PRACTICAL PROCESSING OF MARS EXPRESS HRSC IMAGES IN ISIS AND SOCET SET

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1. INTRODUCTION

We have created and describe here a set of software tools for analysis of images from the Mars Express High Resolution Stereo Camera (MEX HRSC). HRSC is a pushbroom scanner with 9 detector lines, enabling it to obtain multiple stereo views of a target region and/or color coverage on a single orbital pass. Our approach uses the USGS digital cartography system ISIS (Integrated Software for Imagers and Spectrometers) and the commercial stereomapping software SOCET SET ® from BAE Systems, and is thus independent of the standard team pipeline. The work reported here is a continuation of our earlier development effort that was evaluated as part of the HRSC team's digital topographic model (DTM) comparison project. It incorporates substantial advances in many areas of the software, leading to improvements in DTM quality and large improvements in usability.

We had several goals in undertaking this development:

- To provide an independent verification of the results of the stereo pipeline used to produce archival products by the mission team
- To assess the quality of DTMs we could produce (using software and techniques we apply to many other missions) in relation to other approaches and especially those tailored specifically for HRSC
- To enable members of the planetary community who do not have access to the specialized VICAR software used by the HRSC team to produce their own DTMs and orthorectified (map projected) image products, particularly in the interval between the release of the images and the delivery of higher-level derived products by the team
- To make ISIS processing capabilities that are unique or particularly strong, in particular photometric modeling and correction and photoclinometry (shape-from-shading), available for use with HRSC data
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The capabilities described below are now available to the planetary science community in the latest releases of ISIS and through the NASA-USGS Planetary Photogrammetry Guest Facility, which provides access to (and training for) SOCET SET.

2. TECHNICAL APPROACH AND RELATION TO PAST WORK

We use SOCET SET for stereo processing of HRSC (and many other datasets), including controlling images by bundle adjustment, producing initial DTMs by automated image matching, interactive quality control and editing of DTMs, and projection of images onto the DTMs to form orthoimages. We use ISIS to ingest the images and metadata in standard formats used by the mission and translate them into formats readable by SOCET SET. For HRSC we use the "Level 2" image products, which are radiometrically calibrated but in native camera geometry.

At the start of HRSC operations in 2004 we developed software in the older ISIS 2 system, including ingestion of data, a sensor model, and translation for use in SOCET SET. This software had numerous shortcomings: it could not deal with changing line exposure times, requiring most images to be broken into multiple sections, and could not handle reduced resolution images, so they had to be enlarged for use. SOCET SET could only adjust the HRSC image channels independently, and could only match images in pairs. These problems had two general consequences: (a) much of the geometrically strength of HRSC as a multi-line stereo scanner was lost because the images had to be controlled separately and matched in pairs rather than multiples; and (b) the labor of mapping with HRSC was multiplied enormously because large numbers of image segments had to be controlled independently and matched in many different pairwise combinations, and then the results combined. As a result, the DTM comparison concluded the quality of the SOCET DTMs was reasonable but not as good as those produced by algorithms that made use of multiple images in matching, and the human work effort greatly exceeded that for other approaches. On the positive side, we were able to demonstrate unique ISIS capabilities for photometry and photoclinometry.

3. RECENT DEVELOPMENTS

In 2009 we began developing ISIS 3 software for HRSC but lacked resources to complete the work. Much incidental progress was made in the next few years. ISIS 3 matured rapidly and developed a versatile bundle adjustment capability with the jigsaw program and tools for control and ground point measurement. Most of the bugs that hindered our use of SOCET SET were fixed and an improved image matcher (Next Generation Automatic Terrain Extraction, or NGATE) was added.

In 2012-2013 we returned to the problem of improving pushbroom sensor models. The end result was an improved set of core routines for the ISIS 3 pushbroom sensors and a new "USGS pushbroom sensor model" for SOCET SET. These developments share a common code base and the following features:

- Faster and more robust solution algorithm to determine the image line on which a given ground point appears
- Handling of constant or varying line exposure times in the same base model
- Handling of pixel-averaging modes and detectors at arbitrary locations in the focal plane
- Handling of images obtained by spacecraft rotation as well as translation, allowing (for example) analysis of Phobos observations

4. STATUS AND PLANS

We are evaluating the new software just described, and developing the appropriate procedures for its routine use. The data sets used for the HRSC DTM comparison have been analyzed and documented in detail and provide an ideal benchmark for both DTM quality and work effort. We have ingested the test images in the current software and produced DTMs that are controlled based on manual collection of ground control points that are identifiable in both the images and the MOLA global altimetry dataset. The quality of initial DTM products from NGATE without interactive editing or merging of the results from multiple image combinations is similar to or better than that of the highly edited products submitted for the DTM comparison, and the work effort is greatly reduced. We expect to improve the results further by optimizing the parameters for matching in NGATE and adaptively filtering the images before matching, as is done in the standard pipeline. In addition, we are applying surface fitting techniques to control the images to MOLA, which should greatly reduce the effort needed. When these developments are complete, we will document DTM quality and work effort and compare them to the HRSC DTM comparison results. We also plan to use HiRISE DTMs with 1 m/post sampling to evaluate the resolution of our HRSC DTMs.