THE NEXT GENERATION OF MARS IMAGE MOSAICS: CO-REGISTERING MARS RECONNAISSANCE ORBITER CONTEXT CAMERA IMAGES TO MARS-EXPRESS HIGH-RESOLUTION STEREO CAMERA GLOBAL DATASETS S. H. G. Walter (1), A. Neesemann (1), K. Gwinner (2), G. G. Michael (1), R. Jaumann (1), F. Postberg (1); (1) Institute for Geological Sciences, Freie Universität Berlin, Berlin, Germany (s.walter@fu-berlin.de); (2) Institute of Planetary Research, German Aerospace Center (DLR), Berlin, Germany

Introduction: The single image coverage of the currently available Context Camera (CTX, [1]) images converges to the full coverage of the surface of Mars. Still, the individual images show offsets of tens to hundreds of pixels from their real ground position leading to a large-scale processing requirement including definition and application of geodetic control for the images. The lack of ground control points on the inaccessible surface leaves only the use of a globally available reference dataset for ground control. Current efforts for ortho-rectification and lateral control use the MOLA data as this source for geometric correction and for global reference (e.g., [2]). Towards the equator this approach is a major challenge due to the large discrepancy of the spatial resolutions of the two datasets (6 m/px for CTX, 463 m/px for MOLA). Automatic point matching of image pixels to DTM pixels are not reliable, therefore usually the CTX pixels are matched to imagery datasets which are themselves controlled to MOLA, such as the THEMS IR dataset [3]. This of course is sensitive to error propagation as it is not assured that the resulting quality of tie points between the different instruments is equally distributed in all areas.

The global topography and mosaicking campaign of the High-Resolution Stereo Camera (HRSC) team expects to finalize the creation of HRSC global mosaics consisting of bundle-block-adjusted DTMs based on the USGS-invented "Mars Chart 30" quadrangle scheme modified by the introduction of half-quadrangles [4] by the end of the year 2023. The HMC30 products are available at http://hrscteam.dlr.de/HMC30 and under https://maps.planet.fu-berlin.de as a map-based interface. The HMC30 DTMs provide an internal photogrammetric precision better than the 50 m used as the grid size. The deviations from the MOLA profile heights are also less than this single pixel resolution value due to the control to the MOLA dataset as a global geodetic reference during the processing [5]. Their corresponding image mosaics provide precise pixel-by-pixel alignment to the respective DTM in 12.5 m/px resolution and match seamlessly with their neighboring tiles [6]. Here we show a first approach for the use of the HMC30 products as the global combined (image and DTM) reference dataset for Mars, by creating a complete CTX quadrangle mosaic with absolute geodetic control to HRSC (and therefore also to MOLA).

Methods: Generally, first the HRSC DTM is used for the ortho-rectification of the CTX images instead of the MOLA DTM as it is often used for systematic processing. After this geometric correction, the image mosaic is used as a reference for automatic point matching and co-registration. We then apply the well-established brightness correction in a similar way we are using it for HRSC [6]. Ultimately, we combine the multitude of images from a quadrangle together to a seamless mosaic and export it as a single image file. The general workflow of our processing pipeline is shown in Figure 1.

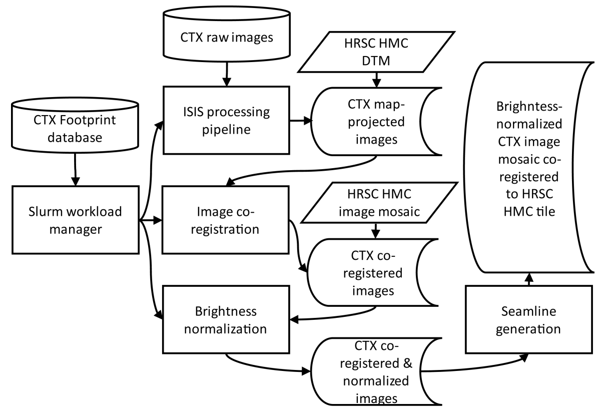

Figure 1: Flow chart of the proposed CTX processing workflow from single images to a complete mosaic.

Owed to the large amount of single CTX images per HMC30 tile, we use a database management system (DBMS) for storage and retrieval of the CTX data catalog. In the spatially-enabled DBMS we perform geometric queries by intersection with the HMC30 boundary with the CTX footprints. The map-projection and co-registration of the data is slow - processing time can be significantly increased by high-performance computing (HPC). The current HPC cluster maintained by Freie Universitaet Berlin provides 5,440 cores for simultaneous processing [7]. We define the main tasks as array jobs: The ISIS [8] processing pipeline performs image ortho-rectification using the HMC30 DTM, which itself has been re-projected to the IAU sphere beforehand. The resulting nominally ortho-rectified CTX images show a significant offset to HRSC based on inaccurate spacecraft attitude control (see Fig. 2 top). For correction, we introduce a subsequent co-registration based on a phase correlation approach [9]. The consecutive brightness correction uses the same HRSC image mosaic as a radiometric reference – the software has been re-implemented for the cluster-based pipeline setup and adapted to CTX properties. A final step for seamline creation and image export is performed outside of the cluster on a high-performance compute server running Desktop GIS software.

