Stereo Reconstruction from Apollo 15 and 16 Metric Camera

Zachary Moratto[1], Ara Nefian[1,2], Taemin Kim[1], Michael Broxton[1,2], Ross Beyer[1,3], and Terry Fong[1], [1]NASA Ames Research Center, MS 269-3, Moffett Field, CA, USA (z.m.moratto@nasa.gov), [2]Carnegie Mellon University, [3]Carl Sagan Center SETI

Introduction

This paper presents the production of digital terrain models (DTMs) and digital image mosaics (DIMs) of the Lunar surface that cover a large portion of the near-side of the Moon at 40 m/px and 10 m/px respectively. These data products, produced under direction of the NASA ESMD Lunar Mapping and Modeling Project (LMMP), are based on 2600 stereo image pairs from the Apollo 15 and 16 missions that were digitized at high resolution from the original mission films [1]. Our reconstruction was carried out using the highly automated Ames Stereo Pipeline software [2], which runs on NASA's Pleiades supercomputer.

Stereo Reconstruction Process

Reconstruction was performed using 1400 images from Apollo 15 and 1200 images from Apollo 16. Images that did not overlap in sequence and those with emission angles greater than 5 deg are discarded. The images were subsampled by a factor of 4 to reduce noise from film grain; resulting in images with a resolution of ∼40 m/px.

Camera locations were provided by ASU from historical documents. These measurements were found to have significant errors due to tracking inaccuracy and incorrectly recorded ephemeris time. Bundle Adjustment (BA) was therefore required and performed using ASP tools. Automated tie-point measurements were extracted using [3]. Tie points were matched according to the overlap described by the original ephemeris. The solutions were controlled with a hybrid method using ULCN2005 and LOLA. Individual images were automatically tied to the ULCN Clementine basemap (ver. 2) using [3]. Those measurements were then constrained tangentially by their ULCN location and normally by LOLA 64 px/deg GDR. The final solution is visually inspected to remove the remaining outliers.

ASP automatically determines the correlation window size and computes the stereo correspondence maps at a subpixel level using the Bayesian affine method described in [4]. This method showed the ability to handle film and scanning noise specific to the AMC images. Processing time for each stereo pair was ∼35 CPU-Hr on a Harpertown class CPU. Processing an entire mission was ∼50,000 CPU-Hr, or a week in wall time.

Results

The stereo pair DTMs obtained as described above are used to create the final LMMP data products. DTM mosaic, DIM, and precision maps are produced for both missions separately.

The DTM mosaic is formed by a weighted average of the stereo pair DTMs. Input DTMs were weighted maximum value at their centers and then feathered to zero at the edges. The DTM mosaics are shown in Fig. 1 and 2.

The DIM was created by projecting the original resolution images onto the 40 m/px DTMs, creating individual orthoimages. Those orthoimages were then mosaicked by a process described in [5] without reflectance. Therefore, only the final image mosaic and time exposures were calculated. Apollo 15's DIM is shown in Fig. 3.

The precision map is the weighted variance of the individual stereo pair DTMs. Weights are calculated the same as in the DTM mosaic. The result was rendered into an image by binning the variance. White represents a variance of 0-25 m, light gray is 25-50 m, dark gray is 50-75 m, and darkest gray is 75-100 m. Black represents either high variance or no data. Apollo 15's precision map is shown in Fig. 4.

Conclusion and Future Work

This paper presents the current Apollo 15 and 16 DTM and DIM generated for LMMP. These corresponding DTM precision maps determine the quality and reliability of these products at every location. Current work is directed towards the joint terrain reconstruction of the Apollo 15, 16, and 17 missions and the comparison of the generated terrain model with LOLA measurements.

References

[1] S. J. Lawrence et al. The Apollo Digtal Image Archive: New Research and Data Products. *LPI Contributions*, 1415, 2008. 2066.

[2] Z. M. Moratto et al. Ames Stereo Pipeline, NASA's Open Source Automated Stereogrammetry Software. In *LPSC*. 2010. 2364.

[3] V. R. Jakkula. *Efficient Feature Detection Using OBALoG: Optimized Box Approximation of Laplacian of Gaussian*. Master's thesis, KSU, 2010.

[4] A. V. Nefian et al. A Bayesian Formulation for Sub-pixel Refinement in Stereo Orbital Imagery. *IEEE ICIP*, 2009.

