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MULTI-OBJECTIVE OPTIMIZATION OF LUNAR COMMUNICATION/NAVIGATION CONSTELLATIONS BASED ON LPOS AND DROS

Abstract

In the last years, lunar exploration has aroused great interest of the public again, which can not only prepare for other deep space missions but also serve as an important target for scientific investigation and technological development. For the moon's scientific and engineering values, many countries and space agencies have developed an increasing number of lunar missions. These ongoing and planned exploration missions increase the need for communication and navigation services for both on-ground and in-flight users. Therefore, it is necessary to deploy constellations around the moon with appropriate functions.

Libration point orbits (LPOs) in the Earth-Moon system, due to their unique geometry and flexibility, are extensively studied by researchers for communication and navigation constellations. Constellations using LPOs require fewer satellites and can cover a wider lunar surface than conventional constellations with the Kepler orbit, widely employed around the Earth. In particular, they can easily achieve continuous coverage of some specific areas, such as the far side of the moon.

To cover the lunar surface, we choose LPOs near the moon to build constellations. These constellations include halo, Lyapunov, and near rectilinear halo orbits (NRHOs), all of which are located about the collinear L1 and L2 libration points. Additionally, distant retrograde orbits (DROs) are also considered. In previous studies, constellations using these orbits were designed based on fixed configurations, where the number of satellites and the orbital type were predetermined. Moreover, the orbital parameters of satellites are not optimized or only optimized with a single performance index as the objective.

In this study, we present a multi-objective optimization (MOO) framework for lunar constellations with variable configurations. First, relevant performance indexes of constellations, such as the number of satellites, availability, and geometric dilution of precision (GDOP, only for the navigation constellation), are identified. Then, they are mapped to different regions of interest, including the lunar far side, south pole, equator, their combinations, and the whole moon surface. Finally, a MOO algorithm is used to detect the best orbital parameters and initial phases of satellites, with the mentioned performance indexes associated with different regions included in the cost function.

Based on the proposed optimization framework, optimal and non-dominated solutions can be retrieved by Pareto front plots. It is conducive to extracting optimal orbital architectures of constellations for expected performance index in designated regions. These constellations can provide specialized communication and navigation services for the various lunar missions anticipated in the future.