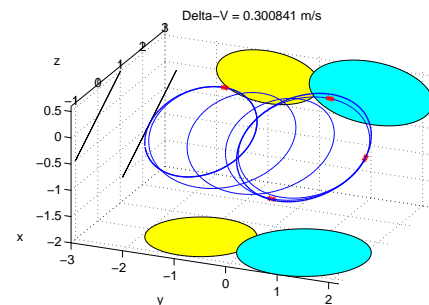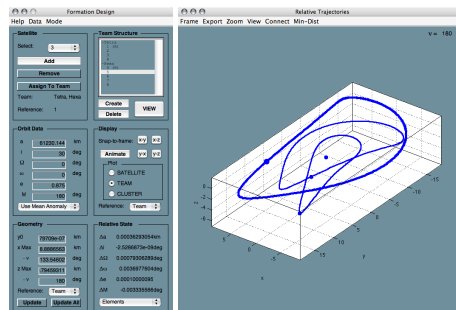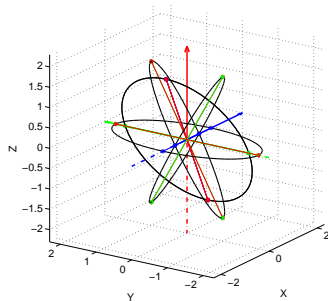# Formation Flying Module

The FORMATION FLYING MODULE is an add-on product for the Spacecraft Control Toolbox. This is a specialized toolbox, for use with MATLAB, that provides a wealth of design, simulation, and analysis tools for spacecraft formation flying.

Features

The Formation Flying Module provides a comprehensive set of tools that enable you to:

- Initialize, simulate, and visualize spacecraft formations for both circular and eccentric orbits

- Perform coordinate transformations between ECI, Hills, LVLH, Frenet, and differential element frames

- Simulate relative orbits with a variety of dynamic models, including: Hills equations, Lawdens equations, and Gauss' variational equations.

- Express periodic trajectories in terms of geometric parameters, to focus on the design of formation geometries.

- Design formation geometries and organizational structures using the powerful Formation Design GUI

- Apply, configure, and analyze decentralized optimal guidance routines that share information to assign target states.

- Apply, configure, and analyze model predictive control (MPC) algorithms that compute fuel-optimal impulsive control trajectories to reach target states

- Perform collision monitoring and avoidance, using algorithms based upon set membership theory.

- Conduct fully integrated simulations with the decentralized formation flying (DFF) control system prototype developed for NASA Goddard.

Background

Developed over the course of two NASA SBIR contracts, this toolbox provides state-of-the art numerical simulations and advanced algorithms for optimal guidance and control. Full source code is provided, enabling a straightforward customization for your own mission.

Documentation

The Formation Flying Module provides a detailed Users Guide with numerous examples. The Users Guide can be downloaded for free from our website at:

http://www.psatellite.com/sct/formation_flying.php

In addition, PSS now offers a textbook on "Spacecraft Attitude and Orbit Control", which includes a chapter dedicated to formation flying.

Coordinate Frames

Perform coordinate transformations with ease between a number of relative frames, including Hills, LVLH, Frenet, differential elements, and geometric parameters.

The figure at the right shows a periodic relative trajectory in an eccentric orbit. Geometric parameters are used to define the trajectory shape. The green areas show the projections on the $x - y$ and $x - z$ planes.
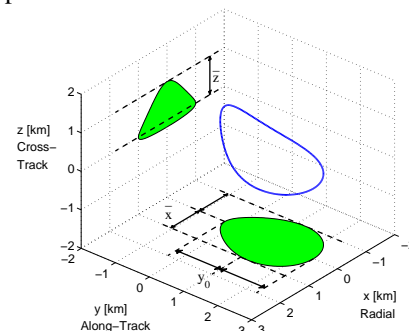
Relative Orbit Dynamics

The equations of motion for relative orbit dynamics in circular and eccentric orbits are provided in multiple coordinate frames. You may use the Clohessy-Wiltshire (or Hill's) equations for circular orbits, Lawden's equations for eccentric orbits, or Gauss variational equations for either orbit regime.