[5] A. V. Nefian et al. Towards Albedo Reconstruction from Apollo Metric Camera Imagery. In *LPSC*. 2010. 1555.

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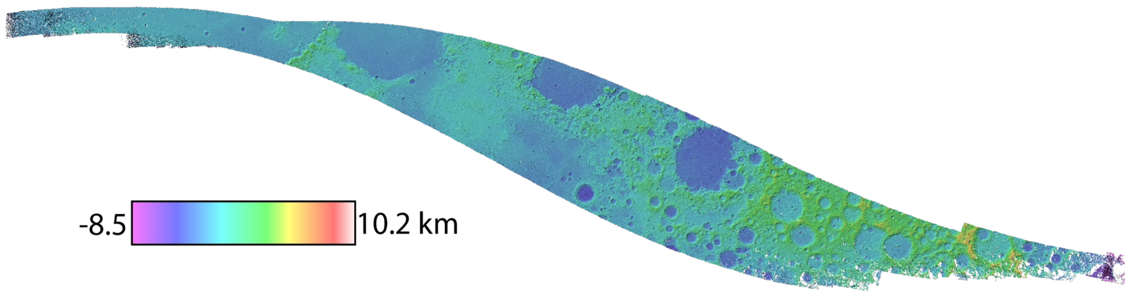

Figure 1: Apollo 15 DTM Mosaic

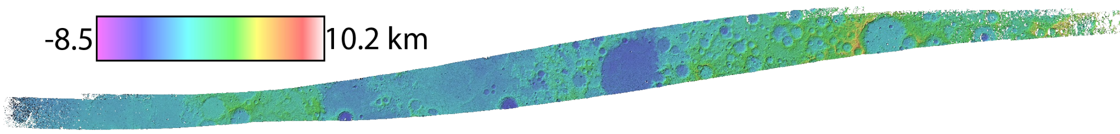

Figure 2: Apollo 16 DTM Mosaic

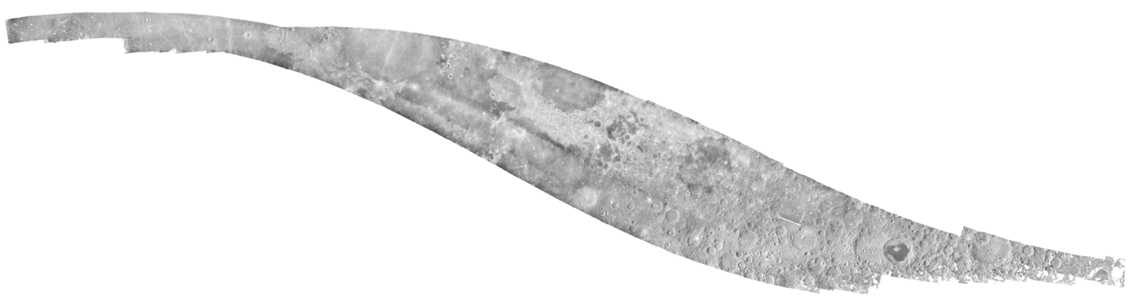

Figure 3: Apollo 15 DIM

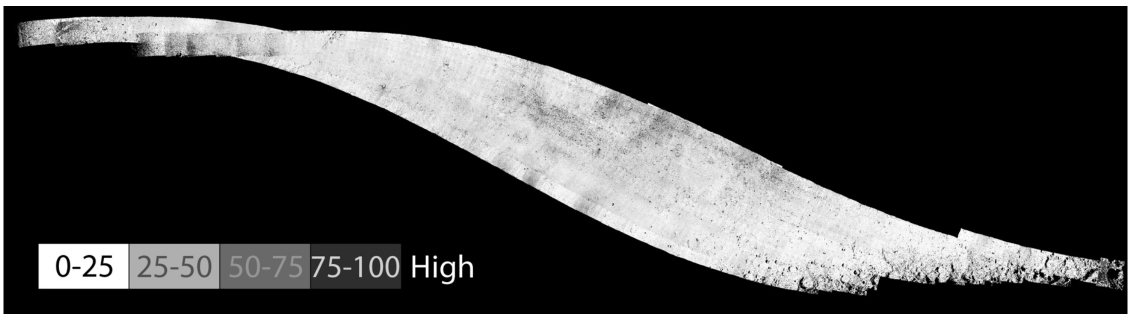

Figure 4: Apollo 15 Precision Map