An Integrated Workflow for Producing Digital Terrain Models of Mars From CTX and HiRISE Using the NASA Ames Stereo Pipeline

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Overview

- Stereo images are a key dataset for producing digital terrain models (DTMs) of Mars but only ~300 of ~4500 HiRISE stereopairs and 0 CTX stereopairs have been transformed into DTMs and released through the PDS
- The NASA Ames Stereo Pipeline (ASP) [1,2] is a free software package that can be used to produce CTX and HiRISE DTMs from stereo image data
- We describe our workflow for producing CTX and HiRISE DTMs in order to encourage community discussion on development of best practices for using ASP make DTMs of Mars.

Applications

We are using DTMs produced through this workflow in several research projects presented at this conference:

- **Abs. #1209** Investigating the effects of sediment compaction on layer orientations [3]
- **Abs. #2219** Making layer orientation measurements to test formation hypotheses for sedimentary rock mounds on Mars [4]
- **Abs. #2681** Estimating the volume of chloride-bearing deposits [5]

Code on GitHub

The shell scripts that implement this workflow and associated documentation are being made available through the University of Chicago's Git repository:

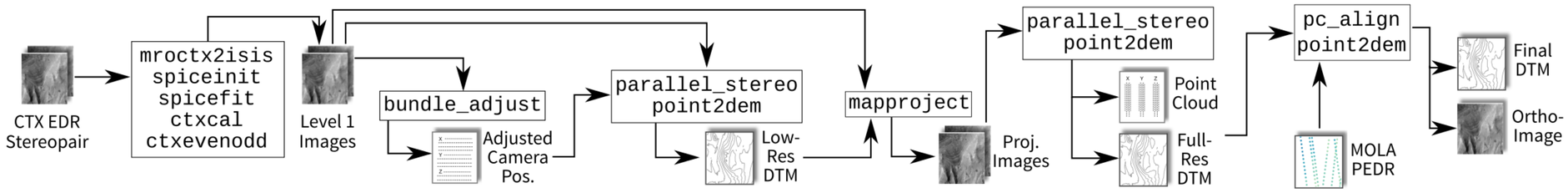
`https://psd-repo.uchicago.edu/groups/kite-lab`

We encourage members of the community to try our code and provide feedback.

DTM Availability

We have produced ~80 CTX and ~50 HiRISE DTMs, mostly over areas of sedimentary rock mounds and alluvial fan-bearing craters. Our CTX and HiRISE DTMs are available without restriction upon request to the lead author.

CTX Processing



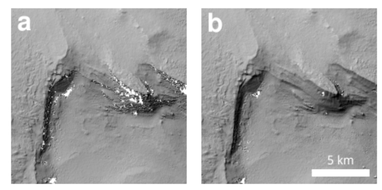
1. Data Preparation

CTX EDRs are prepared for ASP using a series of ISIS3 routines to apply SPICE kernels, smooth the SPICE data and apply radiometric corrections.

The prepared images are then automatically bundle adjusted using ASP's built in `bundle_adjust` tool. This step reduces the magnitude of triangulation errors and can minimize unwanted effects such as "washboarding" in the final DTM.

2. Initial DTM Generation

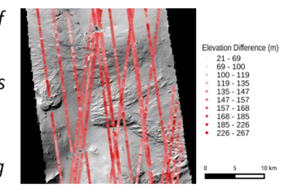
We use a two- stage process for generating a DTM. This approach combines the complementary advantages of using bundle-adjusted (but unprojected) images and map-projected images, thereby improving stereo correlation on steep slopes (Figure 1).



◂ **Figure 1:** *Hillshades of DTM built from* ***(a)*** *bundle-adjusted, unprojected CTX images and* ***(b)*** *bundle-adjusted images projected onto low-resolution DTM, showing removal of jagged artifacts on steep slopes and fewer "holes" where stereo correlation failed. B08_012862_1684_XN_11S073W/B11_013930_1681_XN_11S073W.*

3. Alignment/Final DTM

We align the revised point cloud to MOLA shot elevation data (PEDR) using ASP's `pc_align` tool. We first estimate the maximum expected displacement between the MOLA shot data and the full-resolution DTM by examining the elevation differences between the two datasets in a GIS (Figure 2) and pass this value as a parameter to `pc_align`. We interpolate the aligned point cloud to a final DTM (Figure 3) and create an orthoimage from the nadir-most member of the stereopair.



▲ **Figure 2:** *MOLA shot data (points) used to estimate maximum displacement for pc_align. Colors represent difference between MOLA and CTX elevations before point cloud alignment. Max displacement is typically ~95th-99th percentile of elevation differences.*

