From Mars to the Moon: Lessons Learned from Using the Autonomous Soil Assessment System (ASAS) in the Semi-Autonomous Navigation for Detrital Environments (SAND-E) project

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Motivation

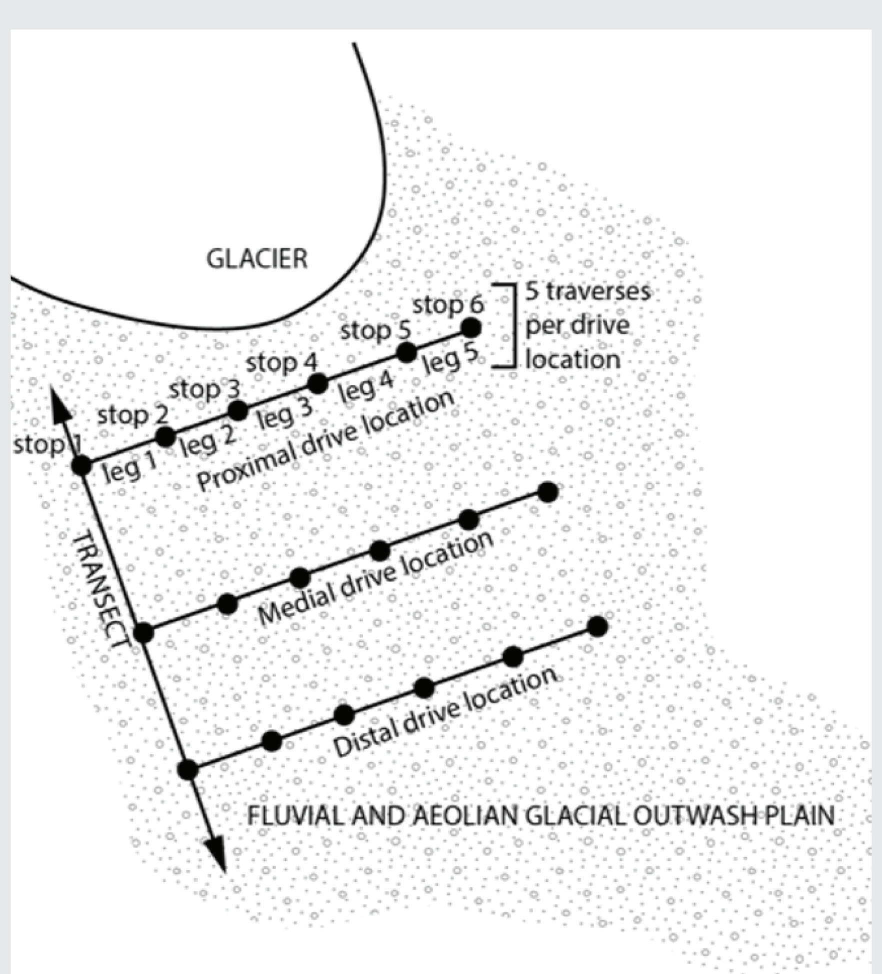
Does automated terrain classification improve scientific return?

