Problem Set 1

AA279D: Dyn, Nav, Ctrl of DSS
Spring Quarter 2022/2023
Due: April 12, 2023, Wed, 3:00PM 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 or handwritten notes.

Topics

Week 1. Project kick-off. Interpretation of specifications. Mission selection. Absolute orbit simulation.

Problem 1: Your Mission, Your Challenge

Conduct a survey of distributed space systems (DSS), either proposed, under development, or operational. Make sure to look at a wide variety of mission domains, such as Earth/Planetary science/remote sensing, Astronomy/Astrophysics, Space Situational Awareness and Infrastructure, Technology demonstrations.
From your research, select a candidate DSS which will serve as the framework for your course project. You should provide the following information on it as available in public resources:

- Mission name and operator (agency, nation, company, etc.)
- Primary and secondary mission objectives
- Number and type of satellites
- Absolute and relative orbit parameters, tentative launch dates, mission duration
- Basic description of functioning/scientific principle, how does the payload or instrumentation work
- Key DGN&C requirements
- Classification of DSS according to separation between elements and required navigation/control accuracy (e.g. formation-flying, constellation, rendezvous and docking, swarm, fractionated, etc.)

Notes: The mission could be at any stage of actual development or fictional. The content of the class is mainly in the perturbed restricted two body problem; however, you can choose an orbit environment in the restricted three body problem if you will.

Problem 2: Orbit Simulation, Review of Astrodynamics

We would like to explore the properties of unperturbed and J2-perturbed absolute orbit motion using known analytical solutions and numerical integration. To this end, you are asked to:

a) Define the initial conditions for the mission you identified in Problem 1. Most likely the initial conditions are provided in literature by a set of Keplerian orbital elements and an initial launch date and time. You are allowed to choose some consistent initial conditions arbitrarily if not available.
b) Treat these initial conditions as osculating quantities and compute the corresponding initial position and velocity in the inertial frame of choice.
c) Perform a numerical integration of the equations of motion using position and velocity as state variables and the initial conditions from b). You should perform simulations including and excluding J2 effects. Provide plots of the paths of at least one of the satellites of your DSS in the inertial frame. Note that the simulation should be long enough to appreciate secular J2 effects, i.e. an integer multiple of the orbital period if in a planetary orbit.
d) Verify that your integrator performs properly by comparing output with analytical Keplerian propagation. This is a comparison between output of c) excluding J2 effects and Keplerian propagator. Plot the error in absolute position and velocity expressed in the RTN frame. *Hint*: You should only observe numerical integration errors. Eventually reduce integrator step-size to reduce numerical errors.
e) Compute and plot osculating Keplerian orbital elements, eccentricity vector, angular momentum vector, specific mechanical energy throughout the numerical simulations of c). Verify the quantities which are constant when including or excluding J2 effects. What happens when you include J2 effects? Are the results as expected from averaging theory?
f) Now consider the linear differential equations for the mean classical orbital elements including J2 effects. Verify and show the general consistency with the osculating elements from e) by superimposing results. *Hint*: The simulation should be at least a few orbital revolutions long since the mean elements refer to an orbit average.
g) You could encounter some inconsistencies when comparing osculating and mean orbital elements due the initialization procedure. In fact, c) needs osculating states as inputs and provides osculating states as outputs, whereas f) needs mean states as inputs and provides mean states as outputs. How would you reconcile this issue?

***