TOOLS FOR AUTONOMOUS ROVER SCIENCE: PREPARING FOR ANALOG FIELD EXERCISES

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Introduction: The autonomous rover project of the Toolbox for Research and Exploration (TREX), a NASA SSERVI node, is investigating tools and techniques designed to improve operational efficiency and science yield of future rover missions.

Central to our investigation is the concept that rover activities should not be prescribed uniquely by a tight operator/robot iterative process that often reflects limited knowledge of the field area; instead, it should be open-ended and responsive to ongoing observations, even without iterative operator feedback. We propose that robotic explorers should be able to plan traverses and observations that address driving hypotheses and require little to no input from outside operators. Periodically, or when the robotic explorer encounters circumstances that fall outside the realm of expected observables, the robotic explorer contacts the operator to offer updates or request new directions.

Our approach transforms the relationship from one in which the science/operations team “joysticks” every aspect of the mission, into a collaboration in which the human and robot work together. This strategy is expected to improve operations efficiency and increase science yield.

Approach: We are integrating multiple tools onto Carnegie Mellon’s intelligent robotic testbed in order to enable the rover to 1) autonomously perform observations and analyses, 2) identify targets for contact studies and sample collection, and 3) report higher-level findings. These tools include a new decision-making technique known as the hypothesis map [1,2] and the Tetracorder system [3-5]. The rover’s instrument suite includes spectrometers observing in the 0.2–14 µm range - a spectral region containing a broad range of mineralogically diagnostic features - as well as a gamma ray spectrometer and an X-ray diffractometer.

Hypothesis Map: The hypothesis map represents the basis for decision-making and reporting undertaken by the robot. It contains a set of hypotheses to be explored (*e.g.*, the geologic history of a field site), and observables that allow these hypotheses to be weighted (*e.g.*, mineralogy) as measurements are acquired and interpreted. Given this map and its associated uncertainties, the rover calculates and executes a traverse profile that optimizes for uncertainty resolution, terrain, and resources. Throughout the traverse, the rover performs observations with its instrument suite and interprets the data, stopping to contact the science team at predetermined waypoints or when it makes unanticipated findings.

Tetracorder: A Tetracorder module operating in real-time on the rover’s computer will allow the rover to constrain mineralogy and address the hypotheses it is tasked to evaluate. The Tetracorder system consists of a family of algorithms and tools that allow interpretation of spectral data. It has been central to dozens of studies on Earth, other planets, and moons [3-5] and has verifiably delivered robust mineralogical interpretations in numerous settings.

Implementation: In our work, the hypothesis map is generated by the science team from analyses of remote sensing data of the field site. It corresponds to an image cube whose rows and columns correspond to the spatial extent of the site, and each plane corresponds to a different geologic origin. Pixel values correspond to the relative probability of a geologic origin at a given location (Fig. 1). Uncertainty is in turn ascertained by the number of possible geologic origins with nonzero probability values. The rover then uses the cube and associated uncertainties to implement a traverse with the objective of reducing uncertainty in geologic origin.

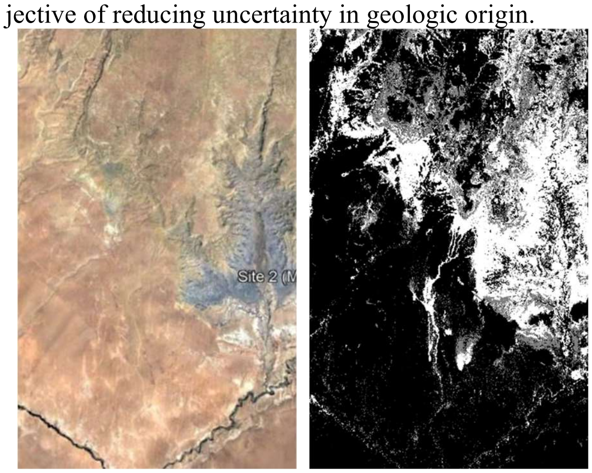

Fig. 1. (Left) True-color aerial image of analog field site at the Painted Desert. (Right) Sample plane from geologic origin cube describing likelihood of a pedogenic origin (higher values correspond to higher likelihood). Image width is 10 km across.

References: [1] Thompson, D. R., *et al.* (2011) *J. Field Robotics, July / August*. [2] Candela, A., *et al.* (2017) *IEEE Intl. Conf. on Intellig. Robots and Systems.* [3] Clark, R.N., *et al.* (2003) *JGR* Vol. 108(E12), 5131. [4] Clark, R. N., *et al.* (2010) *JGR*, 115, E10005. [5] Clark, R. N., *et al.* (2012) *Icarus* 218.