Field Testing of Rover GN&C Techniques to Support a Ground-Ice Prospecting Mission to Mars

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Extended Abstract

This presentation will provide an overview of an integrated field campaign that demonstrates the viability of the key rover guidance, navigation, and control (GN&C) technologies required to carry out a ground-ice prospecting mission to Mars. Tests were conducted on Devon Island in the Canadian High Arctic.

Environmental conditions on Mars today are such that any water reserves will be in the form of ice, either in the polar caps or as ground ice at lower latitudes [1]. Deposits of ground ice may be key sites for future human exploration missions due to the possibility for in-situ resource utilization. For example, polygonal terrain (a network of interconnected trough-like depressions in the ground) is a landform commonly found throughout the polar regions of both Earth and Mars [5], which can contain ground ice. On Mars, the recent Phoenix mission [6] appears to have confirmed the presence of an ice-bonded substrate in polygonal terrain, but the nature of underlying massive ice bodies has not yet been determined.

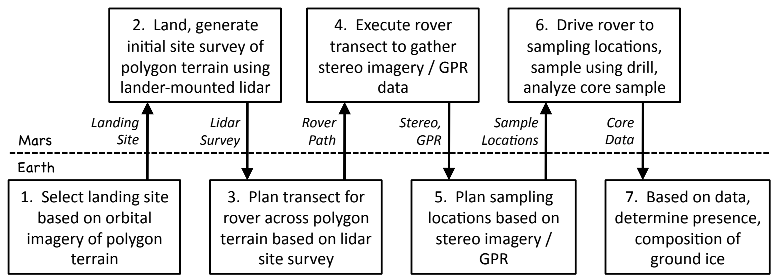

Fig 1: Operational steps of ground-ice prospecting mission.

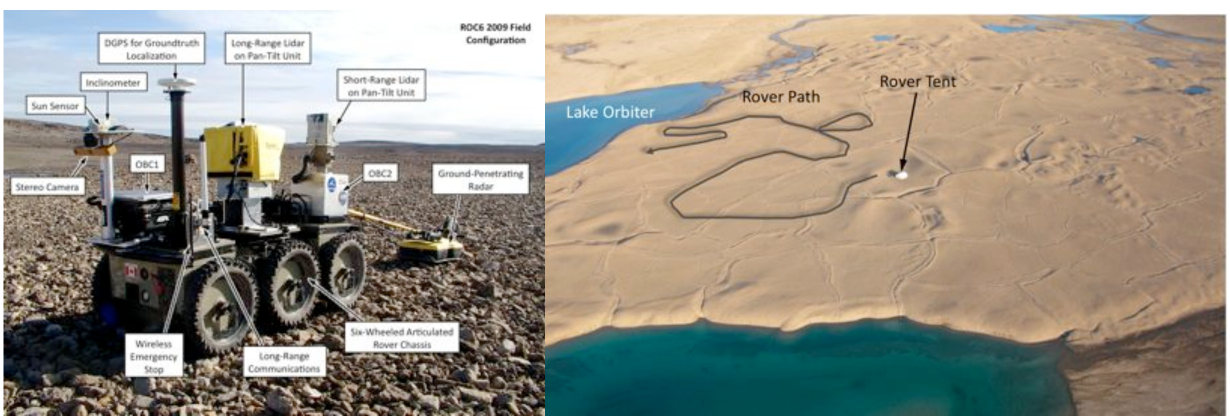

Fig 2: (left) Rover equipped with lidar, stereo camera, and GPR. (right) Aerial view of Lake Orbiter polygon site on Devon Island with rover traverse shown (photo: Haughton-Mars Project)

We have been investigating a concept, perhaps as a follow-on to the Phoenix mission, to carry out ground-ice prospecting using a rover equipped with a lidar (Light Detection And Ranging), a stereo camera, and a ground-penetrating radar (GPR) [1]. The main operational steps of our mission concept are shown in Fig 1. A landing site (e.g., containing polygonal terrain) is selected based on orbital imagery; the system lands. A large-scale initial site survey (out to a few hundred meters) is gathered using a lidar. A path is carefully planned (by a human) for the rover to traverse the terrain (e.g., crossing polygon boundaries perpendicularly to enable GPR scans). The rover (see Fig 2) drives the path, using visual odometry (VO) for motion feedback, while gathering information about the surface (using the stereo camera) and the subsurface (using the GPR). A coupled surface-subsurface model is created based on the VO motion estimate and the stereo/GPR data (see Fig 3) [4]. Based on the stereo/GPR model, potential ground-ice deposits are identified for sampling. The rover uses a visual back-tracking technique [3] to return along its path to the sample locations (and possibly all the way to the lander/ascent vehicle in the case of a sample return scenario).

