Fabrication and Stabilization of Rotary Inverted Pendulum Setup using a PID Controller (STRIPS 1.0)

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Abstract

This paper presents the fabrication and control of a low-cost 2DOF (degree of freedom) Rotary Inverted Pendulum setup (STRIPS 1.0), commonly known as a Furuta Pendulum. It consists of a base frame on which the arm is mounted and a pendulum link that rotates in the vertical plane. For the control of the pendulum, a Proportional-Integral and Derivative (PID) controller was implemented on the physical system. The whole setup was developed to be cost-effective. In conclusion, the system-maintained stability in the upright position. The physical system and controller design are presented in this paper.

Introduction

One of the primaries, however, fascinating problems in the field of control theory is the inverted pendulum control. It is a challenge that can be readily envisioned since everyone at one time has attempted to balance a broomstick on their hand. While the broomstick is a relatively simplistic demonstration, it highlights the inherent instability of the inverted pendulum system. The problem can be modeled as a rotary inverted pendulum in which the human arm is mimicked by a rotating link, actuated by an actuator, and the broomstick modeled as a pendulum, with control torque given to the arm link in order to stable the pendulum in an upright position.

Controller Design

The primary goal behind a control system is to find out how to provide the appropriate actuating signal or input so that our system produces the desired controlled variable or output. In feedback control, the output of the system is used as feedback and is compared to the target value. The difference between the two is referred to as an error term. If the output exactly matches the required value, the error of the system is set to zero. In this project, we utilize a PID controller for the Rotary Inverted Pendulum to drive the error term to zero.

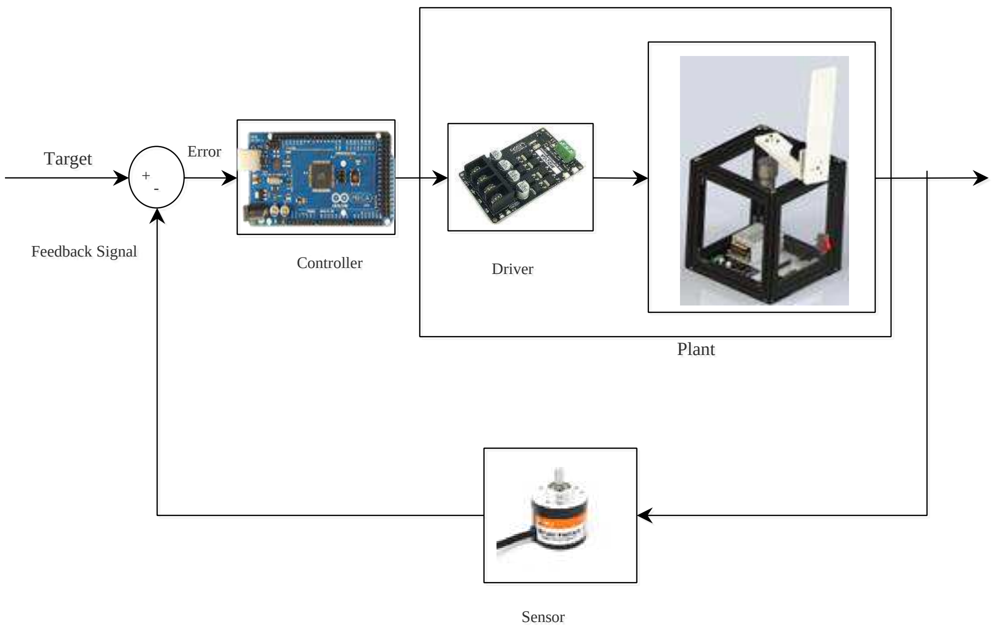

Figure 1: PID control Algorithm

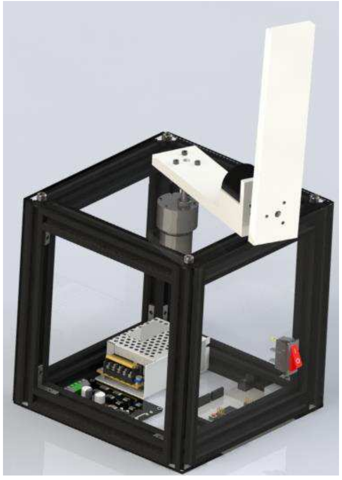

Figure 2: Final CAD model of the setup

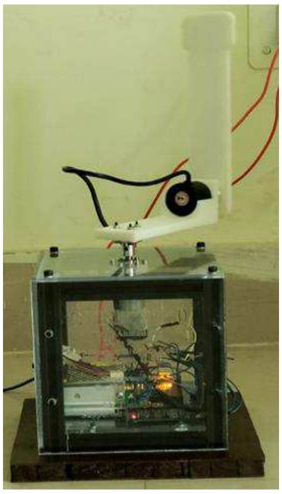

Figure 3: Completed pendulum Assembly (Controller switched on)

Experimental results

The trial begins when the pendulum link is manually placed to its upright position as the system is linear. The figure 4 depicts the pendulum link's angular position during the balancing act. It shows the experimental performance of the PID controller for 20 seconds. when the pendulum is stabilized at the upright position.The pendulum oscillates slightly (within a small range) around the upright position because of backlash present in the DC geared motor and base vibrations of the setup.

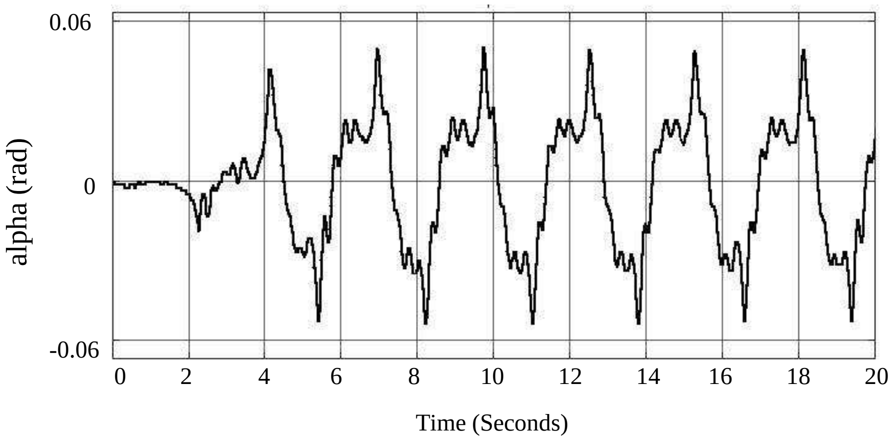

Figure 4: Angular position of Pendulum vs time

Conclusion:

The work intends to develop a cheap control system Rotary Inverted Pendulum. It would be helpful for undergraduate/graduate students to give a practical experience in experimentation setup for control courses. The novelty of the STRIPS 1.0 system is the open-source approach, which accomplishes repeatability, robustness, and low cost. This project aims to make it accessible to students in the future so that they can grasp the fundamentals and advanced aspects of control systems.

References

[3] Akhtaruzzaman, Md, and Amir Akramin Shafie. "Modeling and control of a rotary inverted pendulum using various methods, comparative assessment and result analysis." In 2010 IEEE International Conference on Mechatronics and Automation, pp. 1342-1347. IEEE, 2010.