Project Update #2
Jared Porter, Ethan Thompson, & Mary Thompson
Draft of final report

Abstract:

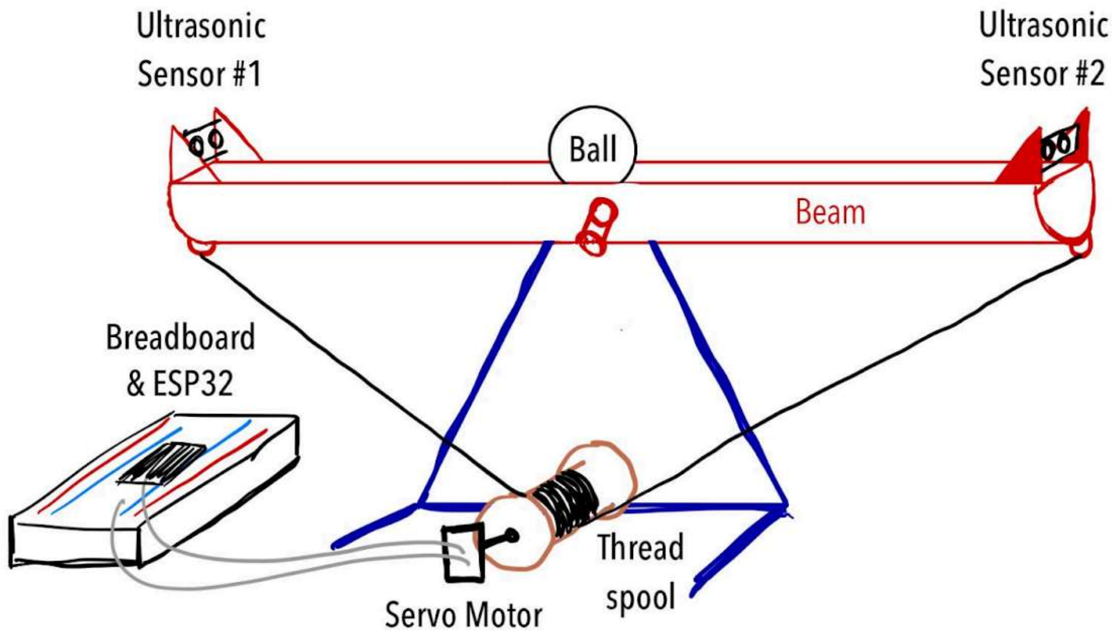
The objective of this report is to stabilize a ball along a beam using data from an ultrasonic sensor and a PID controller. The set point along the beam should be adjustable and the controller should restabilize when exposed to disturbances like flicking the ball. The actuator will be the servo motor controlling the string connected to the edges of the beam. The measurement will be the position of the ball on the beam. The controller is the PID controller created by the code

Introduction:

Literature Review

The ball-and-beam system is a foundational example in control systems, illustrating feedback principles through the challenge of maintaining the ball's position on a pivoted beam. Studies, such as Găşpăresc (2014), have demonstrated the effectiveness of Parallax Ping ultrasonic sensors in this application. PID-based ball-and-beam controllers are well-documented (e.g., Saad, 2017), the novelty of this project, however, lies in the use of spools and thread, driven by a servo motor, to control the beam's torque, offering a unique mechanical approach to actuation.

Theory:



Primary goal: maintain the ball at a desired position, stabilizing the system despite disturbances

Key variables:

There are several variables at play in this simple ball and beam case study, and they can largely be divided into three categories: constants, the process variable, and the controlled variable. The constants include things like the length of the beam and the mass and size of the ball. The measured process variable is the position of the ball, which can be used to calculate the velocity of the ball if taken in two instances. Finally, the controller output is functionally the angle of the beam, which is indirectly controlled through direct control of the angular velocity and run time of a servo motor.