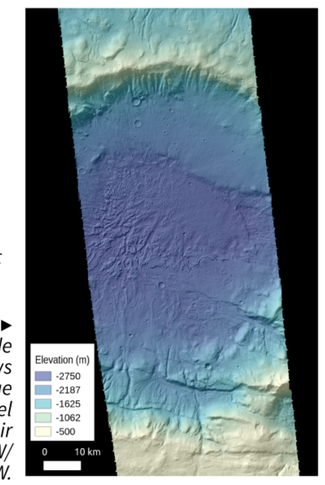
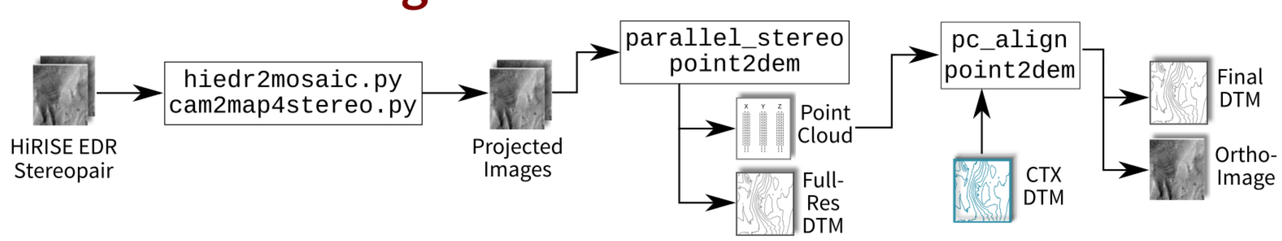


Figure 3 ▸ *Example of final CTX DTM and hillshade produced using this workflow. Scene shows an unnamed crater in Acheron Fossae containing gullies and inverted channel features. CTX stereopair F01_036151_2188_XI_38N135W/ F02_036507_2187_XI_38N135W.*

HiRISE Processing



1. Data Preparation

HiRISE EDRs are prepared using a pair of Python scripts included with ASP. These are wrappers around a series of ISIS3 routines that, mosaic the individual CCDs from each observation apply radiometric corrections and transform the images to a common map projection and spatial resolution.

We do not currently use `bundle_adjust` in our HiRISE workflow. We do occasionally request jitter-corrected images from the HiRISE Operations Center at the Univ. of Arizona in order to mitigate unwanted effects in the final DTM.

2. Initial DTM Generation

The map-projected images are passed to `parallel_stereo` to create an initial 3D point cloud. The point cloud is interpolated to an intial DTM using `point2dem`.

3. Alignment/Final DTM

We use pc_align to align the HiRISE point cloud to one of our CTX DTMs, more closely tying the HiRISE point cloud to MOLA elevations. We estimate the maximum displacement parameter for `pc_align` as the ~95th-99th percentile of the elevation difference between the initial HiRISE DTM and the CTX DTM (Figure 4).

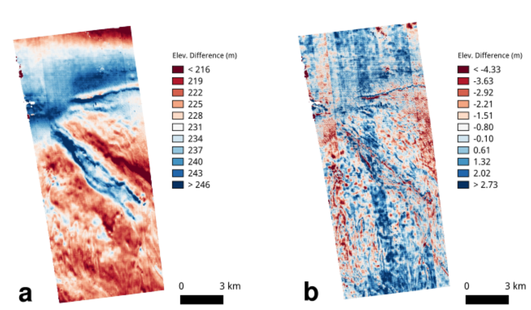


Figure 4: *Difference between HiRISE DTM and CTX reference DTM elevations* ***(a)*** *before and* ***(b)*** *after point cloud alignment. Scale clipped to middle 96% of data. Note different scales between panels. HiRISE stereopair ESP_013719_1665/ESP_021789_1665. CTX stereopair D18_034250_1676_XI_12S070W/D21_035450_1674_XI_12S070W.*

Finally, we interpolate the aligned point cloud to a DTM and create an orthoimage from the nadir-most member of the stereopair (Figure 5).

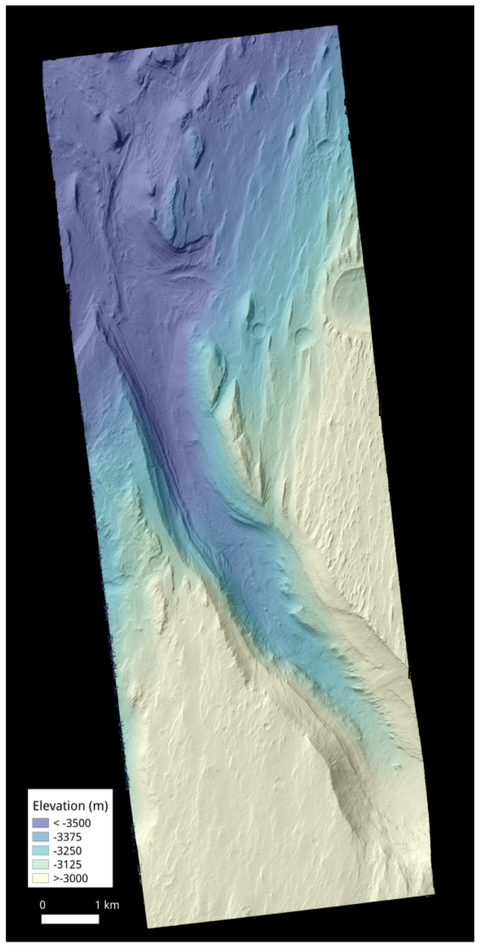


Figure 5: *Example of final HiRISE DTM and hillshade produced using this workflow. Scene shows a canyon incised into the large sedimentary mountain inside Gale crater. HiRISE stereopair PSP_006855_1750/PSP_007501_1750.*

References

[1] Moratto et al. (2010) *LPSC XLI* Abs. #2364. [2] Broxton and Edwards (2008) *LPSC XXXIX* Abs. #2419. [3] Gabasova and Kite (2016) *LPSC XLVII* Abs. #1209. [4] Sneed et al. (2016) *LPSC XLVII* Abs. #2219. [5] Melwani Daswani and Kite (2016) *LPSC XLVII* Abs. #2681.

Acknowledgements

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