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GENERATION OF HIGH-RESOLUTION DIGITAL TERRAIN MODELS AND ORTHO-IMAGE MOSAICS OF MARS, ON THE BASIS OF MARS-EXPRESS HRSC DATA

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Introduction: Since December 2003, the European Space Agency's (ESA) Mars Express (MEX) orbiter has been investigating Mars. The High Resolution Stereo Camera (HRSC), as part of the scientific experiments onboard MEX, is a pushbroom stereo colour scanning instrument with nine line detectors, each equipped with 5184 CCD sensor elements. Five CCD lines operate with panchromatic filters and four lines with red, green, blue and infrared filters under different observation angles [1,2]. Until now, HRSC has covered an area of about 100 million km^2 at a resolution better than 60 meters per pixel. Such data is utilized to derive high resolution digital terrain models (DTM), ortho-image mosaics and additional higher-level 3D data products. Geoscientific studies can be carried out in single-orbit image data, but in order to obtain a more comprehensive view of regional processes on Mars, images as well as topographic data have to be mosaicked photogrammetrically. Some of the prime test targets are the Olympus Mons, Valles Marineris and the Thaumasia Highland. Currently, standardized highest-resolution single-strip digital terrain models (using improved orientation data) are being derived at the German Aerospace Center (DLR) in Berlin-Adlershof. These datasets, i. e. high-resolution digital terrain models as well as orthoimage data, will be made available to the science community through ESA (http://www.rssd.esa.int/PSA) and NASA (http://pdsgeosciences.wustl.edu/missions/mars_express/) planetary data archives [3] and are distributed as Vicar image files (planned to also be made available in PDS format) via the FU/DLR web-interface [4], accessible at http://hrscview.fu-berlin.de. For geoscience analysis and as part of the agency-funded contribution from our group at Freie Universität Berlin, multi-orbit-digital terrain models as well as orthoimages data are calculated through block-adjustment methods and will also be distributed via the HRSCview webinterface as well as via the ESA Planetary Science Archive (PSA) and NASA Planetary Data System (PDS) interface in the near future.

Methods: Derivation of DTMs and ortho-image mosaics are basically performed using software developed at the German Aerospace Center, Berlin and which is based on the VICAR tools developed at JPL. The standard processing workflow is described in detail in [5, 6]. The main processing tasks are (a) pre-rectification of image data using global MOLA-based DTM, (b) least-squares area-based matching between nadir and other channels (stereo and photometry) in a pyramidal approach and (c) DTM raster generation. The result is a preliminary HRSC-based DTM which is used for further refinements in subsequent processing iterations. Iterative image filtering is applied in order to improve the image matching process by increasing the amount and quality of object points and in order to reduce possible misdetections caused by image-compression artifacts. For all our calculations we have only used objects points defined by at least triple intersections, and in order to eliminate blunder effects a threshold value for the intersection accuracy is set. The DTM-grid size depends mainly on the object point distribution, point accuracy and matching resolution. DTM-raster generation effects by interpolation and filtering of multiple object points. As an additional DTM-quality control we calculated elevation differences to the MOLA DTM, generated shaded relief DTMs, and created ortho-images with superimposed elevation contour lines.

Apart from the DTM quality, image mosaicking also depends on the quality of exterior orientation data and in order to generate high resolution DTMs and ortho-images, these data have to be corrected. For this purpose, new exterior and interior orientation data, based on tie point matching [7, 8] and bundle adjustment [9, 10] provided by the Leibniz Universität Hannover, Technische Universität München and Freie Universität Berlin have been used. This allows us to adopt HRSC-derived data to the global Mars-reference system as defined by MOLA. The new exterior orientation data refinements have been applied for individual strips thus far. Additionally, there are bundle-block adjustments for combined orbits covering the test regions.

Results: Image filtering approaches are advantageous for nearly all HRSC orbit strips, however, problems usually occur in featureless images. The area based matching shows a higher correlation in textured image parts and a lower image correlation in less-textured images parts. DTM-derivation using interior and exterior orientation data that were adjusted in a strip could be used for ortho-image mosaics and DTMs, and provided good results. The displacements are smaller when compared to the nominal exterior orientation data. Consequently, elevation differences to the MOLA DTM are usually smaller. In principle, there are no systematic variations between HRSC DTM and the MOLA DTM. Higher-resolution HRSC-based DTMs as well as the lower-resolution MOLA DTMs include areas without any object point information. In these areas elevation differences are relatively large. However, this is not due to an incorrect HRSC DTM, and it is likely that the MOLA and HRSC DTMs contain not enough object information in this area. As expected, the orbits that were adjusted in a block have a slightly higher accuracy when compared to the orbits adjusted in a single strip. A Panchromatic HRSC ortho-image mosaic has been generated successfully and methods described above will now be extended to adjacent nadir strips and colour channels too.

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