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QUASI-SOLAR SYNCHRONOUS ORBIT AROUND THE MOON BASED ON SPATIAL DISTANT RETROGRADE ORBITS

Abstract

The last several decades have witnessed the rapid development of lunar exploration, promoting researches on various types of lunar orbits including Distant Retrograde Orbits (abbr. DRO) that are feasible for orbiting tasks due to their stability. Many applications of DROs have been proposed, e.g., Batcha et al. (2020) utilized a DRO as the transfer target of uncrewed Orion vehicle in NASA's Artemis I mission. Pushparaj et al. (2021) constructed low-energy transfers through segments of different DROs for JAXA's MMX mission. Our recent work indicates that there're spatial DROs around the Moon with continuous lighting interval longer than 12 hours, especially significant for lunar spacecraft. Therefore, this paper proposes a new concept of 'quasi-solar synchronous orbit' (abbr. QSSO) based on the spatial DRO in the multi-perturbed circular restricted three body problem (abbr. CR3BP) and develops a two-level orbit+attitude shadow-avoidance strategy. It remarks that the classic solar synchronous orbit around the moon is constructed by eliminating the precession of spacecraft's orbital plane w.r.t the Sun using the Moon J2 effect in the two-body problem.

First, based on planar DRO families in CR3BP, spatial DROs are obtained by continuation. An archive of DROs is established. To deal with the multiple perturbations in the proximity of the Moon, a multiple shooting algorithm is employed to provide the correction of initial guesses of spatial DRO considering solar gravity, Moon J2 and lunar obliquity. In order to detect the lighting conditions of spacecraft on DROs, the umbra-penumbra model is introduced and the shadowing index is evaluated with different weighting factors which is 1 for umbra and 0 for sun-lighting but in between for penumbra based on lighting strength (Hubaux et al. 2013). Subsequently, the shadowing index for each spatial DRO is estimated through ergodic visiting all members in the archive. Different from the classic concept of solar synchronous orbit, the QSSOs are then defined as those spatial (quasi-)DROs that own total lighting time larger than 95% of its period with shadow intervals generally shorter than 10 minutes. Finally, to avoid shadow intervals, a quick transfer strategy based on invariant manifolds of spatial quasi-DROs is discussed and an attitude adjustment strategy by sliding mode control is developed to optimize the orientation of solar panels according to the direction of sunlight. Furthermore, the feasibility of QSSOs as relay communication orbits for the far side of the Moon or observing orbits on the lunar polar surface is assessed.