Improving Tie Point Extraction by Anisotropic Diffusion

R. Schmidt[1], C. Heipke[1], G. Neukum[2], and the HRSC Co-Investigator Team.

[1] Institute of Photogrammetry and GeoInformation (IPI), University of Hannover
[2] Institute of Geosciences, Remote Sensing of the Earth and Planets, Freie Universität Berlin

Commission IV, WG IV/7

Abstract

Mars Express is in orbit for over two years now and has returned almost 1.000 image strips to earth taken by the multiple line scanner camera HRSC (High Resolution Stereo Camera). The three-dimensional position of the spacecraft is determined by the Flight Dynamics Team (FDT) at ESOC (European Space Operations Centre) in Darmstadt from ranging and Doppler shift measurements. An onboard star tracker is used to control the spacecraft's attitude (and thus the pointing of the body-fixed camera). These values result in a three-dimensional position and attitude of the spacecraft over time (termed "exterior orientation" (EO) in classical photogrammetry). Unfortunately, these parameters are sometimes poorly constrained. However, the HRSC experiment with its multiple stereo lines is designed with the goal in mind to improve these nominal values of exterior orientation by means of photogrammetric techniques. This is accomplished in two steps. First, a large number of tie points between the multiple stereo strips are extracted via digital image matching (DIM). Then, a bundle adjustment (BA) is performed to correct the EO, using the collected tie points as observations for the unknown EO parameters.

The automatic determination of tie points is carried out at the Institute of Photogrammetry and GeoInformation (IPI), University of Hannover. The subsequent BA is carried out at Department Photogrammetry and Remote Sensing (FPF), Technical University Munich (Ebner et al., 2004). The remaining processing like digital terrain model (DTM) and ortho photo generation is done at Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR) in Berlin Adlershof (Scholten et al. ,2005). Until now the first 600 orbits have been investigated by IPI and FPF and about 450 of them have been processed. The remaining 150 orbits could not be considered for processing because of too low texture, dust in the atmosphere, data gaps, limb images or overexposure. A detailed description of the applied image matching is given in Heipke et al. (2004).

Under optimal geometric and radiometric imaging conditions very good results could be achieved (Albertz et al., 2005) but there are also orbits with degraded imagery because of low texture on the surface or dust in the atmosphere. In these cases only a low signal is received by the camera which results in a noisy image. But there is another effect which could degrade the quality of the imagery. Because of a limited data rate between the spacecraft and earth it is not possible to transmit uncompressed imagery. Hence, onboard the spacecraft the images are being compressed on-line with a DCT (Discrete Cosine Transformation) approach known from the JPEG algorithm. The compression ratio is adapted automatically depending on image contrast, so for areas with low texture a high compression ratio is achieved. In this case visible artefacts appear in the images which disturb image matching.

For the derivation of high resolution DTMs from HRSC data an adaptive Gauß filter has been developed by Gwinner (2005) to reduce image noise and compression artefacts. This approach achieved higher matching success rates, higher acceptance of corresponding object points, and higher filling rates of the final DTM products. Unfortunately, as shown in Witkin (1983) the Gauß filter results in eliminated, displaced and blurred edges which is not desired for image matching. There are also more suitable approaches available which are specialised in reducing compression artefacts. An effective operator in noise reduction - and also image segmentation - was introduced by Perona & Malik (1990). The general idea of Anisotropic Diffusion is to preserve edges while filtering the image in other areas. It has been shown in Perona & Malik (1990) that Anisotropic Diffusion avoids all the above mentioned disadvantages of the Gauß filter. For the reduction of the compression artefacts the method developed by Alter (2005) is applicable.

The objective of reducing image noise and compression artefacts is to improve the reliability and completeness of the feature extraction and the correlation in areas with a low signal-to-noise ratio by enhancing contrast and edges. In this paper a short introduction to Anisotropic Diffusion and reducing compression artefacts will be given and the improved results concerning matching reliability and completeness obtained by investigating several image strips with degraded image quality are shown.

References

Albertz, J., Attwenger, M., Barrett, J., Casley, S., Dorninger, P., Dorrer, E., Ebner, H., Gehrke, S., Giese, B., Gwinner, K., Heipke, C., Howington-Kraus, E., Kirk, R.L., Lehmann, H., Mayer, H., Muller, J.-P., Oberst, J., Ostrovskiy, A., Renter, J., Reznik, S., Schmidt, R., Scholten, F., Spiegel, M., Stilla, U., Wählisch, M., Neukum, G., and the HRSC CoI-Team, 2005. HRSC on Mars Express – Photogrammetric and Cartographic Research , *PE&RS*, (71) 10, pp. 1153–1166.

Alter, F., 2005. Adapted Total Variation for Artifact Free Decompression of JPEG Images, *Journal of Mathematical Imaging and Vision*, 23, pp. 199–211.

Ebner, H., Spiegel, M., Baumgartner, A., Giese, B., Neukum, G., and the HRSC Co-Investigator Team, 2004. Improving the exterior orientation of Mars Express HRSC imagery, *IntArchPhRS*, (35) 4, pp. 852–857.

Gwinner, K., Scholten, F., Giese, B., Oberst, J., Jaumann, R., Spiegel, M., Schmidt, R., Neukum, G., 2005. Hochauflösende Digitale Geländemodelle der Marsoberfläche auf der Grundlage von Mars Express HRSC Daten, *Photogrammetrie Fernerkundung Geoinformation (PFG)*, 5/2005, pp. 387–394.

Heipke, C., Schmidt, R., Brand, R., Oberst, J., Neukum, G., and the HRSC Co-Investigator Team, 2004. Performance of automatic tie point extraction using HRSC imagery of the Mars Express mission. *IntArchPhRS*, (35) 4, pp. 846–851.

Perona, P., Malik, J., 1990. Scale-space and edge detection using anisotropic diffusion, *IEEE Trans Pattern Anal. Mach. Intell.*, Vol 12, pp. 629–639.

Scholten, F., Gwinner, K., Roatsch, T., Matz, K.-D., Wählisch, M., Giese, B., Oberst, J., Jaumann, R., Neukum, G., and the HRSC Co-Investigator Team, 2005. Mars Express HRSC Data Processing – Methods and Operational Aspects, *PE&RS*, (71) 10, pp. 1143–1152.

Witkin, A., 1983. Scale Space Filtering, *Int. Joint Conf. Artificial Intelligence*, Karlsruhe, pp. 1019–1021.