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ENHANCING ORBIT DETERMINATION USING OPTICAL NAVIGATION FOR LUNAR MISSIONS

Abstract

The surge in deep space exploration, particularly with the Artemis program, has intensified lunar orbital activities. To support the development of lunar infrastructure, an increasing number of spacecraft are planned to be deployed into lunar orbits. Traditionally, deep space orbit determination relies heavily on ground station communications. However, this approach faces significant limitations due to the increasing number of satellites causing ground station resource shortages, and the inability to establish communication when satellites are physically hidden behind the Moon. During these communication gaps, the absence of observational data leads to substantial growth in orbit prediction errors. To address these challenges, we propose an optical navigation method that utilizes onboard cameras to capture images of celestial bodies such as the Moon and the Earth. By estimating the contours of these bodies as conic sections, the method can derive observational data independent of ground station availability. This approach offers several advantages, including reduced orbit determination errors during communication blackouts, extended autonomy allowing satellites to operate for longer periods without the need for frequent ground station contact, and enhanced mission capabilities enabling precise orbital data even when operating on the lunar far side. In this study, we developed a comprehensive numerical simulation framework consisting of a verification system consisting of an image generation simulator and an orbit determination algorithm employing Kalman filtering techniques. We simulated a lunar orbital environment, comparing observational performance using the Moon and Earth as target bodies. Our analysis examined the impact of image quality and optical navigation frequency on orbit determination accuracy. Preliminary results demonstrate that optical navigation effectively reduces error propagation during periods without ground station contact. This capability is crucial for future lunar missions, enhancing operational flexibility and increasing autonomy and self-sustainability of deep space missions.