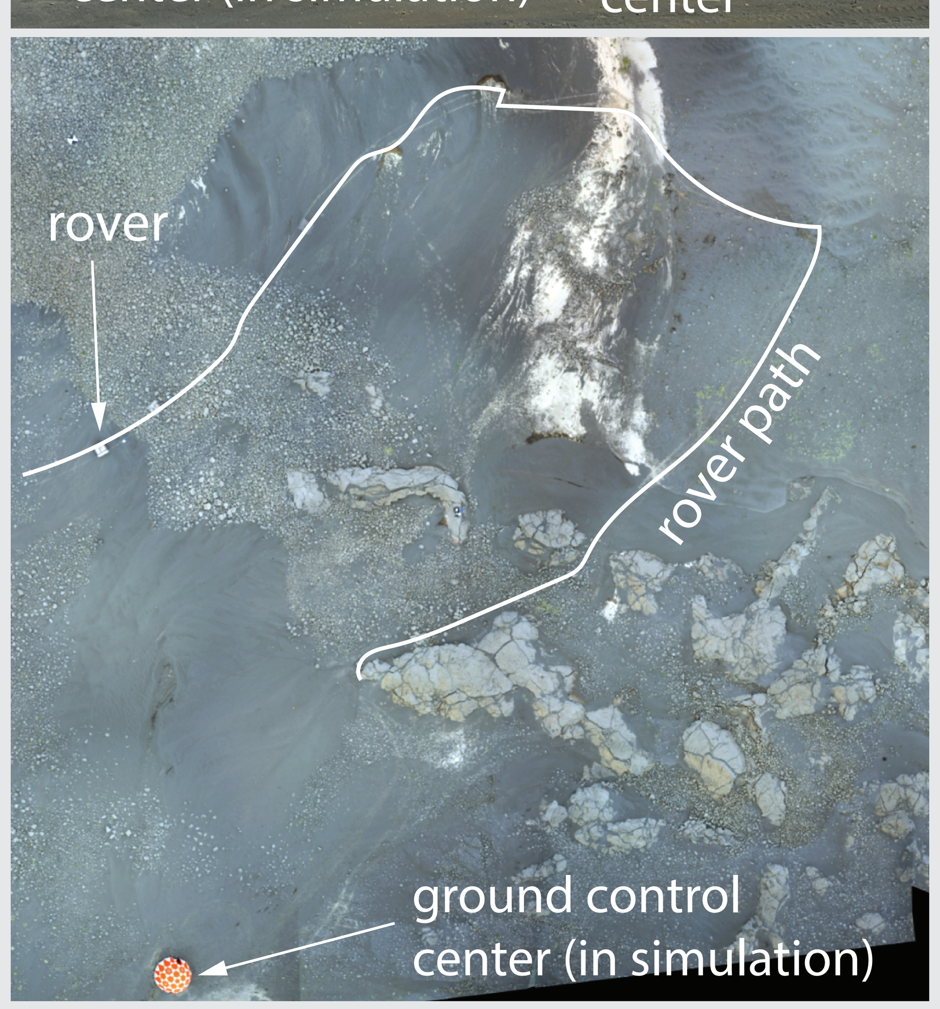
How does automated terrain classification integrate to existing rover operation workflows?

SAND-E is analog science and operations project supported through NASA's Planetary Science and Technology through Analog Research (PSTAR). The project tests robotic operations for science exploration in environments analogous to those found on the Mars. Part of this project examines the capability and efficiency of automated terrain analysis in science operations. Here, we discuss the technology of the Autonomous Soil Assessment System (ASAS) used to characterize basaltic volcanic terrains and the results of its deployment during a scientific investigation.

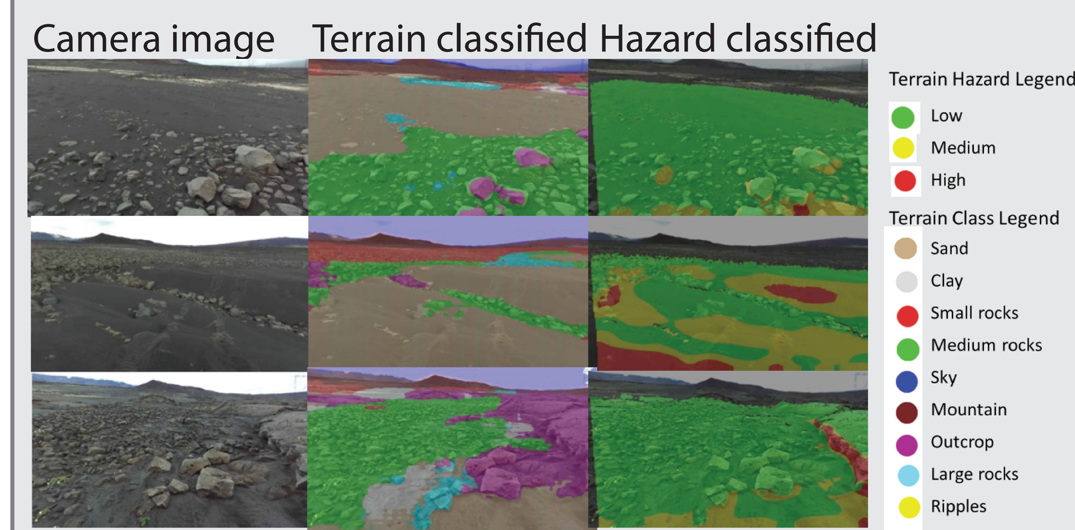
SAND-E Iceland Operations Concept

Six Scenarios
1. MSL *Curiosity*-like rover operation ; 2. Rover with ASAS; 3. 'Walkabout'; 4. Rover with UAS - area restricted to 40 m x 60 m; 5. Rover with UAS - area of entire field area and ASAS; 6. Field geologists walking approximate strategic path.





