

Integration Project Systems and Control (SC42035)

Inverted Pendulum Experiment

Description

The inverted pendulum setup consists of a cart driven by a DC motor. The motor can steer the cart left and right on a track approximately one meter long. On the cart, a pendulum is mounted such that it can freely rotate around an axis that is perpendicular to the direction of motion of the cart. The objective is to control the motion of the cart such that the pendulum is balanced in its upright position. The schematic diagram in Figure 1 shows the construction of the system including all the relevant parameters and variables. Positive directions of variables are indicated by arrows.

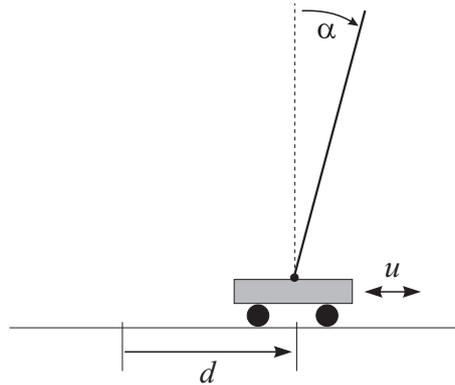


Figure 1: Schematic drawing of the inverted pendulum.

This system has one control input u , which is the voltage driving the cart motor. This input is commanded from the computer and is scaled between -1 (corresponds to the maximal input moving the cart to the left) and +1 (corresponds to the maximal input moving the cart to the right). There are two measured outputs: d – the displacement of the cart from the track center, and α – the angle of the pendulum. These measurements are given in their physical units – meters and radians, respectively. The physical parameters of the system are listed in Table 1. Most of the values can easily be determined by measuring the dimensions and masses (such as the pendulum length, mass of the cart, etc.).

Table 1: Physical parameters and their values.

Symbol	Parameter	Value
l	half length of pendulum	0.30 m
m	mass of pendulum	85 or 210 g
J	inertia of pendulum	$\frac{1}{3}ml^2$
M	mass of cart	0.49 kg

Control Objective

Design a controller that makes the cart follow a specified reference trajectory for d while balancing the pendulum. The controlled system should have zero steady state error in d and adequate disturbance rejection properties, i.e., it should be able to recover from a small tick against the pendulum.

Simulink Template

A Simulink template `pendtemplate.slx` contains the necessary real-time interface blocks and some scopes. Make your own copy of this file and use it as a starting point for your experiments. Before starting the first simulation, define the sampling period h as a variable in the workspace of MATLAB.

Start-up Procedure

First move the cart by hand to the rightmost position (gearwheel above gap in track) and hold it there while switching the box on. Run `calib.m` to calibrate the sensors (needs to be done every time you switch on the system).