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Corresponding author: BŁAŻEJCZYK Michał
e-mail of corresponding author: michetto@agh.edu.pl
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Title

RelGNCPy: A simulation toolkit for relative Guidance, Navigation and Control in Satellite Formations

Authors

*Michał BŁAŻEJCZYK [1]**

** Corresponding author*
[1] AGH University of Science and Technology, Mickiewicza 30, 30-059 Cracow, Poland, michetto@agh.edu.pl

Abstract

Satellite Formations refer to a group of satellites that operate in a coordinated manner to achieve a common goal. The formations of satellites are known to improve the mission return compared to the traditional mono-satellite configurations, and enable completely new mission concepts [1]. Flying multiple satellites can provide a greater baseline for Synthetic Aperture Radar, and lower the cost of replacement in case of a malfunction of an individual instrument [2]. Coordinating multiple satellites requires more complex Guidance, Navigation and Control (GNC) methods, and tools for prototyping and evaluating these methods under realistic environmental conditions.

In this paper, the implementation of a RelGNCPy toolkit for prototyping and evaluating relative Guidance, Navigation & Control methods is presented. The paper addresses modeling of the forces acting on satellites in the Low Earth Orbit. The disturbing forces, namely the atmospheric drag, Solar radiation pressure, Solar and Lunar gravitational field interactions and Earth's oblateness models allow for evaluating the GNC methods in a realistic environment. This work provides a brief review of the absolute and relative satellite motion propagation methods, including the Cowell's method, Encke's method, and a number of relative motion models. The toolkit was developed in Python scripting language, which allows for significant flexibility and a wide range of open-source libraries that can extend the toolkit's functionality. Contrary to the existing software, such as STK or GMAT simulators, the toolkit presented in this work allows for testing control systems implemented in Python in a closed-loop configuration.

To demonstrate the abilities of the toolkit, two use cases are included. In the first use case the limitations of the Clohessy-Wiltshire relative motion model are examined. The motion of a formation of two satellites flying in three different configurations is propagated in the RelGNCPy. The effect of the different baseline length on the Clohessy-Wiltshire model error is examined, which gives an insight into one of the assumptions of the model. In the second use case, finite maneuvers planning for synchronization of the out-of-plane relative motion is described. The implemented guidance subsystem calculated the times and thrust vectors based on the relative position and velocity knowledge from sensors modelled with gaussian noise. The satellites were actuated with impulsive thrusters, which accounted for the thrust limits. After the successful synchronization, the planned maneuvers were exported from the toolkit and compared against the STK Astrogator with the state-of-the-art High Precision Orbit Propagator. The out-of-plane motion was compared between the tools, and the greatest difference between the velocity in the out-of-plane motion was less than 1/40th sigma value of the modelled relative velocity knowledge error. The results of the maneuver planning displayed sufficient accuracy for preliminary analyses of the onboard guidance subsystem.

References

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