Control Systems Lab (SC4070)
Container Crane Experiment

Description

Figure 1 shows a schematic drawing of an overhead crane. A trolley with mass M is driven by a DC motor with input u such that it travels in the lateral direction on a rail. The trolley carries a container of mass m. The container is attached to the trolley by a cable of variable length l. A second DC motor drives the hoist system.

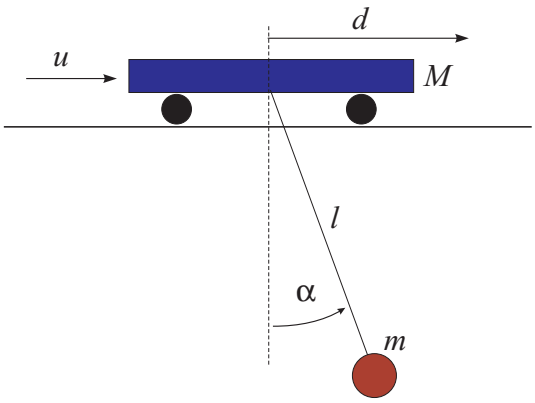

Figure 1: A schematic diagram of the container crane.

This system has one control input u, which is the input to the motor amplifier. This input is commanded from the computer and is scaled between -1 and +1. There are three measured outputs: d – the position of the trolley, α – the angle between the cable and the vertical and l – the cable length. These measured variables are given in their corresponding physical units.

Control Objective

Design an anti-sway controller. The controlled system should be able to quickly follow a reference for the trolley position (given by the joystick or using a predefined signal), while minimizing the container swing. You can start with a constant cable length and, if time permits, design also a controller for the cable length.

Physical Modeling

Simplified nonlinear equations for the trolley and container dynamics are given below. They can be derived by using the Euler–Lagrange equations, neglecting the Coulomb friction and stiction and assuming a constant cable length l:

$$\ddot{d} = \frac{1}{M+m}\Big(k_m u + ml\dot{\alpha}^2\sin(\alpha) - ml\ddot{\alpha}\cos(\alpha) - b_1\dot{d}\Big)$$

$$\ddot{\alpha} = \frac{1}{ml^2}\Big(-mgl\sin(\alpha) - ml\ddot{d}\cos(\alpha) - b_2\dot{\alpha}\Big)$$

The state variables are the trolley position d, velocity $\dot{d}$, the cable angle α and angular velocity $\dot{\alpha}$. The parameters are given in the following table:

Symbol	Parameter	Value
M	trolley mass	$0.95\,\mathrm{kg}$
m	container mass	$1.30\,\mathrm{kg}$
l	cable length	0.20 to $1.20\,\mathrm{m}$
g	acceleration due to gravity	$9.81\,\mathrm{ms}^{-2}$
k_m	motor gain	$-10\,\mathrm{Nm}$
b_1	motor and trolley damping	$10\,\mathrm{kgs}^{-1}$
b_2	cable hinge damping	$0.75\,\mathrm{kgs}^{-1}$

The values of the parameters k_m, b_1 and b_2 are approximate and must determined by means of experiments.

Simulink Template

A Simulink template `cranetemplate.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.