Visualization

A variety of tools are available to help visualize relative motion, periodic trajectories, and formation geometry. The Animation GUI can be used to animate any trajectory. The example shown on the left below is the Animation GUI with the trajectories of 6 spacecraft forming a dual-plane projected circle formation. In addition, any relative trajectory can be shown in 3D with shaded areas to show the projections onto 2D planes, as shown in the image on the right.
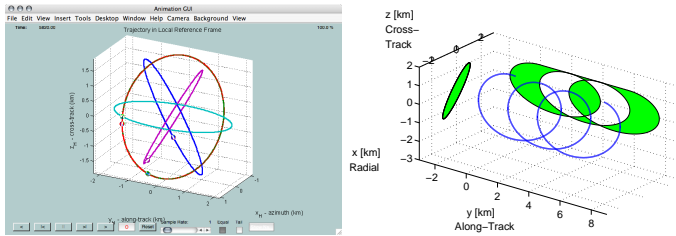

Formation Design

Use the Formation Design GUI to build up a cluster of spacecraft, organize them into teams, and assign relative trajectories to establish a desired formation. Save your work and continue later from where you left off. Visualize and animate the trajectories in 3D as you go. Compute the minimum distance between all pairs of spacecraft with a click of the mouse.
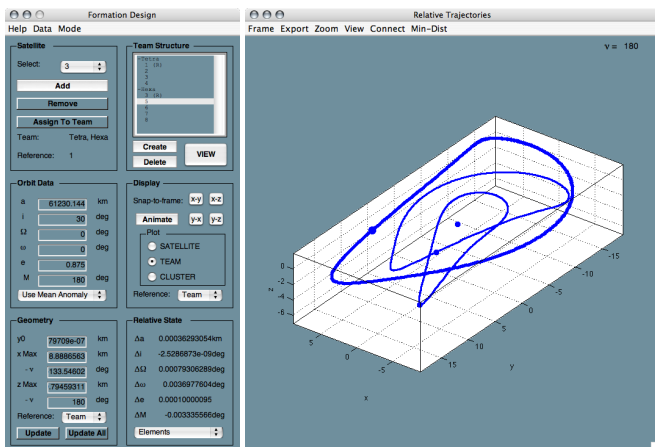
Model Predictive Control

Model predictive control algorithms are provided for maneuver planning with time-varying constraints. An analytic solution is provided for circular orbits, and linear programming (LP) based algorithms are used for eccentric orbits. The figure below shows a hierarchical tree with the various control methods included in the Formation Flying Module.
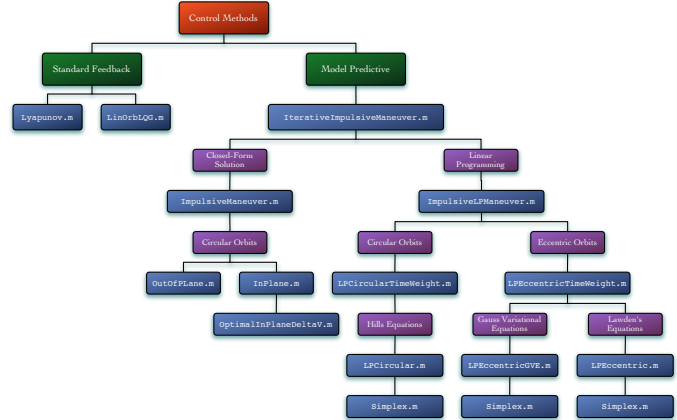
Simulation Tools

A variety of different simulation tools are provided. One focuses on the analysis of relative disturbances and the impact of navigation uncertainty on the performance of relative orbit control algorithms. This is a perfect tool for designing formation keeping strategies.

Another allows you to simulate multiple spacecraft and perform decentralized guidance and control. This is an excellent tool for planning and optimizing reconfiguration maneuvers.

The third is a fully-integrated simulation that implements the prototype DFF software. This includes decentralized guidance and control software, inertial frame state integration, user-defined time-tagged command scripts, and post-simulation analysis tools. This is a comprehensive system that can be tailored to prototype the formation flying software for your own custom mission.

System Requirements

The Formation Flying Module requires the Spacecraft Control Toolbox to run. It is compatible with MATLAB v7.0 and up, Windows XP/NT/2000, UNIX and MacOS X.

For More Information

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