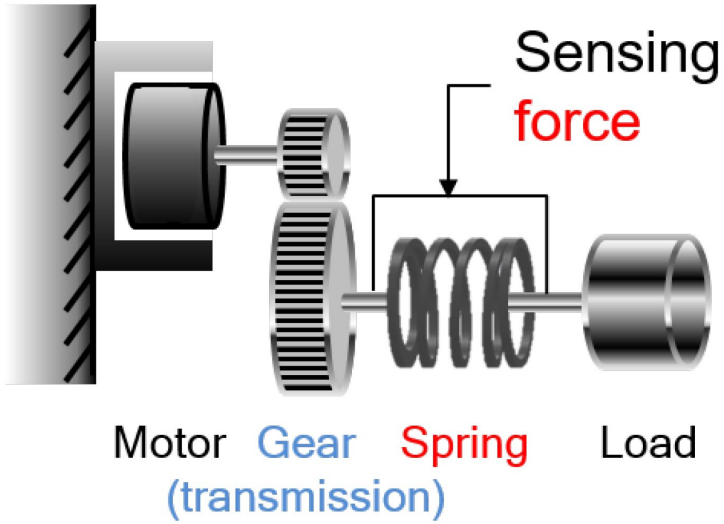
- Need good mechanical design (rigid, low backlash), sensors, and integral control.
- Will need to put your sensors in a good spot.
- Will need to trade off speed
- Can you do it another way?



971 SPARTAN ROBOTICS

Complicated Physics

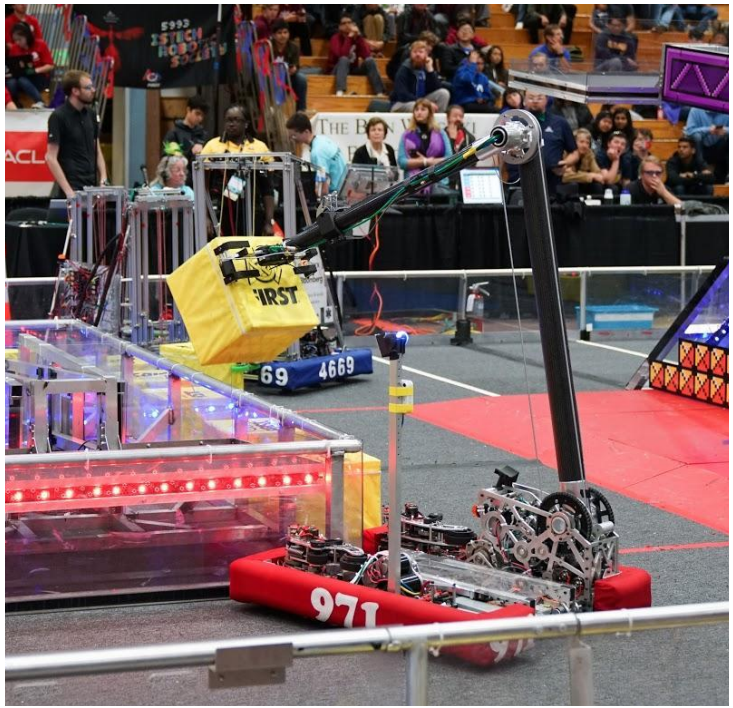
- Don’t do it!



971
SPARTAN ROBOTICS

Non-linear physics

- Don’t do it!

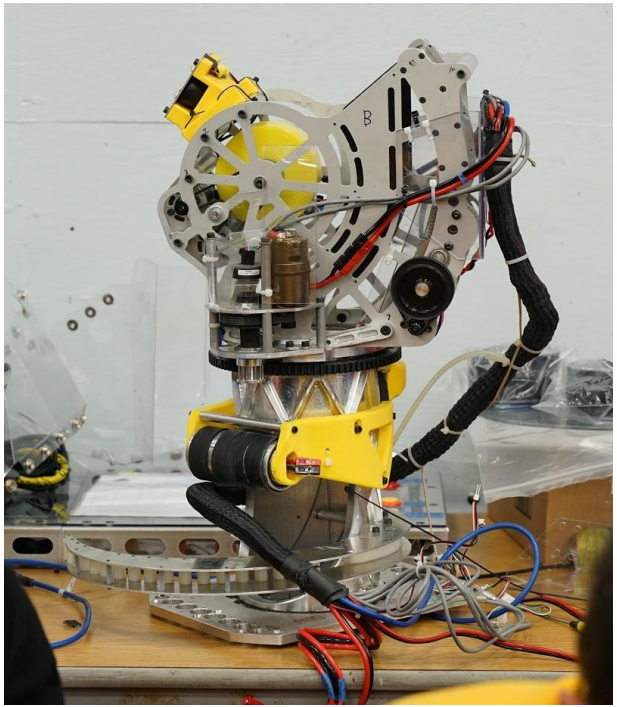


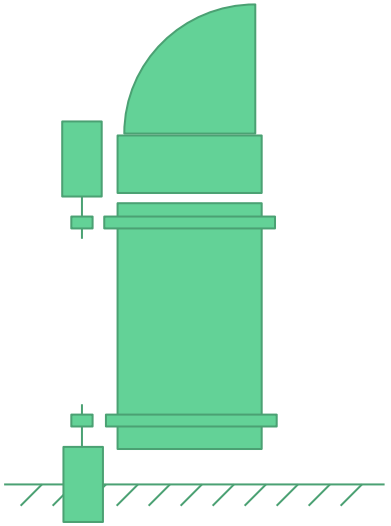
971
SPARTAN ROBOTICS


354
FIRST
POWER
UP
314
1323 254 9323
1678 971 299
10 Auto Run 15
264 Ownership 214
20 Vault 15
60 Endgame 60
0 Foul 10
Auto Quest
Face The Boss
Madtown Throwdown 2018 Red Wins Series 2-0
Playoff F-2

Multiple Input Multiple Output (MIMO)

- Don’t do it!





971 SPARTAN ROBOTICS