Topographic Mapping and Rover Localization during the 2003 Mar Exploration Rover Mission Operations and New Developments for Future Landed Missions. R. Li, K. Di, B. Wu, W. Chen, J. Wang, S. He, J. Hwangbo, Y. Chen. The Ohio State University, Dept. of Civil & Env. Engineering & Geodetic Science, 470 Hitchcock Hall, 2070 Neil Avenue, Columbus, OH 43210, U.S.A. E-mail: li.282@osu.edu.

MER mission operations

In support of Mars Exploration Rover (MER) mission operations, researchers at the Mapping & GIS Lab of the Ohio State University (OSU) have been collaborating with JPL and many other mission teams in performing rover localization and topographic mapping on a daily basis since the landing of the two rovers in January 2004 [1, 2]. From thousands of Pancam and Navcam ground images, we have produced a) rover localization products including accurate traverse maps, horizontal and vertical traverse profiles, plus the Spirit drive metric; b) regular topographic products including DTMs and ortho maps, 3D crater models, and 3D maps of large topographic features; and c) special topographic products such as north-facing slope maps and solar energy maps. These topographic maps and rover localization data have been extensively used in tactical and strategic planning and operations as well as various scientific investigations.

On-board rover localization is performed using wheel odometry, IMU (Inertial Measurement Unit), and a Sun positioning technique using Pancam imagery. A visual odometry technique is applied in order to correct errors caused by wheel slippage and ensure safe drives over difficult terrain as well as to provide high precision approaches to science targets within a relatively short distance [3]. In order to achieve high accuracy over long distances, incremental bundle adjustment (BA) of an image network formed by Pancam and/or Navcam images is carried out on Earth at the OSU Lab. After BA, 2D accuracy generally ranges from sub-pixel to 1.5 pixels while 3D accuracy is at a centimeter to sub-meter level (based on consistency check of the BA results). It has been demonstrated that BA-based rover localization technology has corrected wheel slippage, IMU drift and other navigation errors as large as 10.5% in the Husband Hill area of the Gusev Crater landing site (Spirit) and 21% in Eagle Crater at the Meridiani Planum landing site (Opportunity) [1, 2].

Autonomous rover localization

Recently we developed an innovative method to automate cross-site tie-point selection so that BA-based rover localization can be autonomously performed onboard the rover [4]. This new method consists of algorithms for rock extraction, rock modeling, and rock matching from multiple rover sites. Rocks are extracted from 3D ground points generated by dense matching of stereo images, and then modeled using analytical surface models such as hemispheroid, semi-ellipsoid, cone and tetrahedron. Rocks extracted and modeled from two adjacent rover sites are matched by a combination of rock-model matching and rock-distribution-pattern matching. We have tested our software using a 337m traverse (20 pairs of sites) taken by Spirit at the Husband Hill summit area and a 206m traverse (13 pairs of sites) obtained at a Silver Lake test site on Earth. Test results show the proposed method is effective for medium-range (up to 26m) traverse segments; success rates for the number of site pairs are 65% and 76% (or 81% and 85% after prescreening) for the Spirit and Silver Lake data, respectively. We are further improving our methods and are performing tests using the entire 5-km traverse acquired at Silver Lake, CA, in January, 2007. At the same time, the onboard incremental BA technology we are developing will be integrated with JPL’s visual odometry technology to achieve long-range autonomous rover localization.

Enhanced topographic mapping

With the support of the NASA Applied Information System Research (AISR) Program, we are developing a method for the integration of orbital and ground images for enhanced topographic mapping. In this ongoing research, a combined bundle adjustment of orbital and ground imagery will be used to achieve the best possible accuracy for topographic mapping. We have developed a rigorous photogrammetric model and bundle-adjustment software for MOC NA and HiRISE stereo image processing and achieved sub-pixel accuracy at the MER sites. We have also developed a hierarchical stereo-matching process for DTM generation from stereo orbital images and for tie point selection.

Next, we will develop landmark (e.g., mountain peaks and crater rims) extraction methods for automatic linking between orbital and ground images. Consequently, the combined orbit-ground bundle adjustment will improve the precision of the image orientation parameters. The integration of orbital and ground images will enhance high-precision topographic mapping and rover localization in support of such planetary exploration tasks as pre-landing target selection, high-precision lander localization, and onboard navigation for the rovers.