Optimal Configurations for Nanosatellite Formation Flying in Binary Asteroid Environment

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Formation flying represents an effective solution to avoid the usage of a single, heavy and expensive system, thanks to a distribution of smaller hardware, exploited in cooperation to grant the same performances, at lower weights and costs. This is particularly true when very small satellites are used, allowing great costs savings while mitigating mission abort in case of failures.
The mentioned advantages are of great interest when risky environments, such as asteroids, are targeted, therefore it is worth studying how formation flying of small spacecraft could be used for scientific missions of this kind. However, many issues arise when dealing with small celestial objects: in first place, the unpredictable shape and observation uncertainties force to adopt more precise gravitational models with respect to the classical point mass approximation, widely adopted for massive bodies (planets, stars, etc.), secondly, in case of binary systems it is necessary to exploit the well-known Three-Body problem, hence requiring specific numerical techniques to successfully define periodic orbits suitable for the formation.
The present work aims at the definition of a fast optimization strategy, capable of dealing with the Three-Body dynamics in irregular gravity fields, providing a wide set of orbit families and defining the best combinations among them to place two spacecraft, provided the mission objectives.
The paper will show the study applied to AIM (Asteroid Impact Mission), targeting the binary asteroid system Didymos. Gravity field of the attractors will be modelled according to polyhedral approach [1] and ellipsoid approach [2], to best approximate the real shape, according to observations. Orbits families are generated in the Three-Body frame for point masses, then sampled and corrected to the real gravitational environment through a multiple shooting correction scheme. Finally, corrected orbits are combined to find the best configurations, and subsequently modified according to a local optimization process, based on a single cost function built from the combination of the mission objectives: minimization of the relative displacement between satellites and execution of a tomography to the secondary attractor (Didymoon). Example of a possible configuration, and the relative displacement minimization with respect to the initial guess, are depicted in figures.

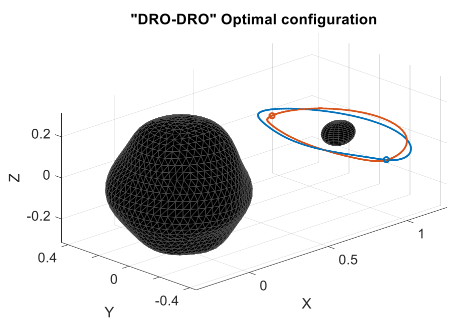

Fig. 1. DRO-DRO formation

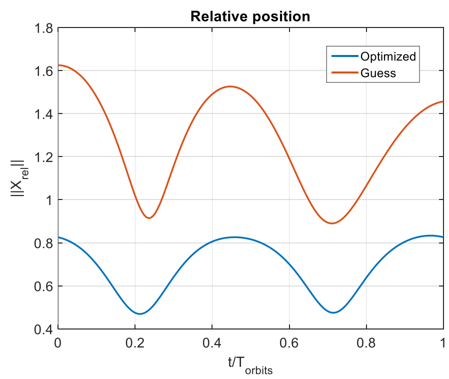

Fig. 2. Relative displacement optimization

References

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