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OPTIMIZATION OF FLOWER CONSTELLATIONS APPLIED TO CISLUNAR ENVIRONMENT OBSERVATIONS

Abstract

Recently, lunar missions have gained a renewed interest from the scientific community. Many space missions have already been planned to be deployed around and on the Moon, including, but not limited to, the new Artemis missions and the Lunar Orbital Platform-Gateway. In particular, the latter represents a permanent cislunar space station exploiting a Near-Rectilinear Halo Orbit in the vicinity of a Lagrangian point of the Earth-Moon system. Therefore, it is essential to start tracking and monitoring the cislunar environment in order to guarantee its safety and reliability, especially for future missions, thus preventing and avoiding any risks of collisions and debris formation. However, the current lack of cislunar observations requires the necessity of designing a suitable infrastructure to fill this gap. The aim of this paper is to optimize the design of a satellite constellation in Low-Earth Orbit to maximize the available observations of the cislunar space. This is carried out by considering the Lattice Flower Constellations (LFCs) theory, which represents the generalization of many analytical constellations formulations based on uniform distributions of satellites in space. By employing this theory, the relative distribution of the satellites belonging to the constellation is fixed and its number of symmetries is maximized. These properties can be used to easily and rapidly compute the minimum separation distance between each pair of satellites to avoid any collisions and guarantee the safety of the LEO environment. In addition, thanks to the recently proposed theory of the Necklace Flower Constellation, new possibilities of design and reconfiguration of satellites within the constellation can be considered. Another reason why the LFCs are considered is that a minimum number of parameters (represented by the number of orbital planes, the number of satellites per orbital plane, and the configuration number) is required to describe the constellation. This is a significant advantage when an optimization procedure has to be performed. Indeed, in this paper, an optimization approach, based on the metaheuristic algorithm Particle Swarm Optimization (PSO), is pursued to maximize the coverage of the cislunar space provided by optical devices mounted onboard satellites belonging to the FC. The minimum number of satellites with a user-defined minimum separation distance will also be enforced within the optimization to reduce the congestion of LEO and the risk of collisions accordingly. Finally, the coverage achieved by the proposed constellation is expected to provide cislunar space observations useful for current and future Space Traffic Management purposes.