MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Aeronautics and Astronautics
16.30: Estimation and Control of Aerospace Systems
Spring 2004

Lab 1: Elevation Dynamics and Control
Due: 03/15/2004

Objective

The objectives of this lab are:

1. To use a collective motor voltage to experimentally determine the plant transfer function for the elevation axis of the Quanser from both step response and frequency response characteristics.
2. To design a controller for the elevation axis which achieves bandwidth of about 3 rad/sec and phase margin of at least 45° with no steady state error.
3. To implement the controller and compare its performance to that of he open loop system in terms of step response characteristics and disturbance rejection.

Administrative

You can do this lab individually or with one partner.

Introduction

Quanser helicopter is a mechanical device that essentially emulates the flight of a reduced degree of freedom (DOF) helicopter. Instead of the usual six DOF of a free-flying helicopter, the Quanser only exhibits three: the roll motion ϕ, the elevation motion θ, and the travel motion ψ. The Quanser system is actuated by two rotors and the inputs to the system are V_{cyc}, which is an electric voltage that results in differential change in the two rotor speeds, and V_{col}, which is an electric voltage that controls the speed of the two propellers collectively. The voltage is limited to 3 volts. The outputs of the system are the three angles: the roll ϕ, the elevation θ, and the travel ψ. Please keep the limits of the system in mind, in particular, the voltage is limited to $[-3, 3]$ Volts, pitch motion should be limited to $[-40°, 40°]$, the elevation motion should be limited to $[-15°, 25°]$.

Getting Started to do Identification

1. You should install Java (*http://java.sun.com/products/archive/j2se/1.4.0_03/*). The camera does not work with Java 1.4.2 so if you have that version, uninstall it and install Java 1.4.0. It is best to use Internet Explorer. Now, make sure you can see Java applets. You might want to check if you can see the camera by going to http://webchopper.mit.edu/javacampush. The experiment is set-up to run only from MIT IP addresses.
2. Connect to http://webchopper.mit.edu, click run experiment, then here. You'll be taken to the University of Siena interface, scroll down to the 3DOF Helicopter experiment.
3. Click "Control Experiment". Enter appropriate personal data, and click "Identification" → "Run Experiment".
4. Unless there is a "Process Busy" message, which means someone else is using the machine, a java window should pop up. On the right you should have a camera window, if it is showing "Loading...Please Wait...", right click your mouse and choose "Restart".
5. This experiment has been set up for you to collect open loop data by applying V_{col} and V_{cyc}. The collective voltage for the identification is limited to [-0.2, 0.3] volts, and the cyclic voltage is limited to +/- 0.2 volts. For this lab, you will only be changing the V_{col}. You can apply either a Step input, or a Sine input, do not forget to click "Update Reference" if you want changes to take effect. For you information, at hover, $V_{col} = 1.55$ volts. In the Sine input options, *Frequency* has units of Hertz (1 Hz = 6.28 rad/sec), and *Center* is the offset of the sine on the y-axis. In order to keep the Quanser from swinging in the roll, you have an option to turn on a "Roll Controller" by changing "Reference Panel" → "Roll Cont" → "Step Value" to some nonzero number.

6. Click “Start Experiment”. It takes 30 seconds for the experiment to initialize. Click on “Reference Panel” → “Show”, here you can change your inputs. To see the output click on the appropriate box in the Graphics Panel. Note that when the supervisor control is on (plot shows 1), such as during initialization, stopping or when it overrides the user’s actions, the outputs are shown to be zero. For visualization purposes, the reference input’s amplitude has been multiplied by 10 and all the angles have units of degrees.

7. When you are done, click ”End Session”. You can save the outputs for later plotting in Matlab in either .mat or .zip format. You can follow these commands to plot the results:

   - load *filename.mat*
   - who
   - plot(rt_tout, rt_ElevationOutput);

   All the angles here have units of radians. Note that the time to do an individual experiment is limited to 5 minutes. Also, if the helicopter approaches its safety boundaries, a supervisor controller turns on and shuts off your experiment, so you will have to start over.