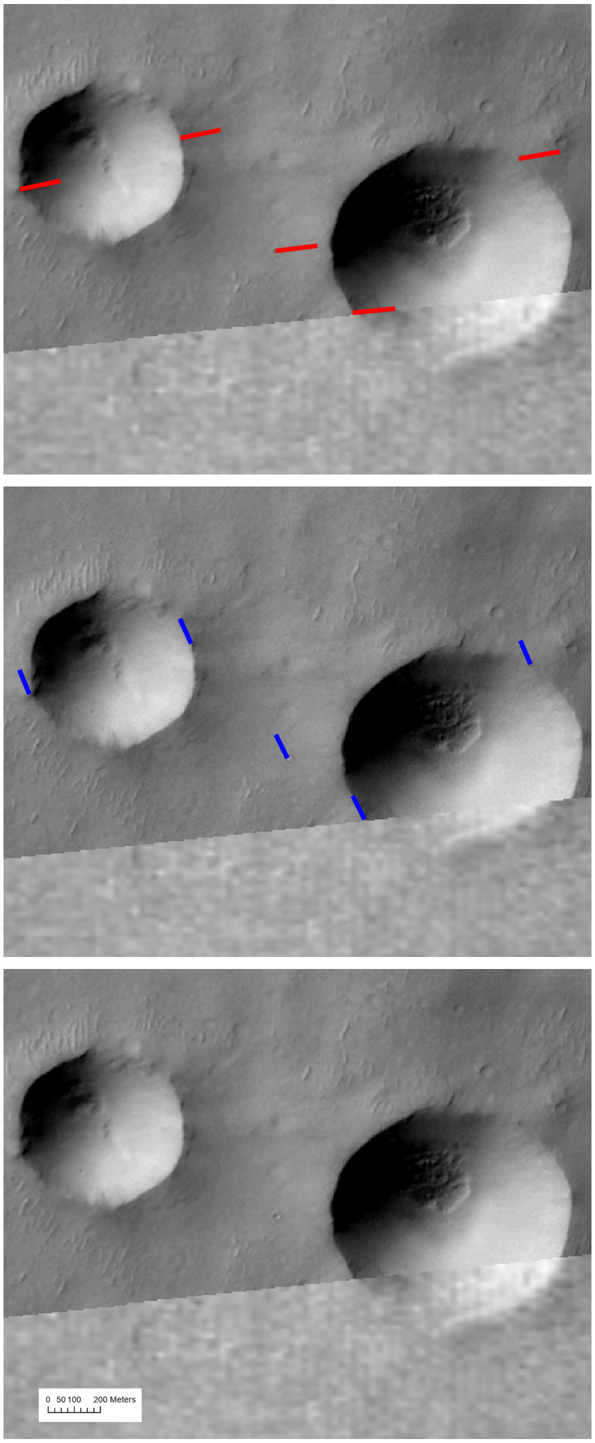

Figure 2: Image offsets between CTX image D02_027799_1580 (6.25 m/px) and HRSC HMC30_20W (12.5 m/px); top: CTX with nominal pointing after ISIS standard processing, offsets to HRSC in red; middle: CTX co-registered to HRSC by global x/y shift, offsets marked in blue; bottom: CTX co-registered by warping to dense network of tie points, with no visible offsets

Results: In a first qualitative assessment of the individual single CTX images, we examined the pixel offsets between the nominal images and their co-registered counterparts. First we tried to translate the images only in x/y direction as a block, but there were significant remaining offsets, increasing in the along-track direction of the spacecraft (see Fig. 2 middle). We achieved better results by transforming the CTX image to the HRSC reference image by the use of a dense network of tie points (see Fig. 2 bottom). In the example given in Figure 2, the offsets measure about 170 m which corresponds to 27 CTX pixels, 13 HRSC image pixels and 3 HRSC DTM pixels.

Based on the processing pipeline described above, we created a complete CTX mosaic of the HMC-20W quadrangle, which will be available on our mapserver (https://maps.planet.fu-berlin.de). The ISIS processing steps were successfully applied to all of the 2062 images intersecting the DTM boundary, and 1692 of the images were successfully co-registered to the HMC30 image mosaic. The processing of the complete CTX dataset consisting of 2062 single images with a resolution of 6.25 m/px took around 3 days on the cluster, but this time is highly dependent on the cluster utilization.

Discussion: The results of the co-registration with a success rate of 82 % are better than we initially expected. The remaining visible image gaps might be filled either by adapted parameters for co-registration or by the addition of manual tie-points. The initial offsets between the nominally-processed CTX images and the HRSC DTM (3 pixels in our example) might be large enough to expect impacting geometric artifacts during the orthorectification process, which will not be removed by the co-registration. Therefore it might be necessary to introduce an additional iterative processing step by feeding the tie-points acquired from the co-registration back into the ISIS pipeline and perform a bundle-adjustment between the CTX image and HRSC as ground and height reference.

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