The Autonomous Soil Assessment System (ASAS)



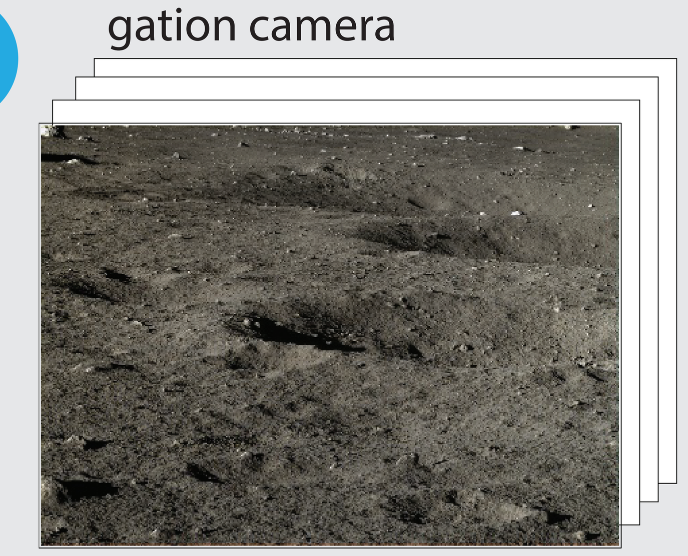
ASAS is a software-based system that comprises advanced image processing and machine learning technologies for two functions.

First, it classifies terrain types from a rover's navigation camera (Mars e.g., sand ripples, bedrock, clay; Moon e.g., craters, rocks, regolith tone) using deep learning models, in semantic segmentation fashion.

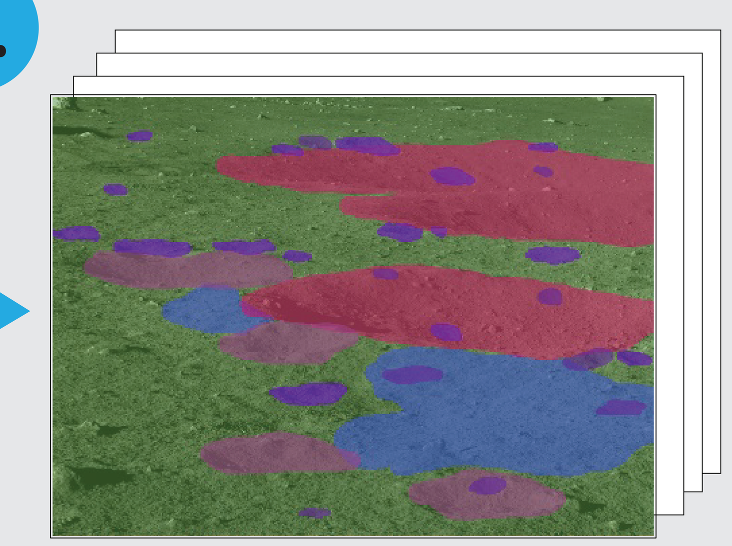
Second, it builds a data-driven trafficability model in real-time using a rover's standard navigation sensors; this is a model of wheel slip against terrain slope for a specific terrain type, which is then used to classify a hazard heuristic (high, medium, low).

