Field Testing of Utility Robots for Lunar Surface Operations

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1. Background

One of the central challenges for lunar exploration is to develop and validate the systems needed for lunar surface operations. In particular, outpost missions will require numerous tasks to be performed on the lunar surface that cannot be achieved through human EVA alone. For example, comprehensive site surveys (for site planning, resource prospecting, geological characterization, etc.) require hundreds of measurements and hundreds of hours of survey time. In comparison, the total duration of lunar surface EVA of Apollo 11 through 17 was approximately 80 hours.

For the past three years, the NASA Ames Intelligent Robotics Group has been developing teleoperated and supervised "utility" robots to perform routine, tedious, highly repetitive, and long duration tasks that would be unproductive for crew to perform manually. Our approach is to automate low-risk, site operations that do not normally require robots to operate in close, physical proximity to EVA crew and that do not require human-paced interaction or continuous control.

2. Visual Inspection

In 2006, we used the NASA Ames K10 planetary rover to perform a remote "walk-around" visual inspection of the NASA Johnson SCOUT crew rover (Bualat, Edwards, et al. 2007). Our goal was to provide a remote human operator (e.g., ground control) with imagery of sufficient resolution and dynamic range to assess vehicle integrity after a sortie.

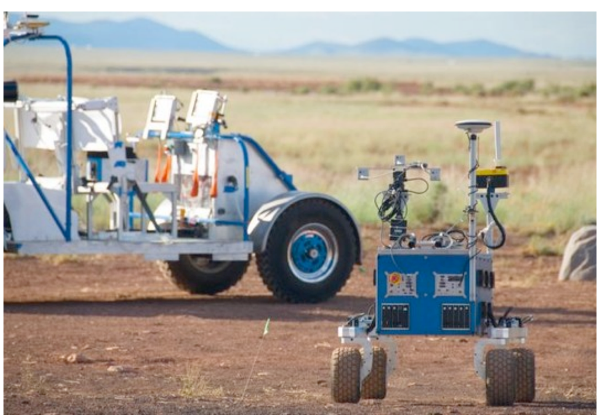

Figure 1. The K10 "Blue" rover inspecting the SCOUT crew rover at Meteor Crater.

During inspection, K10 automatically collected high-resolution, high-dynamic range imagery from multiple locations around Scout. This imagery was then transmitted to the control station, where they were stitched into interactive panoramas. Figure 1 shows K10 and Scout during a field test at Meteor Crater, Arizona (Diftler, Ambrose, et al. 2007).

3. Mapping Survey

In July 2007, we used two K10 rovers to map several simulated lunar sites during a field test at Haughton Crater, Canada (Fong, Allan, et al. 2008). The K10 rovers carried a 3D scanning lidar for topographic mapping and ground penetrating radar (GPR) to map subsurface structure.

Rover operations were designed to simulate a near-term lunar mission, including use of orbital data, interactive robot user interfaces, and remote operations procedures for intra-vehicular activity (IVA) and ground-control. The Haughton-Mars Project base camp served as a proxy for a lunar outpost. During three weeks of operations, the two K10's drove a total distance of 45 km (almost entirely autonomously) and returned more than 25 GB of survey data (Figure 2).

Figure 2. K10 "Red" mapping terrain at Haughton Crater with 3D scanning lidar.

4. Resource Prospecting

In September 2007, we integrated the HYDRA neutron spectrometer (Los Alamos National Laboratory) and a Californium-252 source on to a K10 rover (Elphic, Kobayashi, et al. 2007). We then used the system to prospect for near-surface hydrogenous deposits, such as might be found in permanently shadowed polar craters on the Moon.

A relatively level test site at ARC served as a proxy for the lunar surface. Within the test area, buried sheets of polyethylene and gypsum served as proxies for hydrous minerals and interstitial (pore) ice. During the test, a series of parallel transects were driven to locate potential deposit locations, followed by tight spirals to characterize each location.

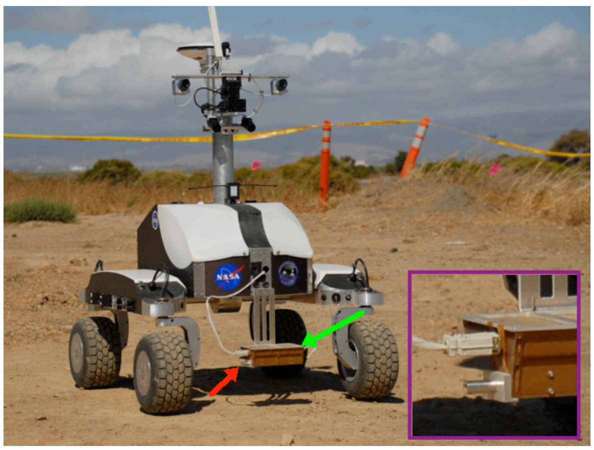

Figure 3. K10 "Black" with the HYDRA neutron spectrometer (green arrow) and a Ca-252 neutron source (red arrow).

5. Future Work

During 2008, we will use our K10's to perform several outpost support functions robotically:

- *Mobile camera platform*. A K10 equipped with a pan-tilt-zoom camera will provide controllable and repositionable views of a remote worksite. Mobile site cameras are important for task performance, for safety monitoring, and for documentation.
- *Wireless communications mapping*. A K10 will be used to systematically map wireless data network coverage around a simulated lunar outpost, with emphasis placed on identifying "dead zones" and maximum reliable range.
- *Surface communications deployment*. A K10 will be used to deploy wireless communication relays. These relays will provide "fill-in" coverage and provide on-demand, temporary networking (e.g., to support sortie operations).

We will field test these robotic functions in June as part of multi-center study of lunar surface operation scenarios. A key part of our testing will be to assess human-robotic system performance using three key metrics: (1) operator workload using NASA Task Load Index (TLX); (2) Mean Time Between Interventions; and (3) Mean Time to Intervene (Shah, Saleh, and Hoffman 2007).

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