SIMULTANEOUS ADJUSTMENT OF INTERIOR AND EXTERIOR ORIENTATION OF HRSC ON MARS EXPRESS. M. Spiegel[1], G. Neukum[2], [1]Photogrammetry and Remote Sensing, Technische Universitaet Muenchen, Arcisstr. 21, 80333 Muenchen, Germany, spiegel@bv.tum.de, [2]Institut fuer Geologische Wissenschaften, Freie Universitaet Berlin, Malteserstr. 74-100, 12249 Berlin, Germany.

Introduction: Since January 2004 the High Resolution Stereo Camera (HRSC) on board the ESA Mission Mars Express is imaging the surface of planet Mars in color and stereoscopically in high resolution. The Institute of Photogrammetry and GeoInformation (IPI) of the Leibniz University of Hannover and the Department Photogrammetry and Remote Sensing (FPF) of the Technische Universitaet Muenchen are jointly processing the data of the HRSC to improve the exterior orientation of the orbiter using MOLA data. In the new approach, the interior orientation is adjusted simultaneously together with exterior orientation. With the result of the processing chain, high quality products such as Digital Terrain Models (DTMs), ortho image mosaics and shaded reliefs can be derived from the imagery.

Input Data: ESA and the German Aerospace Center (DLR) delivers image strips of the HRSC and observed exterior orientation of the Mars Express spacecraft. The MOLA instrument acquired more than 640 million observations by measuring the distances between the orbiter and the surface of Mars which cover the entire surface of the planet. In addition to the surface described by the original, irregularly spaced MOLA track points NASA distributed a grid-based global DTM which is derived from these MOLA points [1]. The interior orientation of the HRSC has been calibrated by Dornier at Friedrichshafen (Germany) [2]. The IPI uses the HRSC data as input for the automatic extraction of image coordinates of tie points via digital image matching. The software delivers a large number of automatically measured tie points [3].

Bundle Adjustment: The bundle adjustment approach estimates the parameters of the exterior orientation only at a few selected orientation points. The mathematical model for photogrammetric point determination with a three-line camera is based on the well known collinearity equations. These equations describe the fundamental geometrical condition between object points and image coordinates [4]. Additional conditions are used to register the HRSC data to MOLA DTM.

Investigations of Image Coordinates: In previous work the interior orientation parameters (geometric camera calibration) have been considered to be stable and the bundle adjustment results show systematic residuals at the image coordinates (Figure 3). In a lot of orbits the systematic residuals have the same dimension. Because of this, it is obvious that the reason is to find in the interior orientation.

Interior Orientation Concept: To adjust the interior orientation simultaneously with the exterior orientation, it is necessary to transform the calibrated interior orientation to few model parameters.

For each line, 3 model parameters of interior orientation are calculated. The displacement in the focal plane can be described by the parameters dx and dy. Also, there are differences rx and ry between the calibrated position and model parameters for each pixel (Figure 1). The third parameter defines the focal length of the camera i.e. the distance between mathematical projection center and the focal plane.

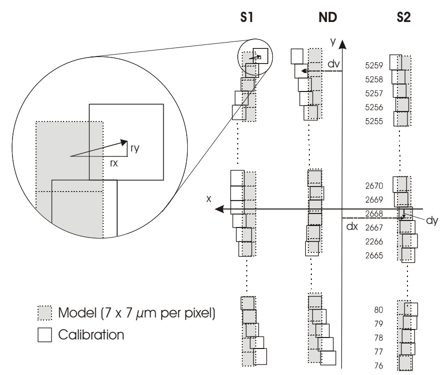

Figure 1: Relationship of dx, dy, rx, and ry.

An investigation shows, that the parameters dx and dy can be improved for 7 of 9 lines. Therefore, two observation equations per line (=14 total) are introduced in the bundle adjustment. The other parameters and differences are constant.

Interior Orientation Results: 46 orbits with good imaging conditions are selected. For all orbits the parameters dx and dy of nadir and the stereo channels (S1 and S2) are improved. For all selected orbits the color lines are not available in adequate geometric resolution. Therefore the color lines can be improved only for 17 orbits. Afterwards the mean values for all orbits are computed and only one new set of interior orientation parameters is created.

