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INFORMED DISTRIBUTED SPACE ASSETS DESIGN ON MULTI-BODY QUASI-PERIODIC TORI BY MEANS OF ENGINEERING PROPERTIES MAPPING TECHNIQUES

Abstract

Distributed systems are becoming appealing solutions to achieve demanding scientific mission objectives while splitting functionalities among several more specialised and less complex orbiting assets.

The application of such systems in regions dominated by multi-body dynamics is nowadays under study for its interesting implication for both engineering and scientific porpoises. Indeed, distributed navigation systems can be used in the cis-lunar environment to autonomously reconstruct the absolute state of orbital assets through the LiANSON method. Moreover, scientific applications, such as exoplanet observation through a telescope-occulter architecture, can benefit from formation flying in the Sun-Earth multi-body environment.

In this scenario, quasi-periodic trajectories can be exploited for formation initialisation, since centre manifolds represent an advantageous initial guess for bounded natural motion around periodic orbits. While extensive work is present for controlled formation flying in this environment, there's a lack of research about the definition of configurations exploiting the natural dynamics in the vicinity of periodic and quasi-periodic solutions. Such configurations can indeed leverage the free dynamics of the system to reduce the control demand on single satellites.

This work focuses on the relative natural dynamics of satellites moving on quasi-periodic trajectories. More precisely, engineering properties of interest for distributed systems, such as baseline, relative angles and sky coverage, are analysed. Concepts like the baseline and angular separation are extended for configurations of multiple satellites through generalised quantities taking into account the shape and dimension variation of the geometrical figure delimited by the elements of the formation.

Instead of focusing on specific cases, the work aims to build an extensive analysis of families of quasi-periodic tori to characterise the value of the engineering properties based on the selected manifolds. To achieve this, a significantly large database of periodic and quasi-periodic trajectories was computed for both the Earth-Moon and Sun-Earth three-body systems.

Quasi-periodic manifolds are characterised by the fundamental frequencies related to the transversal and longitudinal motion along the manifold. Once a sufficient number of trajectories are found, possible distributed satellite formations are composed. For all the combinations of satellites, the engineering properties are computed employing their average value and standard deviation along the orbit evolution. The paper presents the results in terms of the structure of configurations able to achieve the desired engineering properties while minimising their temporal variation. Regression algorithms are exploited to map the intrinsic parameters of the trajectories to the selected engineering properties, to extrapolate useful dependencies for the architecture design phase.