Lunar Topographic Mapping using OSU OrbiterMapper and LROC NAC Stereo Images

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The Lunar Reconnaissance Orbiter Camera (LROC) is an orbital imaging system mounted onboard the Lunar Reconnaissance Orbiter (LRO). The LROC imaging system consists of one Wide-Angle Camera (WAC) and two NAC (Narrow-Angle Camera) cameras. LROC NAC high-resolution images, formed into stereo imagery by combining images from two or more adjacent orbits (cross-track stereo), have been acquired for the assessment of meter-scale topographic features on the lunar surface in support of the long-term goals of lunar landing missions. The Mapping and GIS Laboratory at The Ohio State University has developed the OrbiterMapper system for orbital data processing, which was extended for 3-D topographic map generation using LROC NAC data.

In OrbiterMapper, the entire sequence of photogrammetric processing for DEM generation can be divided into two major sections: 1) image processing that primarily involves image preprocessing and a coarse-to-fine hierarchical matching process for the extraction of dense matching points, and 2) geometric processing including Boresight Calibration (BC) and Bundle Adjustment (BA) to remove any geometric inconsistencies in the Exterior Orientation (EO) parameters among stereo orbits. Several significant improvements to both the image processing and geometric processing have been incorporated into the current version of OrbiterMapper for higher quality DEM generation.

Improvements to the image processing in OrbiterMapper include 1) two rounds of dense grid matching for more reliable matching and 2) three-fold matching along seam lines. Two rounds of dense grid matching can overcome the problem of small artificial bumps due to mismatches in areas of steep slope, where it is difficult to provide appropriate initial positions for least-squares matching from the matching results of previous levels in the hierarchical matching process. Grid matching points from first round must be refined through a stricter outlier elimination step. Once refined, they can offer sufficient predictions with high quality for the second round of the grid matching. In the second improvement, the method of three-fold matching along seam lines was proposed to decrease seam inconsistencies in the DEM overlapping area. The points along the two seam lines can actually have triple matching points: two inter-strip points in the overlapping area of two CCDs in one orbit along with a third one in the other orbit’s CCD. If all three matching points along a seam line can be employed for intersection of the ground points, it is possible that any inconsistencies remaining after geometric processing (about a half pixel) can be distributed to several pixels across the seam line, which would further alleviate seam inconsistencies.

In addition to the above improvements in image processing, new investigations into boresight calibration (BC) have been conducted in order to better estimate the boresight parameters that describe the relative alignment between two NAC CCDs. Two methods were tested. The first

method is an integrated BA and BC. A BA of two left images from adjacent orbits is conducted simultaneously with the BC to jointly solve EO polynomial parameters and boresight parameters. In the second method, the BA and BC are performed separately. The BA of the two left images is performed to derive the estimate of the EO polynomial parameters of two left images. These EO parameters are then used in the BC to estimate the boresight parameters. It was found that the boresight parameters are time dependent to some degree. This may be caused by sun illumination and/or operational conditions of other payload instruments. Therefore, the boresight parameters of different orbits are set to be different. Thirteen stereo pairs from both commissioning and nominal phases of the mission were chosen as experimental data to test these two methods. Results from the first (integrated) method demonstrated that boresight parameters have considerable parametric correlation with the EO parameters of the left images and thus have the potential to affect estimation of either set of parameters, which could yield distortion in the DEM. On the other hand, the second method can avoid this correlation between the two kinds of parameters and solve them correctly while maintaining a high level of accuracy (RMSE of less than half of a pixel for all tie points). DEMs generated by the second method demonstrated a good fit with LOLA profiles.
The latest OrbiterMapper software has been evaluated through a DEM comparison using data covering the Apollo 15 landing site and Tsiolkovskiy Crater, and applied successfully to the generation of 3D lunar terrain for different scientific objectives. To date, more than ten sites have been processed for the generation of topographic products for the LRO science team.

Keywords: Extraterrestrial, Matching, DTM, Mapping, Calibration, Bundle Adjustment