Control of an Inverted Pendulum

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Outline

• Motivation of project, ideas
• Theory, control method
• Complications
• Success
• Conclusion
Motivation

- Wanted to study neural networks
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- “Broomstick Balancer: An important control problem. Balancing an inverted pendulum or broomstick is an essential task in the design of battlefield robots, for example. Input can be speed and acceleration of the pendulum, output the new position of the base of the inverted pendulum”

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• Need a working apparatus before we can implement a Neural Network
• Proportional integral (PI) Method was used
Feedback Systems

Applications: **Balance**, rockets, industrial uses, chemical reactions
Our Apparatus

- Want a only a 2D problem
- Linear setup vs. rotational setup
Our Apparatus
Our Apparatus
Pendulum Physics
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Accelerating base $\rightarrow F$ on c.m. of pendulum
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$$\sum_{i} \tau_i = I \ddot{\theta}$$
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Accelerating base $\rightarrow F$ on c.m. of pendulum

$$\sum_i \tau_i = I \ddot{\theta}$$

$$I \ddot{\theta} = -rmg \sin \theta + \frac{\tau_M r}{R} \cos \theta + b \dot{\theta}$$
Control Method

\[ \ddot{\phi} = \frac{\partial \dot{\phi}}{\partial t} \approx \frac{\dot{\phi}_i - \dot{\phi}_{i-1}}{\Delta t} \]
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Ansatz: \(\ddot{\phi} = k\theta\)
Control Method

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\[ \dot{\phi}_i = \dot{\phi}_{i-1} + k\theta_i \Delta t \]
Control Method

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\[ \dot{\phi}_i = \dot{\phi}_{i-1} + k \theta_i \Delta t \]

\[ \lim_{i \to n, \Delta t \to 0} \ddot{\phi}_i = k \int_0^n \theta \, dt \]

This is why it is called the PI method
Complications

Limited motor torque
Complications

Failures at high torque demand
Complications

Digital noise
Complications

Quantized motor speeds
Complications

Quantized motor speeds
Success

Longest Trial

c = 0.07 \quad k = -8000

-10
-8
-6
-4
-2
0
2
4
6
8
10

0 20 40 60 80 100 120 140

-250
-200
-150
-100
-50
0
50
100
150
200
250

0 20 40 60 80 100 120 140
Success

Parameter Data

ave T vs. k: dt = 0.1

ave T (s) vs. k, dt=0.07

k vs T dt=0.05

ave T (s) vs. k, dt=0.03
Behavior

Falling

$k$ too low
Behavior

Overdrive

dt = 0.07, k = -12000

k too high?
Behavior

Fast Oscillations

dt = 0.03, k = -14000

k too high?
Behavior

Oscillations

dt = 0.03, k = -13000
Behavior

Just Giving Up

It’s the motor’s fault
Conclusion

- Algorithm seems to work, but not consistently
- Problems could lie in apparatus
- Need something to compare data to, simulation
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- Problems could lie in apparatus
- Need something to compare data to, simulation
- The first steps towards battlefield robots have been fun!