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LOG-POLAR MULTI-LEVEL MATCHING FOR ROBUST VISION-BASED NAVIGATION UNDER SEVERE ILLUMINATION SCENARIOS DURING LUNAR LANDING

Abstract

Until now unmanned space missions heavily relied on the delayed support of ground operators for the most critical part of operations. This imposes strong limitations on the objectives and achievements that can be pursued by the current space exploration plans. Autonomous Vision-Based Navigation capabilities still have not reached a sufficient Technology Readiness Level (TRL) and robustness to operate successfully under a wide range of operating conditions and to become a baseline for the landing of future space missions. Smart Lander for Investigating Moon (SLIM) is a small and light unmanned spacecraft which Japan Aerospace Exploration Agency (JAXA) is developing as technological demonstration of safe pinpoint landing on the lunar surface. In rare off-nominal cases, SLIM onboard crater-based method for Terrain Relative Navigation (TRN) may fail due to the insufficient number of reliably detected craters and the severe illumination conditions caused by the low Sun elevation angle. In this landing scenario, where the image information content is minimum, even benchmark feature-based methods fail by collating the detected features with the wrong features in the reference map. This work proposes Log-Polar Multi-Level Matching (LPMLM), a robust pipeline for lunar TRN to estimate SLIM's absolute position in visually-degraded (dark) environments using no *a priori* known surface landmarks and with no attitude nor altitude information. The input is the compressed JPEG image taken onboard with a monocular camera while the output is the spacecraft's absolute position in the lunar reference map. LPMLM has been tested by Monte Carlo simulation on synthetically generated images of different regions of the lunar surface with different magnitudes of added noise, demonstrating the impact it can have on the success of TRN in visually-degraded scenarios. In the simulations, the proposed method outperformed Speeded Up Robust Features (SURF) and Accelerated KAZE (AKAZE) in terms of robustness to a combination of noises and alterations from different sources including compression artifacts, distortions, motion and changes in brightness, contrast, rotation, and scale.