Photogrammetric Analysis of Huygens DISR Images of Titan

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Introduction: The Descent Imager-Spectral Radiometer (DISR) experiment [1, 2] on the Huygens spacecraft included three imaging cameras: high resolution (HRI), medium resolution (MRI), and side looking (SLI). These returned the first ever high resolution (~60 m/pixel to a few mm/pixel) images of the surface of Titan. We continue our efforts to use these images to map the surface of Titan, so that the information can be used for further geologic study. We are proceeding to take pairs of DISR images that overlap, and in those overlap areas photogrammetrically adjust the orientation and position of the images to create digital terrain models (DTMs). We use a photogrammetric workstation, running commercial (SOCET SET® BAE) software, adapted for planetary mapping use. Once an adjustment is performed, it is usually possible to use automatic matching techniques to derive DTM information. However, due to the noise in the images and their small size, we have had to tediously collect the DTM information ("posts") manually. Still we have been able to map several areas where stereo information is available [2, 3]. Below we describe our efforts on understanding the relative accuracy of our DTMs, our efforts on performing an alternative camera calibration (while considering errors from that source), and our future plans.

Quantifying Stereo Measurement Errors: Our latest DTM results are based on mapping from 2 HRI images (414 and 450), and 3 MRI images (553, 601 and 634). Resolution ranges from 14 to 24 m/pixel. Pairing each HRI image with an MRI image yields six overlapping stereo pairs in this image set. Upon initial evaluation of the DTM, questions arose about the validity of a depression contained in a corner of the DEM. Stereo pairs 414/601 and 414/553 cover the corner of the DTM in question. Separate operators have verified that a depression is evident in 414/601. The pair 414/553 does not show the depression, but it also does not show as much detail as the other stereo pairs. This may be due to the fact that image 553 has the lowest resolution of the image set, or it may be due to residual geometric distortions. To assess the overall DTM quality, three operators independently extracted DTMs from each of the six overlapping stereo pairs. Comparisons were then made using the SOCET SET Quality Statistics tool. Comparing overlapping DTMs extracted by the same operator gives us an understanding of how well the images are bundle adjusted. Person to person comparisons gives us an understanding of the expected precision of the data. We also compared the techniques of merging individual DTMs by including them in a given order (based on stereo pair quality/resolution) or averaging them. Because 553 is of significantly lower resolution than the other images in this set, statistics were compared with and without the influence of 553. As expected, most of the error is attributable to input data quality, rather than operator or method used for merging DTM data. This DTM has an accuracy of 30 meters in surface elevation; unfortunately, we do not have enough redundant data to verify the questionable depression.

Improving Camera Calibration: We have performed an independent reanalysis of the laboratory geometric calibration data for the three DISR cameras in order to estimate the height errors due to camera distortion and to facilitate further mapping work. The laboratory data [4] for each camera consists of (a) observations of a grid target with 150–200 identifiable corner points spread uniformly across the field of view; and (b) observations of a collimated light source at 30–60 somewhat irregularly distributed locations of known azimuth and elevation. The original geometric calibration procedure, used in the generation of the DTMs shown here, consists of a polynomial transformation (of degree 3 in both row and column position) based on the grid data to remove camera distortions, and a second such transformation based on the collimator data to map image coordinates to azimuth-elevation space or onto a horizontal plane. We have reanalyzed the grid target data in terms of a calibrated focal length and a distortion pattern radial to a center of symmetry whose position in the focal plane we also estimate. This form of model is standard in photogrammetric practice, so the parameters we estimate can be used in SOCET SET to generate DTMs from images that have not been resampled according to the row-column polynomials described above. We find, however, that the residuals to our geometric model are significantly reduced if we allow for a small anisotropy between the pixel spacing in the row and column directions (Table 1). Analysis of the collimator observations confirms that the anisotropy is a real property of the optical system (most likely due to distortions in the fiber optic conduits between focal plane and detector). The collimator data analysis also yields the most accurate estimates of focal lengths (because distances to the grid targets were only measured to an accuracy on the order of 0.5%), the row-column coordinates of the principal point, and the three mounting angles for each camera. These fitted parameters will be used in the near future to produce new versions of the DTMs. Comparison of such products with the DTMs based on the earlier calibration should shed light on the extent to which the recovered topography is affected by residual geometric distortions.

Future Work: In coming months, after we have completed the above work to better quantify the accuracy of the generated DTMs, we plan to first independently adjust all possible stereo pairs of sufficient quality from the DISR imagery and then generate DTMs. The stereo pairs will then be photogrammetrically tied together (and to individual images where stereo is not available), and the DTMs will be carefully merged. The final products will include DTMs for the areas of stereo, orthomosaics, and topographic maps of these areas, as well as controlled mosaics of the areas of other images (without stereo). Another product of this work will be a consistent set of camera (Huygens) positions and orientations for each of the exposures, which can then be used to assist in fitting the spacecraft trajectory. All of these products will be tied to information from other sources, such as Cassini RADAR, VIMS, and ISS images, with the Huygens landing point – known from Earth based VLBI tracking – serving as a fundamental reference point on the surface of Titan.

References: [1] M. Tomasko et al. (2002) *Spc. Sci. Rev*., **104**, 469-551. [2] M. Tomasko et al. (2005) *Nature*, **438**, 765-778. [3] See images at http://photojournal.jpl.nasa.gov/catalog/PIA06441. [4] L. R. Doose et al. (unknown date) "Calibration Report for the Imagers of the DISR Instrument aboard the Huygens Probe of the Cassini Mission." Internal document.

Table 1 - Preliminary Geometric Calibration Parameters of DISR Flight Model

Camera	Calibrated Focal Length (mm) collimator	Maximum Radial Distortion[1] (pixels) grid target	Anisotropy[2] (%) grid target	RMS Residual[3] (pixels) grid target	RMS Residual[3] (pixels) collimator
SLI	6.262	3.7	3.2	0.26	0.37
MRI	10.841	1.8	0.47	0.082	0.25
HRI	21.463	0.10	0.29	0.038	0.32

[1]Positive and negative extremes of distortion within field of view are equal, opposite. [2]Defined as (pixel width - pixel height)/pixel height. [3]Root summed square of row and column residuals.