AE353: Design Problem 01

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1 Goal

The code provided in `DesignProblem01` simulates the rotational motion of a spacecraft. This spacecraft has actuators—these could be reaction wheels, control-moment gyros, or paired thrusters, for example—that can apply torque about two different axes. This spacecraft also has sensors—an inertial measurement unit (IMU), for example—that can measure its angular velocity. The spacecraft starts with some random angular velocity. The goal is to achieve some particular angular velocity that you get to choose.

2 Model

The rotational motion of the spacecraft, if it is modeled as a single rigid body, is governed by the ordinary differential equations

$$\begin{aligned}
\tau_1 &= J_1 \dot{w}_1 - (J_2 - J_3) w_2 w_3 \\
0 &= J_2 \dot{w}_2 - (J_3 - J_1) w_3 w_1 \\
\tau_3 &= J_3 \dot{w}_3 - (J_1 - J_2) w_1 w_2,
\end{aligned}$$

where w_1, w_2, w_3 are the components of angular velocity, J_1, J_2, J_3 are the principle moments of inertia, and τ_1, τ_3 are the two different torques that can be applied.

3 Requirements

You must do *all* of the following things:

- Choose the angular velocity that you want to achieve. You may wish to motivate your choice by some real-world application.
- Linearize the model given above about your chosen angular velocity and express the result in state-space form.
- Consider the application of zero input. Determine if the resulting system is asymptotically stable. Implement a controller that applies zero input and plot the results as evidence to confirm (or deny) your prediction.

- Consider the application of state feedback. Determine if the resulting system is asymptotically stable. Implement a controller that applies state feedback and plot the results as evidence to confirm (or deny) your prediction.

You must also do *at least one* of the following things, and are invited to do more:

- Examine the differences, if any, between predictions made by your linear model and by the nonlinear simulation.
- Examine how the initial conditions affect the resulting motion, if they do at all.
- Design and implement a method of reference tracking.
- Design and implement a method of disturbance rejection.
- Determine the extent to which the stated goal ("achieve some particular angular velocity") is even possible.
- Consider the application of a nonlinear controller (i.e., a choice of input that cannot be expressed as an affine function of the state).

There are many possibilities. You are being given the opportunity to explore. Any additional claims you make must be supported by evidence.

4 Deliverables

You must submit two things by 11:59PM on Friday, February 8:

- Code. This code will be written in MATLAB, using the templates `Controller.m` and `Test.m`. The implementation of the controller you designed will be contained in `Controller.m`. All the commands necessary to run your simulation will be in the script `Test.m`.
- Report. This report will be written in LaTeX. You may never have used LaTeX before. That's fantastic! Help will be provided, and you will learn a lot. You will submit both your LaTeX source files and the PDF document produced by them—only the PDF document will be reviewed. It must be exactly four pages, must include a method of approach and a description of results, and must be named `DesignReport01.pdf`.

You must also meet intermediate deadlines, the details of which will be posted to Piazza.

5 Evaluation

Your work will be evaluated based on completion of the requirements (50%), on submission of working code (20%), meeting deadlines (20%), and your report being formatted correctly (10%). Extraordinary efforts may receive extra commendation. The focus of our evaluation of your report this time (as you learn how to use LaTeX) will be on content—we will not look at style, grammar, or any other aspect of your presentation, as long as there is no barrier to understanding your work. Further detail about point allocation can be found in the rubric. You will also complete a peer review process—details will be posted to Piazza.