Getting Started to test Controller

There are two ways to test your controller. The first one is using the predefined PID controller, where you just input Proportional, Integral, and Derivative gains for the elevation. The second one is by downloading your own controller designed in Simulink, you can also set that one up to change gains in real time.

Predefined PID

1. Before you plug in your controller, you should test it with the developed transfer function in Simulink.

2. If you choose to use a PID controller. Follow the links to the “Control Experiment”, but now click “Run Experiment” for the “Elevation PID Controller”.

3. Unless there is a “Process Busy” message, which means someone else is using the machine, a java window should pop up. On the right you should have a camera window, if it is showing “Loading...Please Wait...”, right click your mouse and choose “Restart”.

4. Click “Start Experiment”. After 30 second initialization, a pre-set PID controller is turned on, you can change the appropriate gains by opening “Parameters Panel”. Do not forget to click “Update Reference” if you want changes to take effect. In the “Reference Panel” you can choose an appropriate input, the units are in degrees (they are internally converted to radians). Here, you also have an option of turning on the Roll Controller by changing “Reference Panel” → “Roll Cont” → “Step Value” to some nonzero number. You can see if the “Roll Cont” in on (on = 1) by clicking on “Roll Control” button in the Graphics Panel. To see the output click on the appropriate box in the Graphics Panel. Note that when the supervisor control is on, such as during initialization, stopping or when it overrides the user’s actions, the outputs are shown to be zero.

5. When you are done, click ”End Session”. You can save the outputs for later plotting in Matlab in either .mat or .zip format. Note that the time to do an individual experiment is limited to 5 minutes.

User-defined Elevation Controller

1. Before you plug in your controller, you should test it with the developed transfer function in Simulink.

2. If you choose not to use a PID controller. Follow the links to the “Control Experiment”. To the left of the “Elevation PID Controller” you will see “Download Model”, download the model onto your hard drive and modify it with your controller in Simulink. Remember that angles are measured in radians. If you want to modify some parameters real time, give them names in the form of *ACT_TP_Var Name*, the way it is done in the template file. It IS case-sensitive.**Save it as a Simulink 3.0 version.** Now go back to that page and upload your controller into “Controller Model” field. “Controller Data” should be left blank, and the “Sample time” should be set to 10 msec. Press “Send Controller”. It takes some time for you controller to compile.

3. Click “Start Experiment”. After 30 second initialization, you controller is turned on.

Lab Procedure

1. Obtain and record the open-loop step response of the transfer function from the motor collective voltage to the elevation. From this data, identify the transfer function as well as you can.

2. Obtain experimental steady-state frequency response data to produce a Bode magnitude and phase plots for the transfer function from the motor collective voltage to the elevation angle. Since you don't get perfect sinusoids and you can't make perfect measurements, at each frequency, you should have a range of possible magnitudes and a range of possible phases. In getting the frequency response, let the system come to steady state at each frequency you try. You may want to run your signals through gains and/or summers with offset constants so that you can get the input and the output at the same magnitude and offset on the same plot in order to make a good phase measurement. Pick your frequencies wisely; start at dc, then 0.03 Hz and up. Please remember that the amplification of the plant is different at different frequencies. Pick the size of your inputs large enough to see the output easily (10-15 degrees is good).

3. Design a controller for the elevation axis that achieves a bandwidth of about 3 rad/sec and phase margin of at least 45° with no steady state error. Test your controller by making a Simulink simulation of your plant and the controller. Finally, implement your controller on the plant. Obtain and record the response of the elevation of your controlled system to a step command input of a change in elevation. Obtain and record the step response of the elevation of your controlled system to a step disturbance at the controller output or plant input.

Post Processing, Requirements and Write-up

- The write-up should be clear and concise. Include graphs or tables of your data as appropriate.
- Include the final model obtained using the open loop step response and the model obtained using frequency identification. Compare the performance of controlled system to the response of the open loop system. Compare the response of the controlled system to the one simulated.