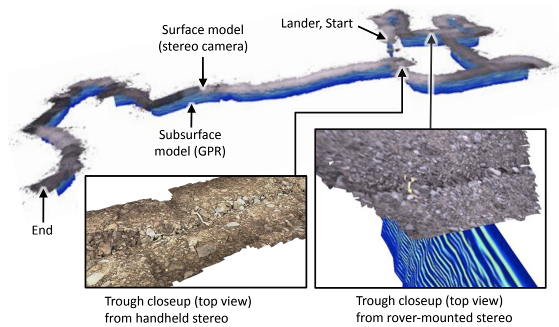

Fig 3: Coupled surface-subsurface model.

We field tested the rover GN&C technologies associated with this mission concept during the summer of 2009 on Devon Island near Lake Orbiter, at 75.493046° N and 89.883164° W. Fig 4 shows three sequential rover traverse legs (346m, 235m, 153m). For each of the three legs, a lidar scan was gathered, a path planned manually, the path driven outward using VO, and driven inward using visual back-tracking. At the end of each leg, the rover's localization was reset by aligning the next lidar scan to the previous one. Our most significant lesson learned to date is that either shorter legs must be driven to limit the growth of error in the VO motion estimate, or higher accuracy VO is required. This can be gleaned from Fig 4, wherein the rover gradually diverges from the planned path on the first two legs. Despite the position error accumulated in the outbound pass, visual back-tracking still returned the rover very accurately along its own path to the start. In conclusion, we believe that we have a viable mission concept and that the enabling rover GN&C technologies required are currently available, but may require modest boosts in performance.

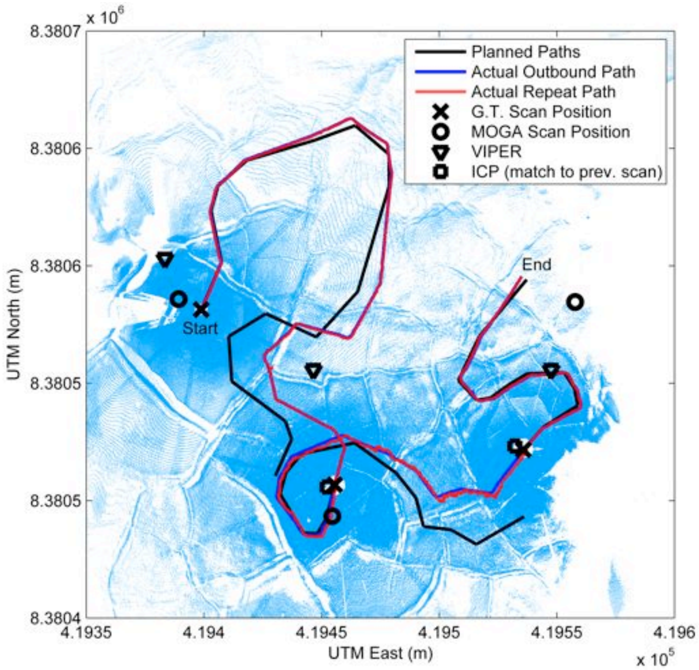

Fig 4: Three aligned lidar site surveys with sequential rover traverses overlaid. Planned path, actual outbound path (driven using VO), and actual repeat/inbound path (driven using visual back-tracking) are shown.

The presentation will provide a summary of the GN&C techniques used in this mission concept (i.e., VO, long-range localization, visual back-tracking, surface-surfacing modeling, sun-sensing), focusing on the results of several field experiments conducted in the Canadian High Arctic on Devon Island during the summers of 2008 and 2009.

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[2] Carr, M. H. (1996). *Water on Mars*. Oxford University Press, New York.
[3] Furgale P T and Barfoot T D. "Visual Teach and Repeat for Long-Range Rover Autonomy". Submitted to the Journal of Field Robotics, on Sept. 30, 2009. Manuscript # ROB-09-0081.
[4] Furgale P T, Barfoot T D, Osinski G R, Williams K, and Ghafoor N. "Field Testing of an Integrated Surface/Subsurface Modeling Technique for Planetary Exploration". Conditionally accepted to the International Journal of Robotics Research, on September 29, 2009. Manuscript # IJR-09-0636.
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[6] Smith, P. H. et al. (2008). "Introduction to special section on the Phoenix mission: landing site characterization experiments, mission overviews, and expected science". Journal of Geophysical Research, 113(E00A18).