

Prototype Design for a Lunar Lander High Resolution Stereo Camera

Shreya Chauhan^{1,2}, Ralf Jaumann¹, Matthias Grott², Christian Althaus²

¹ *Freie Universität Berlin, Institute of Geological Sciences, Berlin, Germany.*

² *Institute of Space Research, German Aerospace Center (DLR), Berlin, Germany.*

Terrestrial exploration with the help of rovers typically employs traditional stereo cameras, relying on binocular optical designs with large, bulky, and often moving parts. The stereo camera design concept presented in this study was developed and built using commercial off-the-shelf (COTS) components, allowing for rapid-prototyping, cost-effective testing, and performance evaluation under simulated mission conditions. An innovative use of four-mirror optical configuration and a monochrome CMOS sensor introduces a novel approach to achieve high resolution stereo imaging, while maintaining low power consumption and space requirements suitable for compact lander missions. By utilizing a single-detector stereo vision, the camera system can effectively create 3D reconstructions of observed objects with a spatial resolution of 54 $\mu\text{m}/\text{px}$, and depth resolution of $<1 \text{ mm}/\text{px}$ with the stereo baseline length of 116 mm, an instantaneous field of view of 601 μrad per pixel. The optical performance was validated with experiments such as the resolution and shape measurement test. The scientific applicability was demonstrated by extracting the static angle of repose of regolith simulants EAC-1A and NU-LHT-2M, as well as the relative surface albedo through a photometric stereo method., providing deeper understanding into the physical and optical properties of lunar regolith analogues. The presented camera design offers a balance between performance with compactness, addressing challenges faced by conventional stereo cameras such as baseline constraints, environmental exposure, and computational efficiency. Further design limitations and stereo matching inaccuracies were identified during testing and characterisation. The stereo camera developed in this study demonstrates capabilities for high-resolution, in-situ lunar surface analysis based on regolith characterization and contributes to an in-depth understanding of lunar regolith properties by close-range scientific analysis of its geo-mechanical behaviour.

Keywords: lunar exploration, rover instrumentation, stereo vision, 3D reconstruction, monocular stereo camera, photogrammetry, regolith characterisation