# Problem Set 5

AA279D: Dyn, Nav, Ctrl of DSS
Spring Quarter 2022/2023
Due: May 10, 2023, Wed, 11:59AM PT
Prof. Simone D'Amico

## Submission Instructions

Please briefly document all tasks outlined below in a report which will grow during the course. You should include a table with change logs since the last submission, and an index for sections at the beginning. Please submit your report as a single PDF file to the course Canvas website. It should include narrative, plots, tables, code, and interpretations. You should use typesetting software like LaTeX or Microsoft Word to produce your document. Do not submit extra files.

## Topics

Week 5. Continuation of project. Discuss requirements. Implement impulsive control law.

## Problem 1: What are the control objectives?

To continue your project, you will need to motivate the development of your control laws by designing some scenarios of interest and associated requirements. In the context of relative motion, we are generally interested in two types of control frameworks: those for formation keeping, and those for reconfiguration. As such, you should consider the following information in your formulation of requirements:

1. What are the significant operational modes of your formation? Some examples may include station-keeping mode, scientific observation mode, and rendezvous/docking mode, though the needs of your mission may vary. Be sure to define at least 2-3 modes.
2. How are these modes defined? Think about the absolute and relative motions of your spacecraft. You might use sets of absolute or relative orbit elements to characterize each mode, for example.
3. When operating within these modes (i.e. formation keeping), what sorts of control requirements may your formation be subjected to? You should consider parameters like allowable separations, necessary precision of knowledge and actuation, limitations on burns, etc.
4. When switching between modes (i.e. reconfiguration), what kinds of control requirements are present? Some examples include time to reconfigure or any safety concerns.
5. What actuators are you considering, high-thrust/low specific impulse or low-thrust/high specific impulse?
6. Given the control requirements (or other mission specific requirements), what absolute and relative orbit dynamics models are needed? Linear vs nonlinear? Cartesian-based vs ROE-based? Two-body vs Three-body problem? Discuss pros

and cons as related to your mission. Implement and verify the models for your mission in open-loop (no control inputs).

## Problem 2: Impulsive Control Law

Now that you have set up the necessary framework and know your objectives, you will design and implement your first impulsive control law for your mission. The details of this implementation will be left to you, however a base set of tasks is provided below:

1. Consider implementing different impulsive control laws for formation keeping and reconfiguration. The specifics of these control laws are left entirely up to you (e.g. the tracked state, in-plane vs out-of-plane control, pairs vs triplet of in-plane maneuvers, control windows, etc.). You may choose from the formulations discussed in class or even look at other literature within the field. If you are involved in relevant research, this is an opportunity to apply your work.
2. If you decide to follow more closely the class material and what's done in practice, you could do the following:
    a. Define and setup the formation reconfigurations you want to solve (i.e., chief's orbit OE, initial ROE, final ROE, duration).
    b. Apply naïve least-squares solution to solve the guidance (short-term) and/or control (long-term) problems (this requires the selection of waypoint times and maneuver times a-priori).
    c. Apply closed-form maneuver scheme based on reachable set theory, in this case maneuver times are given by analytical formulas, delta-vs are given by analytical formulas or the solution of a well-conditioned linear system.
    d. Compare approaches and compare with delta-v lower bounds.
3. Justify your choices and describe the implementation in detail, including:
    a. Dynamics model implemented for ground truth simulation
    b. Selection of dynamics model and state representation for controller/maneuver planner
    c. Actuator implementation as impulsive delta-v vs applied thrust
    d. Inclusion of uncertainties (e.g. noisy sensors and actuators)
4. Discuss the performance of these control systems with visualizations and interpretations of results:
    a. Include plots of control tracking error, maneuver scheduling, and delta-v over time.
    b. Comment on the strengths and weaknesses of your implementation(s)
    c. Compare the performance against your expectations regarding parameters like delta-v budget, delta-v lower bound, frequency of maneuvers, maneuver directions
    d. If the controller does not work for the application of interest, explain why

*Note: This is a challenging problem as you face several choices and bugs in implementation are likely. It will be evaluated with a focus on methodology at this stage rather than accuracy. You will have a chance to improve this for the final project.*

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