TBD

Advancement of Deep Learning and Geometric Methods for Active Terrain Relative Navigation

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EXECUTIVE SUMMARY

To enhance NASA's precision landing capabilities, in conjunction with the development of a novel active terrain relative navigation (ATRN) and terrain mapping system, denoted SHERIF, this work performed a comparative analysis between both deep-learning (DL) based and geometric approaches to hazard detection (HD) and safe-site-identification (SSI) through hardware-in-the loop testing on the Six degree-of-freedom Tendon Actuated Robot (STAR).

The Standalone Hazard Evaluation and Refinement using Instrument Findings (SHERIF) system is capable of ingesting sensor data at an asynchronous rate, stitching successive terrain scans together to yield a high-resolution digital elevation map (DEM), performing absolute and relative localization using novel 3D feature extraction and matching methods, and HD/SSI activities.

The DL-based HD/SSI algorithm provides a modular alternative to classical geometric approaches which have performance times that scale with map resolution. As the adoption of AI solutions become more prevalent for autonomous system decision making, it is prudent to explore the utility of such solutions in applications where they traditionally excel, such as image classification. Along with the development of a DL-based HD system, this work performed the first comparative analysis between DL and geometric approaches to HD/SSI using real sensor data from real-time testing in a relevant environment.

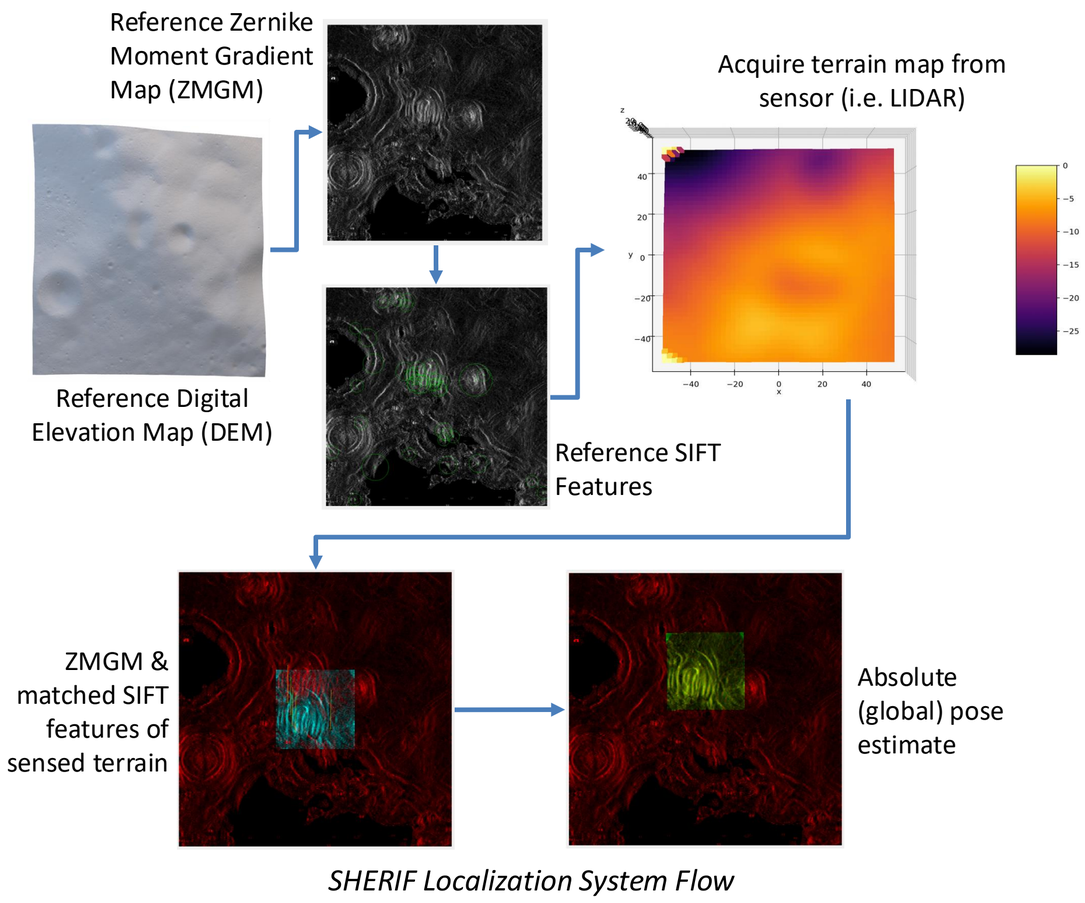
INNOVATION & BENEFITS

Improving upon the state-of-the-art for localization error during precision landing operations which is on the order of kilometers, SHERIF enables localization with precision on the order of 1-10 meters, depending on the resolution of the incoming scans and the availability/quality of a reference DEM, satisfying precision landing requirements for future manned/robotic exploration missions to sites exhibiting challenging lighting conditions.

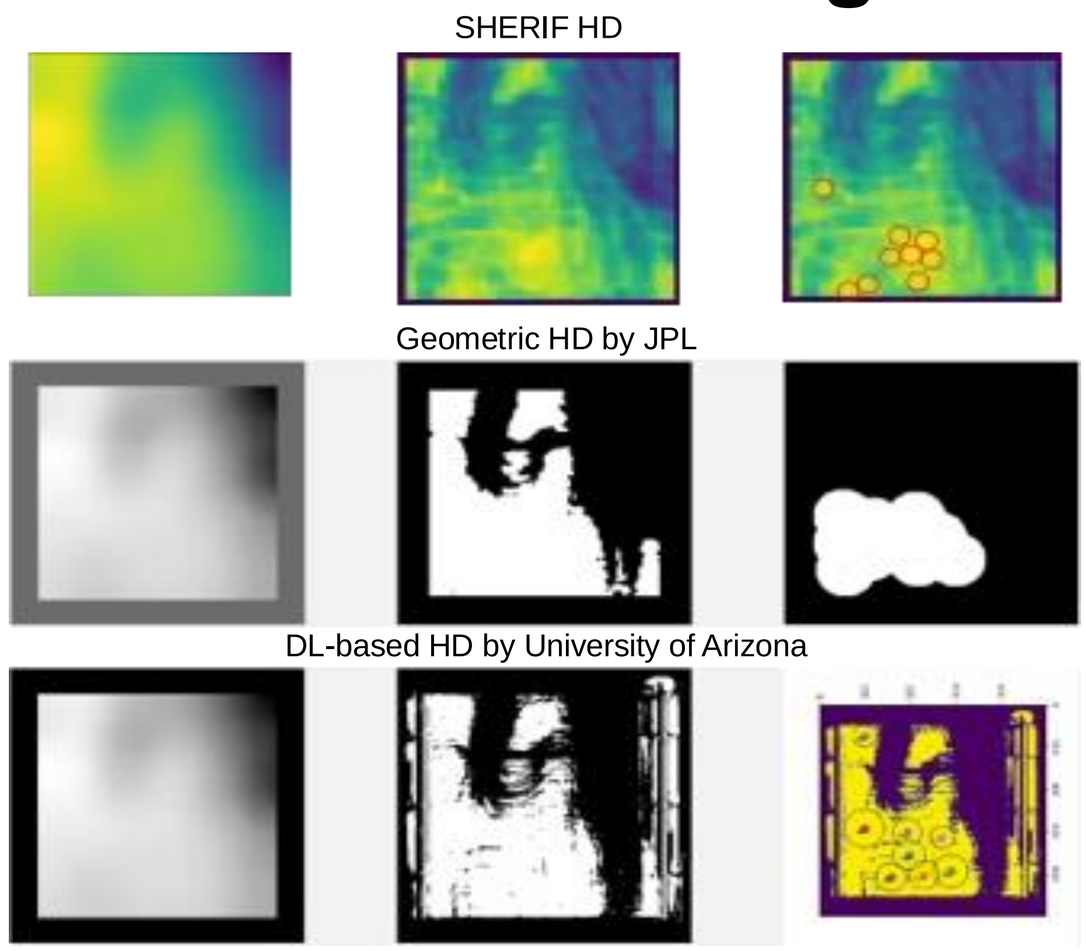
This work also generated two new, light-weight approaches, one geometric and one DL-based, for digital elevation map-informed hazard detection and safe-site-identification/selection. These methods will aid in the verification of existing solutions and expand the range of options for GN&C system developers seeking HD/SSI capabilities for precision landing operations.

