PHOTOGRAMMETRIC PROCESSING OF HIGH-RESOLUTION PLANETARY ORBITAL IMAGERY FOR LARGE-AREA TOPOGRAPHIC MAPPING. Y. Chen, J. W. Hwangbo, R. Li, Mapping and GIS Laboratory, The Ohio State University Dept. of Civil & Env. Eng. & Geodetic Science, Columbus, OH, 43210-1275 (chen.1256@osu.edu)

Introduction: High-precision topographic information is critical to planetary exploration and surface operations. The availability of ultra high resolution (sub-meter) stereo planetary orbital imagery opens a possibility to generate highly detailed topographic products for areas of interest. Software developed at Mapping and GIS Laboratory for mapping the Martian surface can be used to generate high-quality DTMs in the context of the entire landing site using the two Narrow Angle Cameras on LRO. Having a similar ground resolution and swath, the High-Resolution Imaging Science Experiment (HiRISE) on the Mars Reconnaissance Orbiter provides an opportunity to develop and demonstrate our capability to map the entire landing site with the highest achievable accuracy.

Imaging Geometry of HiRISE: HiRISE is a pushbroom imaging sensor with its exterior orientation (EO) parameters changing along image lines. A third-order polynomial is employed to model this change. Fourteen CCDs (10 red, 2 blue-green and 2 NIR) are fixed on its focal plane (Fig. 1), therefore only one set of polynomial coefficients are needed to model the positions and pointing angles of all CCD chips. The orbit's initial positions and pointing angles are provided in the SPICE kernels. For any given ephemeris time, the EO parameters can be retrieved by interpolating the spacecraft's trajectory and pointing vectors.

HiRISE Mapping Data: Four HiRISE image strips covering the Spirit landing site have been used to form three double-coverage and two triple-coverage stereos (Fig. 2). Triple-coverage stereos are critical to the bundle adjustment because they will help remove inconsistencies between different image stereos. Dust devils that touched down in the landing site area in 2007 left tracks on the Martian surface that make it difficult to perform stable image matching in this area.

HiRISE Image Matching: A hierarchical stereo-matching process has been developed. Before processing, systematic strip noise in each raw HiRISE image is removed. Then, an image pyramid is constructed that consists of five levels (Fig.3). Starting with the original resolution, each of the subsequent levels is created by sub-sampling of the previous level. Interest points are generated by Förstner operator at every image level. Matching starts from the images of lowest resolution; results are transferred to the next higher level, with more interest points being extracted and matched at each level. After matching of the highest resolution images, relatively evenly distributed matched interest points are selected as tie points between the stereo images. Lastly, grid points are defined and matched to generate a DTM of the terrain.

Bundle Adjustment of HiRISE Stereo Images: Based on the rigorous HiRISE camera model and the results of tie point matching, bundle adjustment is performed on all participating images. This bundle adjustment takes all five image stereos and adjusts the EO parameters of all four participating images in one system. Bundle adjustment results are showed in Table 1, where it can be seen that any bias errors in the EO parameters have been removed and that the standard deviations are significantly reduced. It can also be noted that the inconsistencies before bundle adjustment vary significantly from stereo to stereo. With only 3~4-pixel inconsistency, the time between the acquisition of the two images in Stereo 1 is only 20 days, while the more than 1000-pixel inconsistency in Stereo 2 has been created by the pairing of an image acquired more than one year after the first image. This indicates that error

accumulates with time in SPICE kernels.

Spirit Landing Site Topographic Mapping: Based on bundle adjusted EO parameters, dense matching is performed on all image strips. Intersection generates all corresponding 3-D points on the Martian surface. Five-meter resolution DTM is generated by interpolating all these 3-D terrain points using the Kriging method. Then, an orthophoto at the same resolution is generated by back-projecting the DEM grids onto the original image (Fig 4). These topographic products are generated in separate stereo pairs. By selecting 18 features in the areas of overlap between different pieces of orthophotos, horizontal inconsistencies of orthophotos from different stereos were found to be smaller than 1 m. By calculating the pixel-to-pixel differences in DEMs from different stereos, it has been concluded that the vertical inconsistencies have a standard deviation of 2.5 meters.

