CALIFORNIA INSTITUTE OF TECHNOLOGY
Control and Dynamical Systems

CDS 111
Problem Set #2

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1. Starting with the controller that you designed in HW #1 for stabilizing the altitude dynamics, implement and test a controller for the y dynamics on the ducted fan. You should lock down the pitch axis so that only the vertical dynamics are excited. You may redesign your controller if you are not happy with its response on the actual system.

   (a) Plot the theoretical response of your (final) controller to a step input of magnitude 28.8 cm.

   (b) Plot the experimental response of your controller to a step command input from 0 cm to 28.8 cm. Comment on any unusual or interesting features that you notice and compare your result with the theoretical response from part (a).

   (c) Plot the experimental response of your controller to a step command input from -14.4 cm to 14.4 cm. Comment on any unusual or interesting features that you notice and compare your result with the theoretical response from part (a).

   Be sure to describe how you are transforming the controller from continuous to discrete time.

2. Consider the pitch axis dynamics for the ducted fan with center of mass below point of attachment for the stand. The transfer function from the sideways force to the pitch angle is given by

$$P(s) = \frac{r}{Js^2 + m_f g l} \qquad \begin{array}{ll} g = 9.8 \text{ m/sec}^2 & m_f = 2.2 \text{ kg} \\ r = 25 \text{ cm} & J = 0.0475 \text{ kg m}^2 \\ l = 5 \text{ cm.} & \end{array}$$

   Note that the counterweight does not affect the pitch axis and hence gravity is 9.8 m/sec^2. (In homework set #1, the scaled gravity should have been labeled as γ to distinguish it from g.)

   We wish to track reference signals with frequency content up to 10 rad/sec (approx 1.5 Hz) with less than 5% error.

   (a) Design a controller for the system which gives the desired amount of performance. Use a frequency domain plot of the sensitivity function to verify that your controller meets the specs.

   (b) Plot the response of your controller to a step input of magnitude 0.8 radians.

   (c) Implement your controller on the ducted fan and plot the response to a step input of 0.8 and -0.8 radians. Plot both the pitch and altitude response and comment on any unusual or interesting features that you notice either in your plots or in the physical system itself.

   (d) Using the joystick, capture the response of your controller to a manually generated trajectory and plot the desired versus actual trajectory. Comment on any unusual or interesting features that you notice.

   You should use the altitude controller from problem #1 when testing your pitch controller on the experiment.

   Please note that you may not be able to design a controller that meets the desired performance objective and is also stabilizing. If not, you can scale back the maximum frequency in the performance spec, but be prepared to explain why you are having problems. In any event, use the *same* controller for answering parts (a) through (d).