ASAS enables a way to intelligently characterize terrain types and mobility hazards using the rover's own data

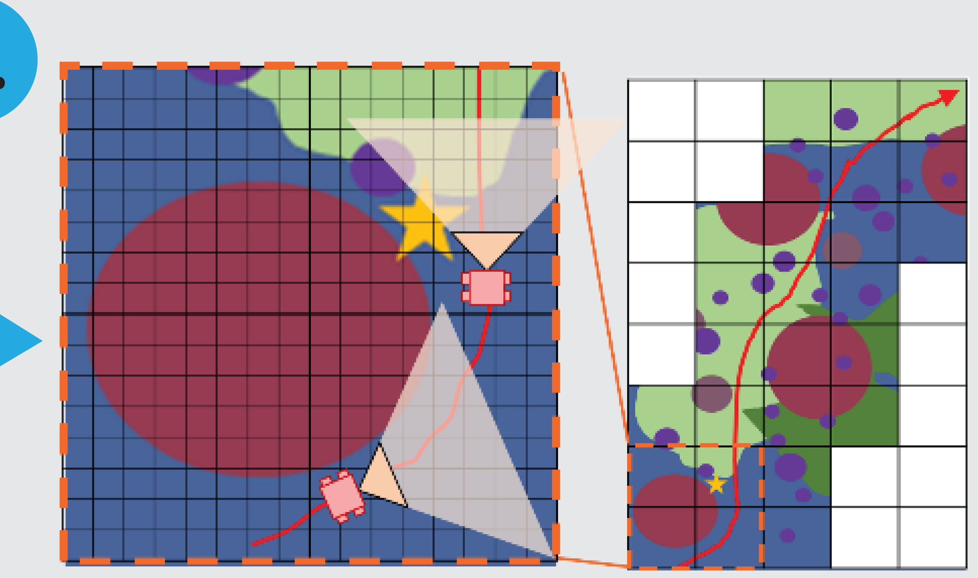
1. Images from Rover's navigation camera



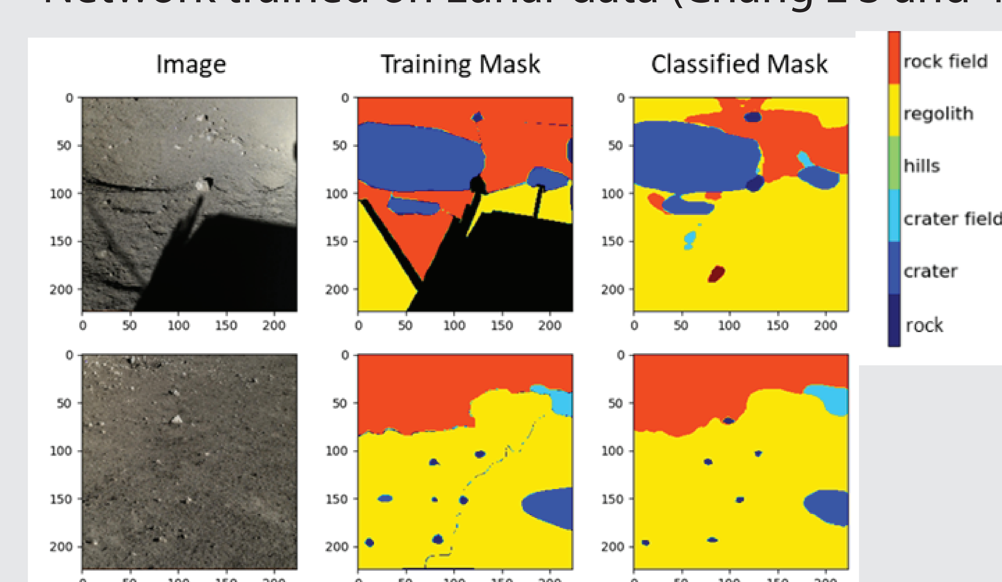
2. Classify terrain types and novel features



3. Aggregate data onto map tiles



Early prototyping results: Convolutional Neural Network trained on Lunar data (Chang'E 3 and 4)



4. Use outputs for autonomous decision-making onboard or support operations in the ground segment

Powering the AI

Integrated on COTS processor (Xiphos Q8S)

Algorithms profiled: 35Hz at 2.4W

Preliminary radiation analysis complete

Results and Lunar applications

ASAS was most useful to scientists during the 'walkabout' scenario, in which the rover traverses the terrain prior to scientists seeing any data. In this scenario, scientists used the classifications to quickly assess terrains in the study area.

During typical scenarios, ASAS data compounded other scientific data, resulting in cognitive overload for the scientists. In these scenarios, ASAS was not frequently used for scientific path-planning or targeting.

ASAS will be valuable for rapid exploration and decision making during lunar exploration and prospecting. On-board processing and downselection of data using these autonomy methods will streamline operations and provide automated, high-level scientific decision making.