National Aeronautics and Space Administration

FY23 Strategic Initiatives Research and Technology Development (SRTD)

ShadowNav: Lunar Absolute Localization in Darkness using Craters as Landmarks

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Strategic Focus Area: Long Range Lunar/Mars Surface Mobility | **Strategic Initiative Leader:** Larry H Matthies

Objectives:

The overall objective of this task was to develop and validate autonomous absolute localization for long-range Lunar navigation in the dark. Specifically, to utilize crater rims as landmarks which are detected on the surface and matched with a known orbital crater. The target metric is to correct for up to 10m absolute position error to under 5m absolute position error.

Figure 1: data collection rig and rig capturing a crater at night.

Significance/Benefits to JPL and NASA:

The new Decadal Survey recommends the Endurance-A Lunar rover mission should be implemented as a strategic medium-class mission as the highest priority of the Lunar Discovery and Exploration Program.

- Endurance will need to conduct ~70% of drive during the night because the majority of day hours must be spent for science and sampling.
- Key capabilities needed for autonomous surface operations include navigation, pose estimation, instrument deployment/placement, and global localization (i.e., determining the vehicle's location relative to orbital maps).
- Global localization is necessary to maintain an error of < 10 m relative to the orbital maps.

Background:

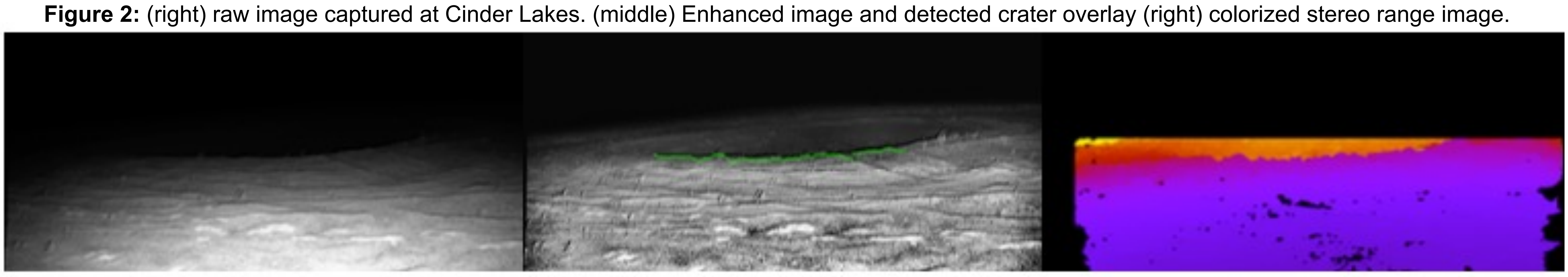
JPL conducted three Planetary Mission Concept Studies on long-range Lunar rovers as inputs to the 2022 Decadal Survey: (1) Endurance [2], (2) Inspire, and (3) Intrepid. ~70% of the total distance of Endurance-A and ~75% of Inspire must be driven at night to allow sufficient time for day-time science activities. Therefore, the Endurance and Inspire studies found that both of these rovers need onboard absolute position estimation against orbital map at night and in shadow, which did not exist before ShadowNav.

Approach and Results:

Craters are the most abundant terrain features on the Lunar surface and therefore are promising to use as landmarks for absolute localization. To perform this localization using craters, we propose an approach in which crater rims are detected in surface imagery and matched with known craters within an orbital map. Using a stereo camera and an external illumination source, craters can be detected by discontinuities in the disparity image. To localize these detections in the context of an orbital map, we utilize a particle filter with each particle representing a possible pose of the rover. Based on each pose, the detected rims are compared to the orbital map and evaluated for overlap. The particle filter predicts both the position of the rover and an uncertainty based on the scores of all of the particles. We validate this approach in simulation and on data collected at Cinder Lakes Apollo Training Area. Figure 1 shows the data collection rig at Cinder Lakes, Figure 2 shows a perception sample from Cinder Lakes, and Figure 3 shows results for absolute localization along multiple different trajectories collected at Cinder Lakes.

Figure 3: Histogram of Monte Carlo final absolute errors on Cinder Lakes trajectories

Figure 2: (right) raw image captured at Cinder Lakes. (middle) Enhanced image and detected crater overlay (right) colorized stereo range image.



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Publications:

Cauligi, A.*, Swan, R. M.*, Ono, M., Daftry, S., Elliott, J., Matthies, L.. Atha, D., "Shadownav: Crater-Based Localization for Nighttime and Permanently Shadowed Region Lunar Navigation." in IEEE Aerospace 2023. *equal contributions

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