Improving the Exterior Orientation of Mars Express Regarding Different Imaging Cases

M. Spiegel[1], U. Stilla[1], G. Neukum[2] and the HRSC Co-Investigator Team

[1]Photogrammetry and Remote Sensing, Technische Universitaet Muenchen, Arcisstr. 21, 80333 Muenchen, Germany, spiegel@bv.tum.de
[2]Institut fuer Geologie, Geophysik und Geoinformatik, Freie Universitaet Berlin, Malteserstr. 74-100, 12249 Berlin, Germany.

The High Resolution Stereo Camera (HRSC) on board of ESA Mission Mars Express started imaging the surface of planet Mars in color and stereoscopically in high resolution in January 2004. The Institute of Photogrammetry and GeoInformation (IPI) of the University of Hannover and the Department Photogrammetry and Remote Sensing (FPF) of the Technische Universitaet Muenchen are jointly processing the data of the HRSC. The primary goal is to register the HRSC data to the Mars Observer Laser Altimeter data (MOLA). In this Paper the HRSC and MOLA-data, the concept, and results of photogrammetric point determination regarding to different imaging situations will be described.

There are two different data sources: The HRSC data and the MOLA data. The HRSC Data are provided by the ESA and the German Aerospace Center (DLR) by delivering images strips of HRSC and observed exterior orientation of Mars Express spacecraft. In general, one strip has a length of about 300 km up to 4000 km. At pericenter one image strip has as swath width of about 60 km and has a ground resolution of 12,5 m. The IPI uses these data as input for the automatic extraction of image coordinates of tie points. The matching software delivers a large number of automatically measured tie points between the multiple stereo strips. During the operation time (1997-2001) the MOLA instrument acquired more than 640 million observations by measuring the distances between the orbiter and the surface of Mars. These 640 million observations cover the entire surface of Mars with high and consistent accuracy. In combination with orbit and attitude information these altimeter measurements have been processed to coordinates of points on the ground. In addition to the surface described by the original, irregularly spaced MOLA track points NASA distributed a grid-based global Digital Terrain Model (DTM) which is derived from these MOLA points. MOLA global terrain models have been recommended as reference surface for the planet.

In the bundle adjustment using none MOLA DTM the concept of orientation images is used. This approach estimates the parameters of the exterior orientation only at a few selected image-lines, at the so-called orientation images. The mathematical model for photogrammtric point determination with a three-line camera is based on the well known collinearity equations. These equations describe the fundamental geometrical condition that the rays through the three corresponding image points and the corresponding perspective centers intersect in the object points. Two collinearity equations are established for each image point. For every object point there are several equations, because corresponding image points are found in images of different sensor lines. In general, the classical photogrammetric point determination requires image coordinates of tie points, interior and exterior orientation, and ground control points (GCP). In case of HRSC on Mars Express there are no GCP available and observed parameters of exterior orientation will probably not be precise enough for a consistent photogrammetric point determination on a global level. Nevertheless, the observed parameters can serve as good approximate values. But additional control information is necessary in order to fit photogrammetrically derived object points into the existing reference

system on Mars. Instead of classical GCPs there is a large number of ground points measured by MOLA. The special thing about the laser points is, that they can not be identified in the images in an easy way. I.e., image coordinates of most of these points can not be measured, and therefore, it is not possible to use them as normal GCPs in a bundle adjustment. As a remedy it is proposed to use control surfaces. After this step the HRSC points are fitted optimally into the MOLA reference and with the HRSC point cloud also the exterior orientation of HRSC imagery is registered to the global reference frame provided by MOLA data.

This approach is investigated with different imaging cases. Case A deals with the number of extracted image coordinates of tie points depending on texture and length of the image strip. The number of object points can differ between about 500 and 30000 in one image strip. Case B considers the changing flying altitude of the orbiter during imaging which can differ between 270 km at pericenter and more than 1000 km at remote orbit points. Case C: it has been realized, that many datasets suffer from data gaps. The gaps can comprise a few lines and in rare cases increase up to more than 1000 lost lines. In the proposed approach these gaps are bridged by interpolation. Furthermore, in case D the improvement of exterior orientation by using MOLA DTM registration is investigated with respect to the terrain slope. In all of these cases the accuracy improvement of the exterior orientation and the object points after bundle adjustment compared with normal cases is shown. Finally, the current state of the investigation of all HRSC imagery is illustrated.