Control of a Motorised Pendulum

Lab 5: Closed loop control – Proportional gain.

Warning: Be careful of an unstable system!

1. Previous

To this point we have developed an open loop control system for our pendulum, with the motor voltage being controlled by a PWM signal which is set by an analog output voltage from the computer. Based on previous calibration of the system, we can set the desired angle and our system would hopefully have an output angle very close to the setpoint. However, drawbacks of such an open loop system include the fact that it cannot act against disturbances as well as the fact that the response dynamics (settling time, % overshoot) are purely determined by the system properties.

Both the above drawbacks can be improved in a closed loop system, where we compare the actual angular position of the pendulum arm (measured by the rotary potentiometer) to the setpoint and use this error signal as the actuating signal. At the same time we can also add a compensator (controller) in the loop that will help us improve the system response.

2. Simulating the closed loop system

First determine the closed loop transfer function of your system from the open loop transfer function you had derived in lab 3. That is, you should consider the situation of connecting the potentiometer output directly to the PWM input signal. Will this response be stable?

Use Matlab to predict whether the system will be stable or not. Can you predict a value for the steady state error in the closed loop response? Simulate the closed loop response and determine the expected response characteristics. Compare to the original open loop response characteristics.

3. The theoretical effect of proportional gain.

The use of a proportional gain element is an almost always an essential part of a closed loop control system. Incorporate such a gain element, K_p, in your forward path and write down the transfer function for both open loop and closed loop system with this element in place. What effect would the value of K_p have on the stability of the system? Can you predict values of K_p where the system should be stable?

There are a variety of tools that can be used to answer these questions, including the root locus plot or the Routh-Hurwitz test. We may not have covered these when you reach this part of the project. Ensure that you consider them when writing up your report.

4. Construction of a closed loop system.
Now change your Simulink model in order to facilitate a closed loop configuration. Be aware that you **will** create a system that is closed loop unstable.

- Consider the likely behaviour of the pendulum when unstable.
- Add a "kill-switch" to your Simulink model that can instantly cut power to the motor.

Try to run the system in the closed loop using different values of K_p (careful – begin with small values for K_p). How does the system stability depend on the actual values of K_p used? How does the actual closed loop response compare to that predicted by simulation?

Comment on the advantages and disadvantages of this proportional control scheme.

Be aware of the fact that we now do not have a continuous control scheme as we have assumed in all our theory, but that we are actually using sampled data to measure the output and implement a control scheme. This in itself can lead to instability in our system (see ECEN320 for details of the z transform). However, for now this problem can solved by ensuring we are sampling at a high enough rate - values of 1 kHz should suffice in our case.

An additional problem comes from the fact that MS Windows is a less than ideal real time operating system, but it is generally adequate at this relatively slow sample rate.