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REAL-TIME LANDING GUIDANCE FOR LUNAR PIT EXPLORATION: OPTIMIZING MULTI-POINT SCIENTIFIC OBSERVATIONS

Abstract

This study investigates landing guidance for lunar pit exploration, focusing on optimizing scientific observations during descent while ensuring a landing. Lunar pit exploration plays a vital role in planetary science, offering access to subsurface geological structures that may provide key insights into the Moon's history. Some exploration plans have considered landing inside the pit. However, such an approach carries inherent risks due to the complex terrain, significantly increasing the likelihood of mission failure. To mitigate these risks, this study explores an alternative flyover-assisted landing trajectory, where the spacecraft performs a pre-landing flyover above the pit. This method enables scientific observations before descent, reducing the risks associated with hazardous terrain and ensuring data collection even in the event of a failed landing. While our approach integrates scientific observations into the descent phase, previous studies have primarily focused on fuel-optimal landing trajectories, with limited consideration for observation optimization. In particular, existing methods do not adequately address the multi-point observation challenge, determining which targets should be observed, when, and where. The key unresolved issues include (1) quantifying observation effectiveness and (2) optimizing the observation sequence along the trajectory to maximize scientific return. To tackle these challenges, we build upon our previous work, where information entropy was used to measure observation effectiveness under the assumption of a single observation target. Information entropy provides a quantitative measure of uncertainty reduction, making it well-suited for optimizing scientific data collection. In this study, we extend this approach to multi-point observations by introducing integer variables that allow the spacecraft to autonomously select observation targets. These variables represent binary decisions (1 = observed, 0 = not observed), ensuring that the generated trajectory dynamically adjusts observation sequences while maintaining line-of-sight constraints. However, solving an optimization problem involving integer variables is computationally expensive, making real-time execution impractical. To overcome this limitation, we relax the integer variables into continuous variables and apply successive convexification and interior-point methods, transforming the problem into a form suitable for online computation. This approach significantly reduces computational complexity while preserving observation effectiveness, enabling adaptive trajectory planning in real-time. Through numerical validation, we demonstrate that an optimized flyover trajectory can be achieved, enabling efficient multi-point observations. This method enhances the scientific capabilities of lunar pit exploration, contributing to a more comprehensive understanding of the Moon's subsurface environment and supporting future planetary exploration missions.