Stereo Processing of HRSC Mars Express Images by Semi-Global Matching

Heiko Hirschmüller[1], Helmut Mayer[2], G. Neukum[3] and the HRSC CoI-Team

[1] Institute of Robotics and Mechatronics, German Aerospace Center (DLR), Oberpfaffenhofen
[2] Institute for Photogrammetry and Cartography, Munich Bundeswehr University
[3] Institute of Geological Sciences/Planetology, Freie Universität Berlin

The High Resolution Stereo Camera (HRSC) is one of the instruments on-board ESA's Mars Express probe. It is used for visual and three dimensional mapping of the Martian surface. Airborne versions of the HRSC have been used for mapping Earth's surface from flight altitudes between 1500m and 5000m in resolutions up to 15cm/pixel. Stereo matching is one of the most critical steps for the generation of Digital Elevation Models (DEM) from HRSC images, as it is generally ambiguous and ill posed. Most difficult to handle are often low textured areas, sharp depth discontinuities and large occlusions. Depth discontinuities and occlusions are typical for urban scenes (e.g. cities), but also for rough terrain. Additionally, computation time is critical due to the huge amount of high resolution data.

Local, correlation based stereo matching methods are often employed due to their efficiency. However, they are well known for having problems at low textures and blurring depth discontinuities, depending on the size and shape of the correlation window. Global energy minimization approaches have been shown to perform much better due to pixel-wise matching, supported by a discontinuity preserving smoothness constraint. However, the complexity and run-time of global methods is usually very high. The Semi-Global Matching (SGM) method [1] combines the best features of both strategies. It has been shown [1, 2] that its performance is comparable to that of some of the best stereo matching methods, but its complexity is that of typical local methods, i.e. linear to the number of pixels and the disparity range.

The SGM method has been applied to the stereo matching problem of terrestrial HRSC images [3]. All pixels are projected onto a common surface for creating nine 2D pushbroom images from each of the nine sensor lines. The camera positions and orientations along the flight path are used for calculating epipolar lines, along which stereo matching is performed. The explicit calculation of epipolar lines is necessary for minimizing computation time, as pushbroom images can generally not be corrected such that epipolar lines are exactly straight [3]. A Mutual Information based matching cost is used by SGM, which makes matching insensitive against many radiometric transformations that often occur in practice. Furthermore, it even allows to perform matching between radiometrically different (e.g. color) channels, which is done for increasing redundancy and decreases matching errors.

The method has been implemented on a processing cluster, which allows DEM and true ortho image generation of hundred of square kilometers in resolutions of 20cm/pixel within just a few days. Around 14000 km² of terrestrial HRSC data have been processed up to now. The results are generally very good, especially for difficult scenes like cities. It is obvious that the same processing strategies could be advantageous for Martian HRSC data too.

This paper describes all processing steps for the creation of DEM's and true ortho images from Martian HRSC data. The unprojected HRSC images and the corresponding external

camera positions and orientations, refined by bundle adjustment serve as input. The data is converted into an intermediate format, that has been used for terrestrial HRSC processing, and fed into the existing processing cluster. Several orbits have been processed. The results are presented and discussed.

References

[1] H. Hirschmüller, „Accurate and Efficient Stereo Processing by Semi-Global Matching and Mutual Information“, IEEE Conference on Computer Vision and Pattern Recognition, San Diego, USA, June 2005, Volume 2, pp. 807-814.

[2] D. Scharstein, Middlebury Stereo Vision Page, www.middlebury.edu/stereo

[3] H. Hirschmüller, F. Scholten and G. Hirzinger, „Stereo Vision Based Reconstruction of Huge Urban Areas from an Airborne Pushbroom Camera (HRSC)“, Proceedings of the 27th DAGM Symposium, LNCS 3663, August/September 2005, Vienna, Austria, pp. 58-66.