COLLABORATION

1. University of Arizona – DL-Based HD/SSI research and development
2. NASA JPL – Baseline HD/SSI algorithm for comparative analysis
3. SPLICE Project – Aid in requirement and CONOPS definitions, key stake-holder
4. University of Texas at Austin - Aid for HD/SSI research
5. Georgia Institute of Technology – Aid for ATRN research

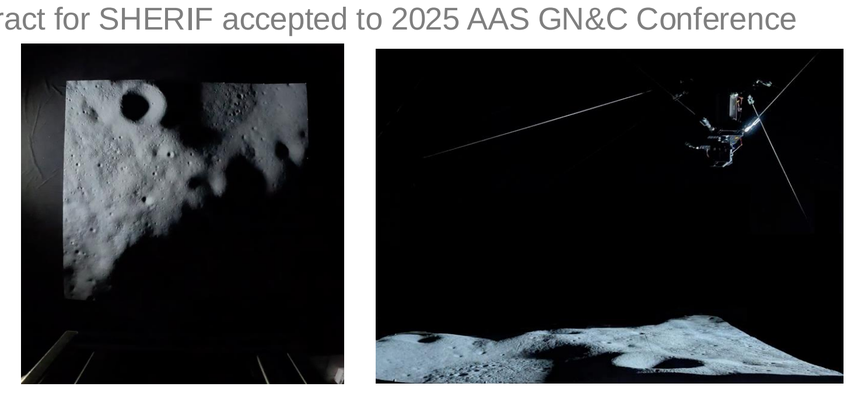


SHERIF Localization System Flow



OUTCOMES & INFUSION

- Developed Aeva Aeries II 4D LiDAR sensor payload
- Managed development, training, and testing of deep learning-based hazard detection and safe-site selection algorithm
- Created novel algorithm to extract, characterize, and match 3D key points from a digital elevation map in a rotationally and scale invariant manner using 3D Zernike moments
- Matured SHERIF system to real-time pipeline
- Performed HWIL testing using A2L sensor payload and new mock lunar terrain tiles in SENSS lab to evaluate the performance of SHERIF and perform comparative analysis of geometric vs. DL-based HD/SSI systems
- Abstract for SHERIF accepted to 2025 AAS GN&C Conference



HWIL Testing with mock Lunar Terrain in SENSS Laboratory

- Developed algorithms and code in accordance to accurate CONOPS for precision landing operations agnostic to navigation sensor, vehicle configuration, or flight profile
- Navigation algorithms are applicable to operations where any 3D terrain mapping sensor is utilized, i.e. surface navigation
- Plans to develop cFS application capable of performing continuous DEM refinement and absolute and relative localization without reliance on peripheral sensors
- Plans to infuse with SPLICE navigation system following CIF Year 2 effort; pursuing infusion with CLPS providers

NEXT STEPS

1. Year 2 CIF awarded - FY25
2. Develop cFS application
3. Validate with flight data from SPLICE helicopter flight test campaign (scheduled for Q2 FY25)
4. Integrate software library into SPLICE FSW system
5. Perform HWIL testing on flight software in simulated environment
6. Run SHERIF on integrated flight test

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