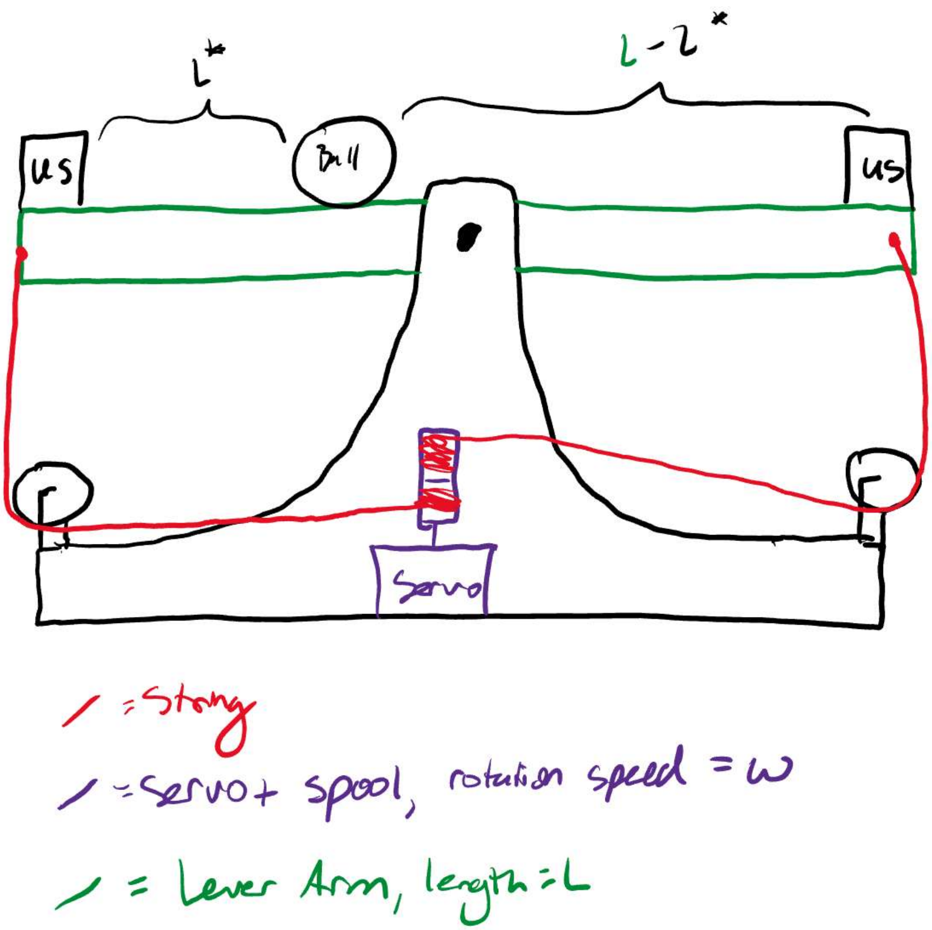
MEMORANDUM

Date: Nov. 21, 2024
To: Dr. John Hedengren
From: Jared Porter, Ethan Thompson, and Mary Thompson
Subject: Process Control Proposal

This memo provides a detailed overview of our process control project, focusing on the design, factors influencing the dynamic response, controlled variables, governing equations, potential uncertainties, and project timeline. The dynamic system we aim to control consists of a center-mounted lever arm with an inlaid trough carrying a ping-pong ball. The objective is to regulate the position of the ping-pong ball along the trough. This is achieved by adjusting the lever arm's angle using a spinning set of spools connected to a central continuous servo motor, which is managed by an ESP32 Arduino system. The position of the ping-pong ball is monitored by ultrasonic sensors mounted at either end of the lever arm, providing feedback for control.

A schematic diagram of the system with all parameters and variables labeled is provided here:



By conducting an initial literature search, we located three articles detailing systems aiming to achieve similar control. The links to these articles are provided at the end of this report.

Factors Influencing the Dynamic Outcome

Several immutable factors influence the dynamic outcome of our system. These include gravity, the length of the platform, the weight and drag of the ping pong ball, and the physical limits of movement, such as the maximum angle the trough can achieve. These parameters are inherent to the system's design and cannot be altered during the process.

In contrast, the rotational speed of the motor, which adjusts the angle of the platform, can directly influence the dynamic outcome and serves as an actuator. Additionally, the system's setpoint, which is manually adjustable, provides indirect control over the dynamic response. Both factors are adjustable and play a critical role in achieving the desired behavior.

Controlled Variable and Setpoint

The controlled variable in this system is the angle of the trough. This angle is determined by the length of the thread, which is in turn regulated by the rotational speed of the motor's central spool. Maintaining the controlled variable within a specific range is essential, as it is bounded by the motor's maximum rotation speed and the physical limits of the trough’s angle. While the setpoint remains constant during operation to allow the system to stabilize, it can be manually adjusted between runs to test different scenarios or achieve new objectives.

Dynamic Equations

The system's dynamic response is governed by several key equations. A momentum balance is required to understand how input changes, such as the angle, affect the motion of the ping pong ball along the trough. Additionally, equations are needed to translate the motor's angular velocity into the corresponding angle of the platform. These equations are essential for designing a reliable control strategy and predicting system behavior under various conditions.

Potential Uncertainties

Several factors could impact the project's success. One potential issue involves the symmetry of the rope’s length changes on either side of the trough as torque is exerted; any imbalance may complicate precise leveling of the platform. Additionally, explicitly deriving the relationship between the motor’s rotational speed and the resulting angle may prove challenging due to the system's complexity. Addressing these uncertainties will require iterative testing and refinement of both the physical system and the control algorithms.

Project Timeline and Final Deliverables

Our project timeline is outlined in a detailed Gantt chart. Currently, we are in the initial phase, focusing on collecting and designing the necessary components. We have procured the microcontroller (ESP32) and a 360° servo motor and are working on designing the base and the servo-string interface. These components are expected to be finalized by the end of Thanksgiving break.

Once the design phase is complete, the next steps involve setting up a physics-based model of the system, performing a step test to approximate relevant values, and implementing a PID controller. We aim to complete the model and step testing within a week, followed by the PID controller setup in the subsequent week. Additionally, we plan to develop an application to simulate or control the system as part of the final deliverables.

Articles Detailing Similar Systems

- **AUTOMATIC LEVELLING OF A PLATFORM TO ACHIEVE ARTIFICIAL GRAVITY**
  https://robotics.estec.esa.int/i-SAIRAS/isairas2018/Papers/Session%209b/3_Carlos_Velosa_-_Automatic_Levelling_of_ROOTLESS-36-63-Velosa-Carlos.pdf
- **An Automatic Headlamp Leveling System Based on the Vehicle Acceleration Information**
  https://www.researchgate.net/publication/365289462_An_Automatic_Headlamp_Leveling_System_Based_on_the_Vehicle_Acceleration_Information
- **Investigation of Automatic Bed Levelling System for Fused Deposition Modelling 3D Printer Machine**
  https://www.researchgate.net/publication/361451653_Investigation_of_Automatic_Bed_Levelling_System_for_Fused_Deposition_Modelling_3D_Printer_Machine