Topomapping of Mars with HRSC Images, ISIS, and a Commercial Stereo Workstation

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HRSC on Mars Express is the first camera designed specifically for stereo imaging to be used in mapping a planet other than the Earth. Nine detectors view the planet through a single lens to obtain four-band color coverage and stereo images at 3 to 5 distinct angles in a single pass over the target. The short interval between acquisition of the images ensures that changes that could interfere with stereo matching are minimized. The resolution of the nadir channel is 12.5 m at periapsis, poorer at higher points in the elliptical orbit. The stereo channels are typically operated at 2x coarser resolution and the color channels at 4x or 8x. Since the commencement of operations in January 2004, approximately 51% of Mars has been imaged at nadir resolutions better than 50 m/pixel. This coverage is expected to increase significantly during the recently approved extended mission of Mars Express, giving the HRSC dataset enormous potential for regional and even global mapping.

Systematic processing of the HRSC images is carried out at the German Aerospace Center (DLR) in Berlin. Digital topographic models (DTMs) at 200 m/post resolution and orthorectified image products are produced in near-realtime for all orbits, by using the VICAR software system. The tradeoff of universal coverage but limited DTM resolution makes the standard products optimal for many but not all research studies. Experiments on adaptive processing with the same software, for a limited number of orbits, have allowed DTMs of higher resolution (down to 50 m/post) to be produced. In addition, numerous Co-Investigators on the HRSC team (including ourselves) are actively researching techniques to improve on the standard products, by such methods as bundle adjustment, alternate approaches to stereo DTM generation, and refinement of DTMs by photoclinometry (shape-from-shading). The HRSC team is conducting a systematic comparison of these alternative processing approaches by arranging for team members to produce DTMs in a consistent coordinate system from a carefully chosen suite of test images. The design of the test and a summary of the results will be reported by Heipke et al., this conference. Here, we describe our own approach to HRSC processing and preliminary results. Final results will be described in our paper .

We have developed an independent capability for processing of HRSC images at the USGS, based on the approach previously taken with Mars Global Surveyor Mars Orbiter Camera (MGS MOC) images [1]. The chosen approach uses both the USGS digital cartographic system ISIS and the commercial photogrammetric software SOCET SET (® BAE Systems) and exploits the strengths of each. This capability provides an independent point of comparison for the standard processing, as described here. It also prepares us for systematic mapping with HRSC data, if desired, and makes some useful processing tools (including relatively powerful photometric normalization and photoclinometry software) available to a wide community of ISIS users.

ISIS [2] provides an end-to-end system for the analysis of digital images and production of maps from them that is readily extended to new missions. Its stereo capabilities are, however, limited. SOCET SET [3] is tailored to aerial and Earth-orbital imagery but provides a complete workflow with modules for bundle adjustment (MST), automatic stereomatching (ATE), and interactive quality control/editing of DTMs with stereo viewing (ITE). Our processing approach for MOC and other stereo datasets has been to use ISIS to ingest images in an archival format, decompress them as necessary, and perform instrument-specific radiometric calibration. Software written in ISIS is used to translate the image and, more importantly, orientation parameters and other metadata, to the formats understood by SOCET SET. The commercial system is then used for "three-dimensional" processing: bundle-adjustment (including measurement of needed control points), DTM generation, and DTM editing. Final steps such as orthrectification and mosaicking of images can be performed either in SOCET SET or in ISIS after exporting the DTM data back to it. This workflow was modified slightly for HRSC to take advantage of the standard processing performed at the DLR. As the first step in DTM production, we import VICAR Level 2 files (radiometrically calibrated but still in the raw camera geometry) into ISIS where they can immediately be used or exported to SOCET SET. HRSC Level 3 and 4 products (DTMs and orthorectified images) can also be imported and used as map-projected data (e.g., Level 4 DTMs from DLR can be compared with those produced in SOCET SET).

Our preliminary results for images from orbit h1235, covering western Candor Chasma, are encouraging even though the analysis did not take full advantage of the multiple-line design of HRSC. We computed offsets to the trajectory and pointing angles for each image of the set as if they were fully independent, rather than requiring a single trajectory and pointing history versus time for all the images. In addition, the version of SOCET SET used is limited to using only two images at a time in the stereo matching process. We are currently working to address these shortcomings by adding constraints to the bundle adjustment and by using a newer version of the software with multi-image matching. The results for both h1235 and multiple orbits in Nanedi Valles will be described in our paper and compared to the preliminary analysis reported here.

The preliminary bundle adjustment yielded RMS residuals of 3.6 pixels in the nadir image, correspondingly less in the other bands. RMS residuals to the ground control provided by Mars Orbiter Laser Altimeter (MOLA) data were ~400 m horizontally but only 1 m vertically. Adjustments to the spacecraft orientation were relatively large, and may be correlated. We collected DTMs at 75 m/post in the canyon interior, 300 m on the walls and surrounding plateau, and merged the results at 75 m/post. Editing was required only to remove a few localized artifacts on the plateau, which is nearly featureless. As would be expected, the resulting DTM appears sharper than either MOLA at 463 m/post or the standard HRSC DTM at 200 m/post, and the added detail is subjectively well correlated with the image. With the DTM translated back into ISIS format, a variety of useful additional processing steps could be demonstrated, such as generation of color-albedo maps and band-ratio images with correction for surface and atmospheric photometric effects. By dividing the nadir image by a smoothed version of the albedo map, we were able to obtain an image in which all but the most localized albedo variations had been removed. The albedo-corrected image was then analyzed by two-dimensional photoclinometry [4] to generate a DTM that contains real geomorphic detail at the limit of image resolution while retaining consistency with the stereo and MOLA data over longer distances.

References

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