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CHARACTERIZATION OF 6DOF NATURAL AND CONTROLLED RELATIVE DYNAMICS IN CISLUNAR SPACE

Abstract

At the 50th anniversary of Apollo 11, the Moon is back to the scene of scientific and commercial space exploration interests. During the next decade, the establishment of a Gateway in cislunar non-Keplerian orbits will open the space frontiers to sustainable manned and robotic missions on and around the Moon. This asset will be exploited to advance technologies, capabilities and best practices to tackle challenges for the next journey to Mars and beyond, while mitigating possible risks. Such infrastructure will require several logistic operations for its assembly and maintenance, which lean on rendezvous and docking/undocking capabilities. Even if few missions have flown on non-Keplerian orbits, thank to the recent progresses in multi-body trajectory design, rendezvous and docking (RV&D) operations have not been performed but in LEO.

Investigations about 6DOF relative dynamics in non-Keplerian environment are now mandatory to highlight criticalities in the design of the cislunar gateway and to translate RV&D protocols, consolidated in LEO for the ISS, to the new non-Keplerian environment.

In this direction, the paper first analyses the orbit-attitude dynamics within the CR3BP framework. A novel perspective of the dynamical structures constituting 6DOF manifolds allows to better characterize the natural relative dynamics in proximity of non-Keplerian orbits. The importance of orbit-attitude manifolds exploitation is underlined for designing reliable and efficient rendezvous trajectories and formation flying applications.

Then, an ephemeris cislunar model is exploited to address cislunar RV&D operations. The control capability is included in the dynamics of the chaser vehicle, which is employed to solve the 6DOF rendezvous problem. The results obtained with the controlled dynamics are compared to those available thanks to natural motion, discussing the energetic and time costs to complete the maneuvers. Operational challenges are discussed about the identified favourable locations along the orbit to perform RV&D operations, highlighting possible relations between RV&D time and non-Keplerian orbit's period.