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STAR OCCULTATION TEMPLATE MATCHING FOR LUNAR ROVER LOCALIZATION

Abstract

Self-localization of exploration rovers on the lunar surface is essential for lunar exploration missions. The lunar poles contain permanently shadowed regions within craters, which are believed to harbour resources crucial for lunar activities, such as water and ice.

This research proposes a novel position estimation method utilizing star occultation. Exploration rovers are equipped with star trackers for attitude determination. These star trackers, comprising highly sensitive cameras, measure orientation by comparing observed star patterns with star catalogues. Our approach extends their functionality beyond attitude determination to enable absolute position estimation.

Our methodology leverages the phenomenon where the lunar terrain skyline occludes stars within star tracker images. We develop a template matching technique that associates the rover's absolute position with star occultation patterns. The algorithm consists of preparation and execution phases. In the preparation phase, we generate templates linking rover absolute position coordinates (X, Y, Z) with corresponding star occultation pattern sets S.

During the execution phase, which occurs in shadowed regions when sunlight does not interfere with imaging, the rover captures star tracker images showing terrain-occluded stars. By comparing the observed star pattern s with the pre-generated templates, we can estimate the rover's absolute position (X, Y, Z) on the lunar surface.

To demonstrate the proof-of-concept for this algorithm, we conducted simulations where rover positions are represented as absolute coordinates (X, Y, Z). Using terrain data modeled with typical geometric shapes and the Hipparcos star catalog, we generated star occultation patterns corresponding to changes in absolute position. We then identified sets of positions that produce identical star occultation patterns. These position sets represent the possible estimated locations of the rover and therefore indicate the inherent uncertainty of the algorithm.

In our simulation framework, we model the skyline using typical geometric shapes such as triangles and trapezoids to represent lunar terrain features. To evaluate the uncertainty of the algorithm, we conduct tests quantifying the absolute positioning accuracy achievable through star occultation patterns. By analyzing how different geometric skyline configurations impact the positioning results, we evaluate the algorithm's robustness to terrain shape variations and identify the limitations of the proposed method.

The significance of this research lies in its potential to provide a reliable positioning method in challenging lunar environments without requiring additional specialized hardware beyond the already-equipped star trackers. This technique offers potential for autonomous navigation in both permanently shadowed regions and temporarily shadowed areas during lunar night, where traditional navigation methods may be limited.