Integration Project Systems and Control (SC42035)
Rotational Pendulum Experiment (II)

Description

The rotational pendulum is in fact a two-link rigid manipulator operating in a vertical plane. The first (lower) joint, is actuated by a torque introduced by a DC motor. The second (upper) joint is free to rotate. Both links (arms) can rotate the full 360 degrees. The objective is to control the motor such that the joints are stabilized at some desired angles. The easiest task is to control the links around the stable equilibrium (both links down). More difficult tasks are when the second link is in its unstable equilibrium (pointing upward). The schematic diagram in Figure 1 shows on the left a photograph of the setup to which this description applies and on the right a schematic drawing with the relevant parameters and variables. Positive directions of variables are indicated by arrows.
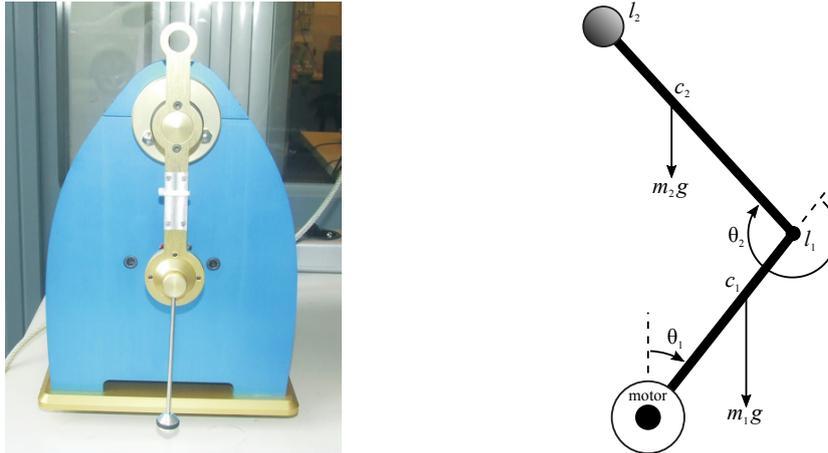
Figure 1: Photograph and schematic drawing of the rotational pendulum.

This system has one control input u, which is the voltage applied to the motor which in turn delivers a torque that accelerates the lower link. This input is commanded from the computer and is scaled between -1 and +1 (corresponding to the maximal voltage moving the lower link clockwise and counter-clockwise). There are two measured outputs: θ_1 – the angle of the lower joint, and θ_2 – the angle between the lower and upper joint. These measured values are given in radians. The physical parameters of the system are listed in Table 1. Note that these are approximate values and may not be entirely correct for your specific setup. Keep this in mind when designing identification experiments and methods.

Table 1: Physical parameters and their values.

Symbol	Parameter	Value
l_1	length of first link	0.1 m
l_2	length of second link	0.1 m
m_1	mass of first link	0.18 kg
m_2	mass of second link	0.06 kg
c_1	center of mass of first link	0.06 m
c_2	center of mass of second link	0.045 m
I_1	inertia of first link	0.037 kgm^2
I_2	inertia of second link	0.00011 kgm^2

Control Objective

Design a controller that makes the angle of first link θ_1 follow a specified reference trajectory while stabilizing the second link in the upright position. It is easier to start with the stable equilibrium (both links down) and just make a controller to damp the swing (like an overhead crane). The controlled system should have zero steady state error in θ_1 (small oscillations around the reference are permitted, as these are caused by Coulomb friction and stiction and are difficult to avoid when using linear control only) and adequate disturbance rejection properties, i.e., it should be able to recover from a small tick against the link.

Simulink Template

A Simulink template rpendtemplate.mdl 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.