Limitations

- Due to the matching frequency of the opposing ultrasonic sensors, we can only run one ultrasonic sensor at the same time, therefore they alternate taking readings every 1/20 of a second
- There is a max angle the beam can reach when correcting, additionally we set an allowed max angle of 30 degrees.
- There is noise in the ultrasonic sensor due to surroundings and measurement errors therefore the recorded location of the ball might not always be fully accurate
- Latency at high speeds, will the controller be able to respond quickly enough?
- Will the servo motor be able to create high enough torque
- The curvature of the ball prevents all ultrasonic readings from returning to the sensor, decreasing accuracy

Challenges:

- Overshoot

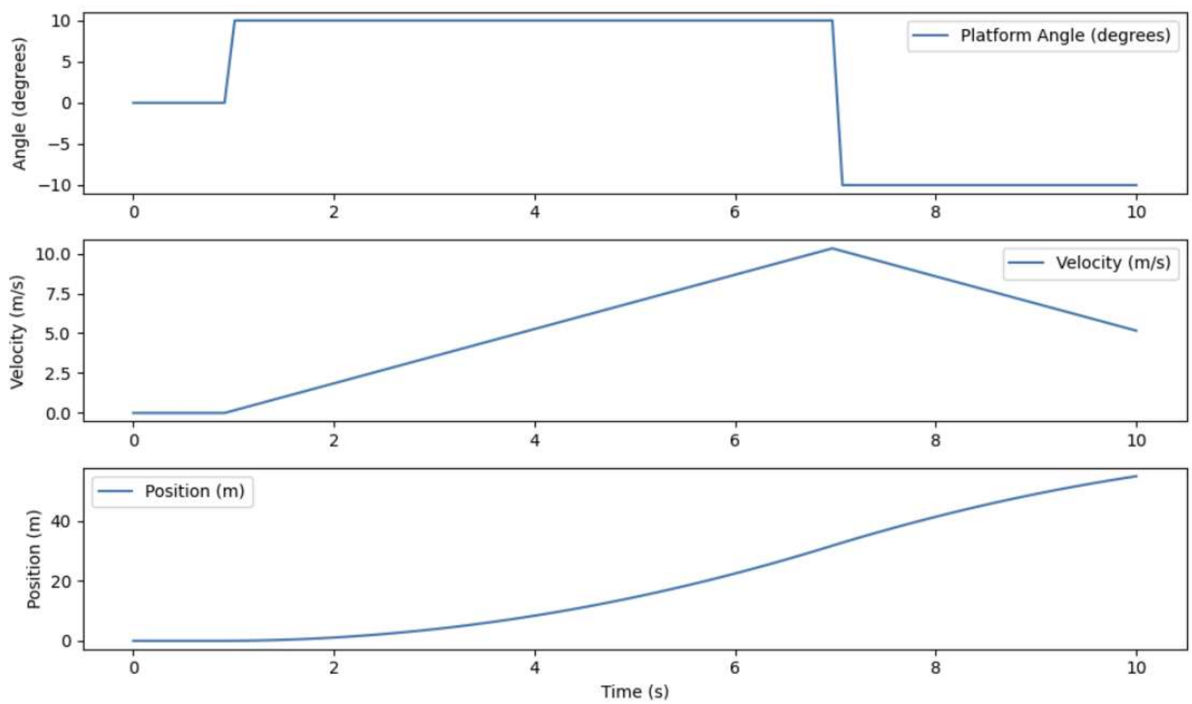
- Settling time
- delay

Discussion/Recommendations:

