SCIENCE ALERT DEMONSTRATION WITH A ROVER TRAVERSE SCIENCE DATA ANALYSIS SYSTEM

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Introduction: The Onboard Autonomous Science Investigation System (OASIS) evaluates geologic data gathered by a planetary rover [1]. This analysis is used to prioritize the data for transmission, so that the data with the highest science value is transmitted to Earth. In addition, the onboard analysis results are used to identify science opportunities. A planning and scheduling component of the system enables the rover to take advantage of the identified science opportunity. OASIS is a NASA-funded research project that is currently being tested on the FIDO rover at JPL for the use on future missions.

OASIS currently works in a closed loop fashion with onboard control software (e.g., navigation and vision) and has the ability to autonomously perform the following sequence of steps: analyze gray scale images to find rocks, extract the properties of the rocks, identify rocks of interest, retask the rover to take additional imagery of the identified target and then allow the rover to continue on its original mission. We have conducted a number of tests of the combined system and individual components. We describe results for the system in detecting and reacting to a science alert, as well as the reliability of the rock finder and run time performance.

Integration with CLARAty: To test OASIS with rover hardware, our approach has been to integrate with the CLARAty robotic architecture [2]. CLARAty is a unified and reusable robotic software architecture that simplifies the integration of new technologies onto different robotic platforms. For this testing, the OASIS rockfinder and planning and scheduling software were directly integrated with CLARAty and handled interaction with other key CLARAty elements that were required to run with rover hardware. Other pieces of OASIS (such as feature extraction) are planned for the future.

Science Alert: One of the modes of operation for OASIS is to search for specific targets during a traverse. These are targets that the science team has specified as important if encountered by the rover. When one of these targets is found, it is identified as a new science opportunity and a “science alert” is sent to the planning and scheduling component of OASIS. After reviewing the rover’s current operational status to ensure that it has enough resources to complete its traverse *and* act on the new science opportunity, OASIS changes the command sequence of the rover.

When a science alert occurs, the rover is instructed to stop its current traverse, locate the rock (target) that triggered the science alert, and take additional data (e.g., color image, closer grayscale image, spectrometer reading) on that rock. Once it has completed this additional measurement, the rover reverts back to its original plan and continues on its traverse.

We have performed a series of tests in the JPL Mars Yard using the FIDO rover to demonstrate the performance of the science alert capability of OASIS. Here we report results from 10 of our most recent runs. These tests were conducted on four different (non-consecutive) days. The runs had an average of 13 images. The criteria specified was based on albedo – identify rocks that were white. An example is shown in Figure 1. The goal was to detect targets if they are within approximately 3m of the forward field of view of the rover as it proceeds along the traverse. Each run had between one and seven targets that the rover encountered within the goal detection range. Over the 10 traverse test runs, this consisted of 40 total target rocks. 36 of these targets were detected (85% detection rate). There were no false alarms during any of the ten runs.

The 85% detection rate indicates how many of the targets were identified at some time over the course of the traverse. During a traverse, however, a target may be imaged multiple times. Over the 10 runs, there were 82 instances of the targets appearing in an image within the detection range. Individual targets were imaged between 1 and 6 times. Of the six targets that were missed, three of these appeared in a single image and three appeared in two images. No target that appeared in more than two images was missed.

Rock finder performance: To identify targets, the rocks are first detected and then properties of the rocks extracted. This relies heavily on the performance of initially finding the rocks in an image. Further, automated detection of rocks in Mars rover images is also a useful ground-based endeavour to alleviate the tedious task of manual effort necessary for rock density analyses as in [3]. In addition to the system testing for science alert described above, we have tested the performance of the rock finder [4] individually. The performance of the rock finding algorithm is measured by comparing the rocks identified in an image by the algorithm the rocks manually identified in the image. Two types of comparison have been used in scoring the labels returned by the rock finder. Candidate rocks produced by the rock finder are compared with the hand labeled rocks based on either the distance between the centers or the number of overlapping pixels. Precision and recall were measured. Scoring, or the matching of detected rocks to hand labeled rocks, establishes the number of True Positive (TP), False Positive (FP), and False Negative (FN) detections.

The performance metrics of Precision is calculated for each of the two scoring methods. Precision is the fraction of total rocks detected that appear in the hand labeled set, Precision = TP / (TP + FP). Precision captures the degree to which the detector finds only rocks; precision is the percentage of objects identified by the rock finder as rocks that are truly rocks. A high precision directly corresponds to a low false alarm rate.

Precision numbers are given for a total 110 of FIDO hazcam images and 2942 total rocks analyzed. The two scoring methods show similar results. The average precision per image using the center matching method was 89%, while the average precision using the overlap method was 87%. 83 images had higher than 90% precision. We are currently evaluating the precision as a function of distance to the rock.

OASIS component run times on FIDO: In addition to testing the rate of detecting targets, as part of our testing, we gathered preliminary statistics on the run time of key OASIS components. While we have not spent significant time optimizing the performance of these components, the numbers provide a general idea of current performance and provide a reference to track future improvements. In a representative run, the OASIS rockfinder processed 11 hazcam images resulting in 5 science alerts being sent to the planner. The rockfinder was run on a 233 Mhz Pentium processor running VxWorks 5.5 with 128 MB of RAM. Rockfinder took an average of 53 seconds to process each image and found about 9 rocks per image with a total of 103 rocks being identified for the 11 images. The OASIS feature extraction component was run on a 930 Mhz Pentium processor running Linux 2.4 with 256 MB of RAM. For the current tests, albedo and shape information were extracted for each rock. For the 11 images processed, feature extraction averaged 0.5 seconds per image. The planning and scheduling component ran on a 2.5 GHz Pentium processor running Linux 2.4 with 1 GB of RAM. In handling the 5 science alerts, the planner spent an average of 6 seconds generating a plan for each alert.

References: [1] Castano, et al., *IEEE Aerospace*, (2005). [2] Nesnas, et al., *SPIE Aerosence* (2003). [3] Golombek, et al, submitted *Nature*. [4] Castano, et al, *LPSC* (2004).

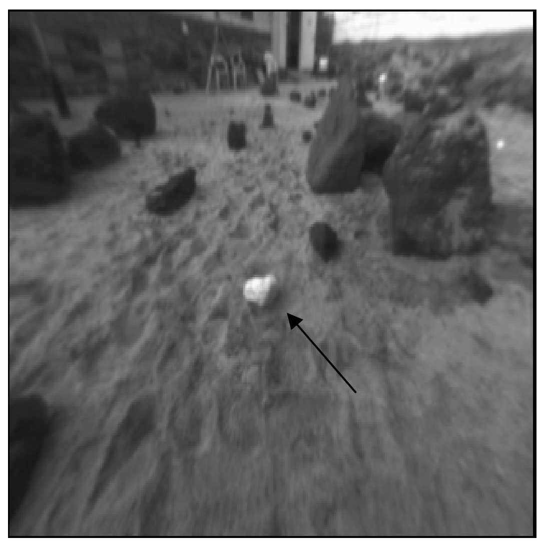

Figure 1. FIDO image. Target rock is indicated by an arrow. This rock was successfully identified.