EPSC Abstracts
Vol. 12, EPSC2018-80, 2018
European Planetary Science Congress 2018

An Integrated Software Environment to Improve the Photogrammetric Control Process for Planetary Mapping

Kenneth L. Edmundson (1), B.A. Archinal (1), J.C. Backer (1), T.L. Becker (2), K.L. Berry (1), C.R. Combs (1), D.A. Cook (1), A.C. Goins (1), I.R. Humphrey (1), J.A. Mapel (1), C.A. Neubauer (1), A.C. Paquette (1), M.R. Shepherd (1), S.C. Sides (1), E.D. Smith (1), S.G. Stapleton (1), T.L. Sucharski (1), L.A. Weller (1), and T.J. Wilson (1). (1) Astrogeology Science Center, U.S. Geological Survey, Flagstaff, AZ, USA (kedmundson@usgs.gov), (2) Lunar & Planetary Laboratory, University of Arizona, Tucson, AZ, USA.

Abstract

The Integrated Software for Imagers and Spectrometers (ISIS3) is developed and maintained by the U.S. Geological Survey Astrogeology Science Center (ASC) for the cartographic and scientific analysis of planetary image data [1]. The rigorous photogrammetric control of planetary images is a key ISIS3 capability, up to now requiring many standalone applications in a process that can be error-prone, inefficient, and costly. The ASC is developing in ISIS3 an *Integrated Photogrammetric Control Environment* (IPCE) offering a seamless, efficient, more intuitive and automated approach by integrating all aspects of the process in one environment [2].

1. Introduction

The quality of digital image mosaics (DIMs) and elevation models (DEMs)—and geologic maps using such products as basemaps—depends greatly upon accurate sensor position and pointing parameters. Spacecraft ephemeris and attitude data provide initial estimates for these parameters. Uncertainty in these data propagate to errors in mapping products (Figure 1). To minimize errors, images are controlled photogrammetrically. Overlapping images are registered to one another by measuring common features (tie points). Images may be tied to the ground by measuring features identifiable on base maps or DEMs (control points). Image measurements are input to the least-squares bundle adjustment (BA) which generates improved sensor position and pointing parameters and tie and control point coordinates [4]. In practice the workflow is complicated and the tasks complex. One measures images; bundle adjusts; analyzes results; fixes errors; adds/removes data and/or measurements; fine-tunes settings; re-measures; re-adjusts; and iterates as necessary. Developing intuitive, user friendly software for photogrammetric control is not trivial.

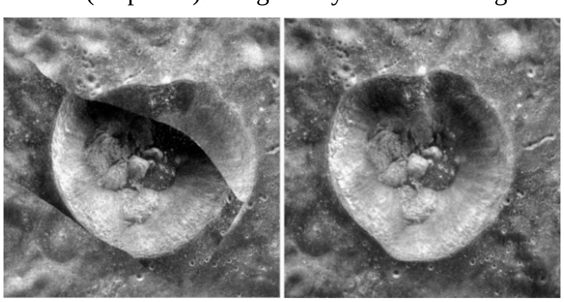

Figure 1: Uncontrolled & controlled mosaics of LRO Mini-RF radar images of the 20 km lunar crater Hermite A (87.94°N, 308.98°E), showing improvement in registration from >3 km to <30 m pixel scale (adapted from [3]).

2. IPCE

IPCE simplifies data management with the ability to save and restore project data and settings. Multiple, integrated views of data and processing results (Figure 2) have streamlined previously time-consuming tasks (e.g. creating, deleting, and editing points). The BA can be performed any number of times with results for each run available for examination via statistical and graphical analysis tools. Adjusted image position and pointing for each run are in the form of ISIS3 detached labels that can be applied to the original image data for map projection and mosaicking. Note that the image data itself is not duplicated.

3. The ISIS3 Bundle Adjustment

The ISIS3 BA is implemented in IPCE and as a standalone application (*jigsaw* [5]). In IPCE it runs in a separate thread from the main interface, so the user can continue to work. Images from different sensor types can be adjusted together and weighted appropriately. We can solve for target body parameters (e.g. pole position, spin rate, mean radius and/or semi-axes) and have applied this in processing a global network of Enceladus consisting of Cassini ISS images [6]. We now represent position and pointing of images from time dependent sensors (e.g. line scanners, radar) with piecewise continuous

