Design, Optimization, and Prototyping a Rotational Inverted Pendulum

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INTRODUCTION

In the study of feedback control systems, an inverted pendulum is among the most common examples for nonlinear systems with an unstable equilibrium. Motivated by its broad applications in both research and instruction, this project is aimed at the design of a low-cost inverted pendulum, optimized for simple fabrication via 3D printing and inexpensively available parts.

BACKGROUND

Use of Linear Time-Invariant Controllers [1]

- Linear approximation for small pendulum angle
  - $\theta \sim 0$, $\sin(\theta) \sim \theta$, $\cos(\theta) \sim 1$
- Proportional, Integral, Derivative Controller

Represents an Underactuated System [2]

- Degrees of Freedom > Actuators
- Reduced Control Effort
- Energy Savings

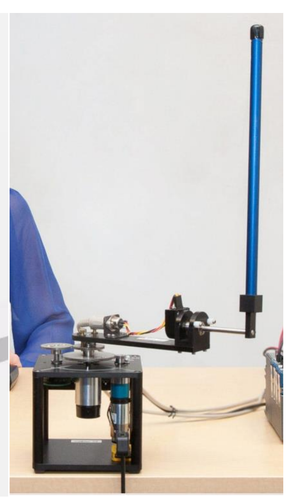
DESIGN TARGETS

- Resistance to torsion as the boom arm rotates
- Lightweight components to reduce moment of inertia
- Serviceable components
- Adjustable parameters
- 3D Printable
- Inexpensive

Existing Models

STM32 $200

Quanser $650 - $950



RESULTS

Mechanical Design

- Frustum Shape
- Interlocking Joints
- 6-piece Arm Design
- Adjustable Arm Length
- Adjustable Pendulum Length

Electrical Design

- Harness Routing
- 12V Fan Circuit
- 2 Limit Switches
- Vibration Dampening Mounts
- Emergency On/Off Switch

Total Build Cost - $378

The design of a linear time-invariant controller is currently in progress.

ACKNOWLEDGEMENTS

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[2] Duart, J. L., Montero, B., Ospina, P. A., & E González. (2017). Dynamic Modeling and Simulation of a Rotational Inverted Pendulum. *Journal of Physics Conference Series*, *792*, 012081–012081. https://doi.org/10.1088/1742-6596/792/1/012081