References: [1] McEwen A. et al. (2007), *JGR-Planets*, 112(E05S02). [2] Li, R. et al. (2007), 2007 AGU Fall Meeting.

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Table 1. Error analysis of bundle adjustment

	Image ID	No. of Tie Points	Mean / stdev before BA	Mean / stdev after BA
Stereo1	PSP_001513_1655	266	3.5 / 2.0	0.0 / 0.28
	PSP_001777_1650	266	-3.8 / 3.3	-0.0 / 1.2
Stereo2	PSP_001513_1655	197	1182.4 / 3.5	0.0 / 0.32
	PSP_006735_1650	197	-1192.0 / 5.6	-0.0 / 0.33
Stereo3	PSP_006524_1650	138	83.3 / 27.4	0.0 / 0.63
	PSP_006735_1650	138	-85 / 75.4	-0.0 / 0.64
Stereo4	PSP_001513_1655	204	3.5/2.0	-0.2/0.83
	PSP_001777_1650	204	-3.8/3.3	0.1/0.73
	PSP_006735_1650	204	-2368.5/2.7	0.2/0.82
Stereo5	PSP_001513_1655	150	1151.2/1.6	0.0/0.86
	PSP_006524_1650	150	-1114.5/2.8	0.0/0.75
	PSP_006735_1650	150	-1224.4/4.5	-0.0/0.73

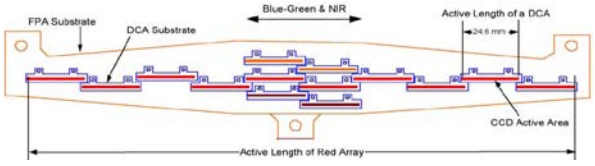

Fig. 1. HiRISE CCD structure on its focal plane. (Alfred McEwen 2007).

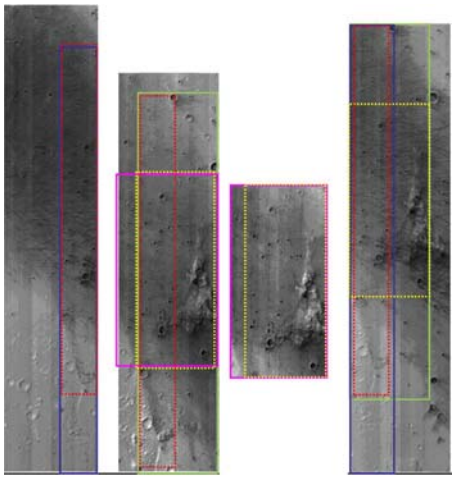

Fig. 2. HiRISE image strips and image stereos used in this research.

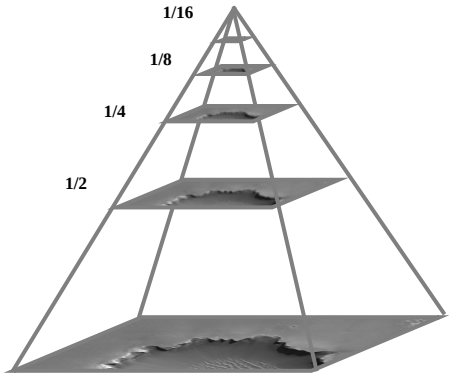

Fig. 3. The image-matching pyramid.

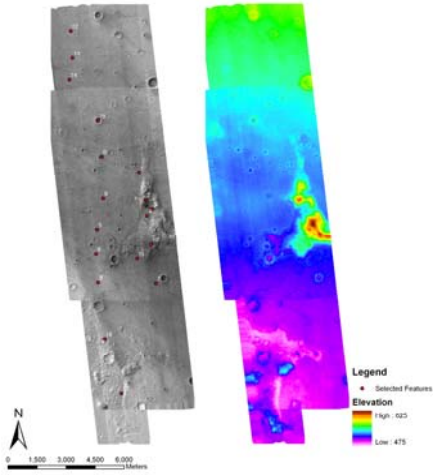

Fig. 4. Orthophoto and DEM of Spirit landing site.