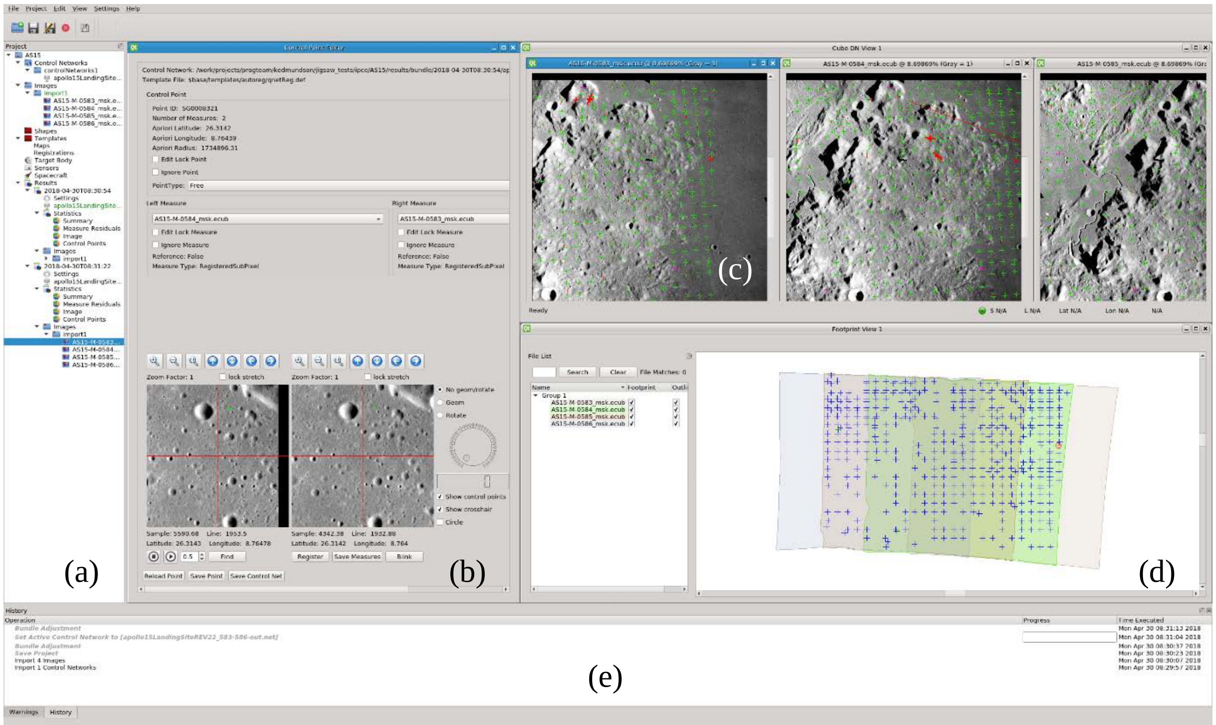

Figure 2: IPCE interface with (a) *project tree*, (b) *control point editor*, (c) *image display* (image measurements and residuals overlaid), (d) *image footprint view* (control points overlaid), and (e) *history* and *warnings* windows.

polynomials. Previously, position and pointing were modeled as single polynomial functions of time. Low-order polynomials cannot accurately represent complex spacecraft motions induced by, e.g. thruster firings, other instruments, or anomalous events. Higher-order polynomials could be used but can cause instability in the BA. In the piecewise polynomial approach, images are divided into segments represented by low-order polynomials [7]. We are currently implementing the rigorous combined adjustment of laser altimeter (LA) and image data in the BA (e.g. [8]). This will enable 1) the generation of improved sensor models, image position and pointing, and LA data sets; and 2) production of higher quality and accuracy digital terrain models that will facilitate landing site mapping, providing a greater margin of safety for future surface operations.

4. Upcoming Work

Plans include 1) improved automated image matching (e.g. [9]); 2) more analysis/visualization tools; 3) monitoring of control network state as edits occur; and 4) output of updated NAIF position/pointing kernels [10]. BA plans include self-calibration, free network adjustment [11], imposing conditions between sensors, variance component estimation [12], improved outlier detection, sequential estimation, and solving for body libration.

Acknowledgements

Funding is provided by a NASA-USGS Interagency Agreement.

References

[1] Sides, S., et al.: *LPS XLVIII*, #2739, 2017. [2] Edmundson, K.L., et al.: *LPS XLVI*, #1454, 2015. [3] Kirk, R.L., et al.: *LPS XLIV*, #2920, 2013. [4] Brown, D.C.: A Solution to the General Problem of Multiple Station Analytical Stereo Triangulation. *RCA Data Reduction Technical Report #43*, 1958. [5] Edmundson, K.L. et al.: *ISPRS Annals, I-4,* 203-208, 2012. [6] Becker, T.L., et al.: *LPS XLVII*, #2342, 2016. [7] Poli, D.: Dissertation #15894, ETH Zurich, 2005. [8] Yoon, J. and Shan, J.: *Photogramm. Eng. Remote Sensing*, 71(10), 1179-1186, 2005. [9] Becker, K.B., et al.: *LPS XLVII*, #2959, 2016. [10] Acton, C.H., et al.: *Planet. Space Sci.*, 44(1), pp. 65-70, 1996. [11] Blaha, G.: *Bull. Géodésique*, 56(3), 209-219, 1982. [12] Koch, K-R.: *Parameter Estimation and Hypothesis Testing in Linear Models*, Springer-Verlag Berlin Heidelberg, 1988.