ONBOARD ROVER END-OF-DAY AND TRAVERSE SCIENCE

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Introduction:
Onboard autonomous science represents one means to balance the large amounts of scientific data that future rovers can acquire with the limited ability to download it to Earth. Several systems are under development to perform autonomous rover science. The Onboard Autonomous Science Investigation System (OASIS) was used in the first formal first formal demonstration of closed loop opportunistic detection and reaction during a rover traverse on the FIDO rover at NASA's Jet Propulsion Laboratory. We have incorporated and demonstrated an end-of-traverse capability that includes taking a partial panorama of images, assessing these for target of interest, and collecting a narrow angle image of the selected target.

Historically, much emphasis in developing onboard science systems has been on the onboard science capability itself. However, the use of onboard science systems represents a departure from standard operations, which closely resemble batch tele-operation. It is important for the science operations team to understand the capabilities and limitations of the onboard system to effectively use the tool of autonomous onboard science to increase overall mission science return, however it is difficult for the science team to get a feel for the onboard system without hands on experience in an operational system setting. This past year, the OASIS team worked with the SOOPS (Science Operations On Planetary Surfaces) [1] task to investigate how science returns for surface missions can be improved through the use of science autonomy.

Field Testing:
Field testing of the OASIS system this year included demonstration of the robust capability to perform autonomous end-of-day science. By analyzing image data onboard, OASIS can autonomously select targets for narrow-field-of-view instruments and execute a set of data collection activities while ensuring that rover resources are not exceeded. These techniques could be used, for example, on the Mars Science Laboratory mission to select targets for the ChemCam instrument to sample.

To select potential targets, a navcam image panorama of the surrounding area is taken, and then using the OASIS rockfinder, rocks in the scene are autonomously identified. Next, a subset of those rocks are selected and prioritized based on scientist-selected criteria using the OASIS target signature algorithm. For instance, the target signature could be based on rock shape, albedo or size. Once a subset of target rocks is identified, points on these rocks are selected as specific instrument targets.

Since only a limited amount of time or resources may be available to take these measurements, the OASIS planning and scheduling subsystem is used to only schedule measurements that can be safely executed based on the rover health and current state. If not all additional measurements can be added due to resource or other constraints, the planner iteratively deletes the lower priority measurements first.

To test OASIS on this application, we have conducted a significant number of tests with the FIDO rover. For testing, the rover would drive to an end-of-day location, where it would then take a full (or partial) panorama with the rover navigation cameras. Images were then analyzed by OASIS for rockfinding and target identification. For this testing, our target signature was to prefer larger rocks for targeting, where this specification was suggested by the MSL ChemCam PI. An example image used to select targets and the resulting measurement (taken with the pancam) are shown in Figure 1.

Operations Testing:
While the field testing was focused on reliable and repeatable system performance, a limited version of OASIS was tested in an operational environment. Several science operations teams tested the system in the context of the SOOPS task using a high-fidelity software simulation of a rover (ROAMS [2]) exploring a remote terrain and realistic operational interfaces (Maestro [3]). The simulation environment combined with the integrated operational system provided situational awareness for the science operations teams.

In the tests, OASIS applied predetermined criteria provided by the scientists to prioritize which image data collected during a traverse to send home, given specified bandwidth constraints. In addition, rock summary information (which requires very little bandwidth) was returned.

Interestingly, each of the four teams took a different approach to using OASIS. All teams expressed that if they were given another chance at developing new command sequences for OASIS, they would have done things differently. Conclusions from the experiments included the assessment that sequencing techniques for the most effective use of the onboard autonomy capability would require operational practice and experimentation. It was generally agreed that the simulation and testing environment were sufficiently realistic to understand and evaluate the operational capabilities of the OASIS tool. However, analysis of real rather than simulated data would be necessary to understand the selection criteria that OASIS used, use the selection criteria effectively to achieve desired science goals, and to judge the scientific utility of OASIS.

RockIT:
OASIS data products were displayed to the science operations teams in both the field testing and SOOPS operational testing using the OASIS Rock Identification Toolkit (RockIT). RockIT is a mature, cross-platform, graphical program originally designed to help geologists rapidly and accurately label rocks (or particles) in images. As images are labeled, RockIT reports both individual rock statistics and overall scene statistics. Golombek et al. [4] used RockIT to compare rock size distributions at several locations along the Spirit traverse. RockIT now has been adapted so that it can also serve as a visual front-end to the OASIS system. While RockIT is not required to use OASIS, when available it provides a window into the inputs and outputs of the OASIS system.

The main image display in RockIT shows images, range data, and rock detections. Selecting a particular thumbnail will display the full image, as well as range data overlay and rock detections for that image in the main display area. The data summarization table provides valuable features and statistics about each rock in the entire traverse whether or not the image of the rock was downlinked. The table is used to create an overhead map view that provides a meaningful way summarize the traverse (see Figure 2).

RockIT simulates data downlink prioritization buy not displaying images that fall below the downlink prioritization threshold. RockIT can run various OASIS prioritization schemes (including key target signature prioritization). We have found this simulated downlink feature to be particularly helpful in conveying the utility of OASIS to potential customers. Even if a particular image is not available, the data summarization table and overhead map provide a wealth of information about what was encountered during a traverse.

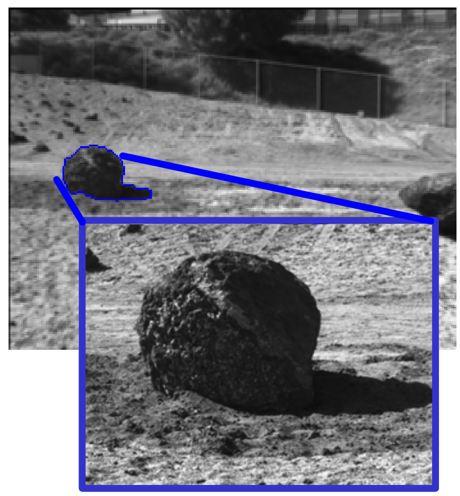

Figure 1. An example of a large rock autonomously selected and targeted by a limited FOV instrument on the FIDO rover (in this case, a high resolution panoramic camera).

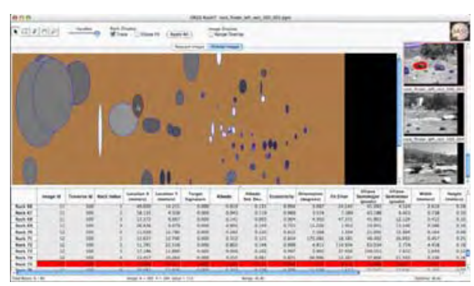

Figure 2. The OASIS Rock Identification Toolkit (RockIT) graphical user interface.

References: [1] Haldemann, et al., LPSC (2007). [2] Jain, et al., *iSAIRAS*, (2003). [3] Norris, el al., *ICRA*, (2005). [4] Golombek, et al, *Nature* (2005).