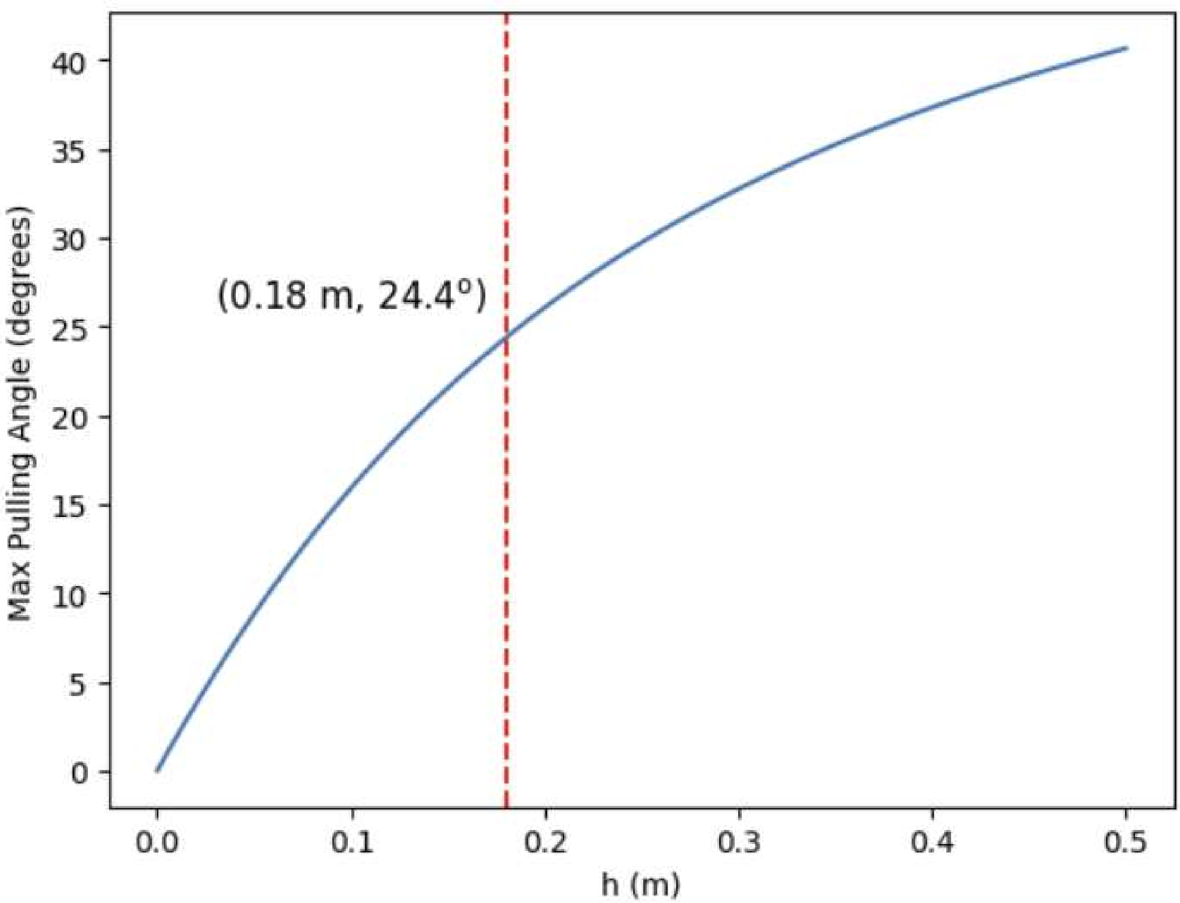
Stability analysis:
Model parameters:
controller/optimizer tuning with justification for best performance:

Servo Motor Test

```
from machine import Pin, PWM
import time

# Function to convert angle to PWM duty
def angle_to_duty(angle):
    min_duty = 26
    max_duty = 128
    return int(min_duty + (angle / 180.0) * (max_duty - min_duty))

# Setup PWM and servo
pwm_pin = Pin(17) # Change with pin configuration
servo = PWM(pwm_pin, freq=50)

# Function to set servo to a specific angle
def set_servo_angle(angle):
    duty = angle_to_duty(angle)
    servo.duty(duty)

startTime = time.time()
maxTime = 30 #seconds
currentTime = time.time()
angle = 0
while currentTime - startTime <= maxTime:
    try:
        angle += 10
        angle = angle%360
        set_servo_angle(angle)
        time.sleep(0.01)
    except KeyboardInterrupt:
        # Use Ctrl-C to end the test early
```



Platform Angle (degrees)
Angle (degrees)
Velocity (m/s)
Velocity (m/s)
Position (m)
Position (m)
Time (s)



(0.18 m, 24.4°)
Max Pulling Angle (degrees)
h (m)

Conclusion:

Consistent with objective in the introduction

Conclusions should include the main results of the study, recommendations, and any future work that could be pursued. The conclusion should address the objective