Evaluation of New Interior Orientation: Now, the systematic residuals at image coordinates are smaller as in the case without new interior orientation (Figure 4).

A comparison of Z-differences between HRSC object points and MOLA DTM shows the advantage of this approach (Figure 2). Certainly, the differences using calibrated interior orientation is better than without any bundle adjustment. But, the results can be improved with the new interior orientation.

Conclusion: The parameter of interior orientation can be improved by using simultaneous adjustment. Furthermore, a reduction of residuals at the image coordinates after bundle adjustment can be reached. Finally, the Z-differences between HRSC object points and MOLA DTM is reduced for all 750 investigated orbits with the new interior orientation, more or less. Therefore, it is absolutely necessary to use the new interior orientation in further investigations.

References: [1] Neumann, G.A. et al. (2003) LPS XXXIV, Abstract #1978. [2] Carsenty, U. et al. (1997) DLR Institut fuer Planetenerkundung, TN-WM-5000 PE/007. [3] Heipke, C. et al. (2004) *IntArchPhRS, Vol. 35 Part B4*, 846–851. [4] Spiegel, M. et al. (2006) *IntArchPhRS, Vol. 36 Part 4*.

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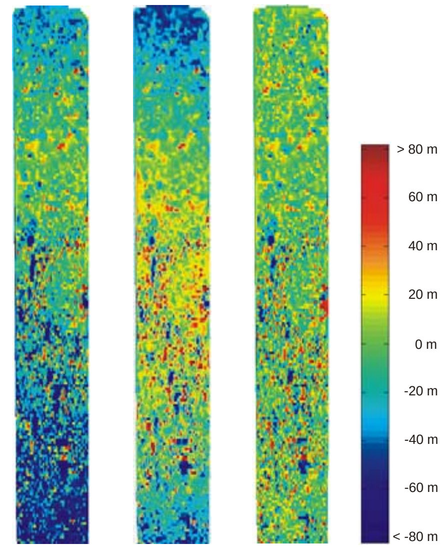

Figure 2: Z-differences between HRSC Object points and MOLA DTM of orbit 2063. Before bundle adjustment (left), after bundle adjustment using with calibrated interior orientation (middle) and after bundle adjustment using the new interior orientation (right).

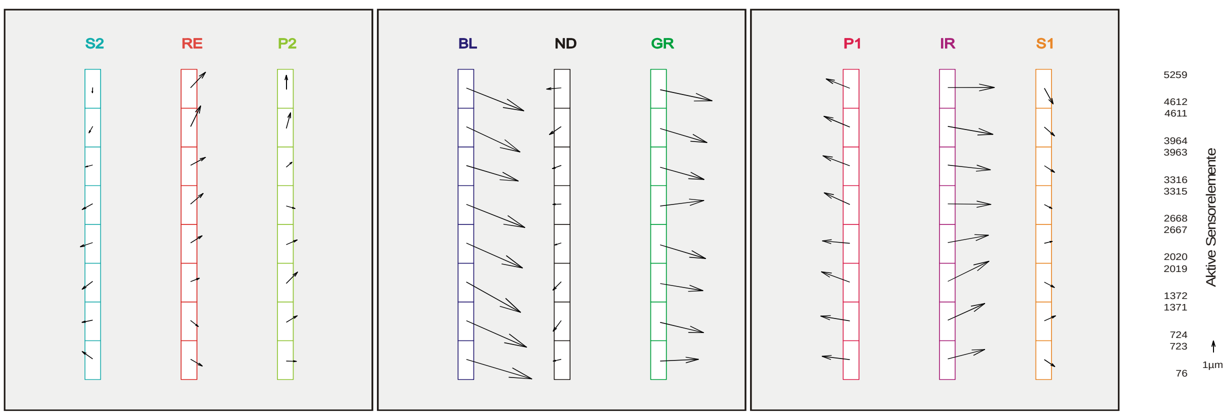

Figure 3: Systematic residuals at the image coordinates (orbit 2063) before adjustment of interior orientation. Each of the 9 lines is divided in 8 parts. For these parts the root mean square error is showed.

Figure 4: Systematic residuals at the image coordinates (orbit 2063) after adjustment of interior orientation. Each of the 9 lines is divided in 8 parts. For these parts the root mean square error is showed.