CONTROL OF A ROTATIONAL INVERTED PENDULUM

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Introduction

The rotational inverted pendulum also known as the Furuta pendulum, consists of a two-link mechanism were a motorized arm, which can rotate in a horizontal plane, is used to control the movement of a freely attached rod[5]. The control task is to swing-up the pendulum from its natural pendant position and balance it in the unstable inverted position, using only rotational movements of the horizontal arm. In addition, it is required to park the arm at some reference angle. This renders the control task more challenging. This control problem is theoretically interesting because it is inherently open-loop unstable, and more importantly because it is non-linear and under-actuated. Consequently, it is a classical benchmark problem in control, and is widely used to illustrate and motivate various control methods. Moreover, the control issues encountered when dealing with inverted pendulums are closely related to real-life applications involving robotics and space-rocket guidance systems.

Project Objectives

- Literature review on the control of inverted pendulum systems [4], particularly focusing on the rotary inverted pendulum configuration.
- Design and implementation of a simulation model of the Furuta pendulum,
- Design and implementation of the rotational inverted pendulum physical setup.
- Design and implementation of swing-up and stabilization control strategies for this pendulum topology.
- Testing and evaluation of both the simulation and experimental results.

Project Methodologies

The following steps were carried out during the implementation of the project:

- Literature review on the dynamic modeling of the Furuta pendulum and the swing-up and stabilization algorithms for its control.
- Derivation of a suitable mathematical model for the Furuta pendulum setup [3].
- Verification and testing of published swing-up [1], [2] and stabilization algorithms, using the simulation model.
- Construction and implementation of the actual Furuta pendulum setup.
- Design and implementation of all the necessary electronics to interface the mechanical setup to the computer-based controller.
- Implementation and experimental validation of researched swing-up and stabilization algorithms on the actual rotary inverted pendulum structure.

Figure 1 – Inverted Position

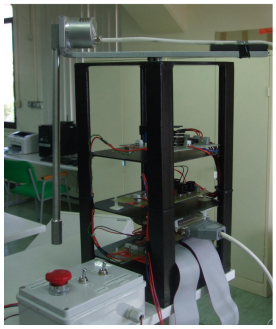

Figure 2 – Furuta Pendulum Setup

Results

The obtained results show that the controllers designed to address the task at hand function successfully; since they swing-up the pendulum and maintain it stabilized in its inverted position, with the horizontal arm homed back to a predefined position. The stabilization controller proved to be highly robust in maintaining the pendulum inverted, even when subjected to external disturbances (manually hitting the pendulum). Results also show that the control task is ultimately fulfilled for any given initial conditions.

References

[1] K.Yoshida, "Swing-up control of an inverted pendulum by energy-based methods," proceedings of the American control conference, pp.4045-4047,1999.

[2]K.J. Åström and K.Furuta, "Swinging up a pendulum by energy control," presented at 13th IFAC world congress,1996.

[3]M.Gäfvert, "Modeling the Furuta Pendulum," Department of Automatic Control, Lund Institute of Technology,1998.

[4]M.Bugeja, "Non-linear swing-up and stabilizing control of an inverted pendulum system." , May 2002,http://www.eng.um.edu.mt/~sgfabr/bugeja.html.

[5] http://www.control.tfe.umu.se/Set_Ups/Furuta_Pendulum/Furuta_Pendulum_info.html