Rigorous Photogrammetric Processing Of Chang'E-1 And Chang'E-2 Stereo Imagery For Lunar Topographic Mapping

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Chang’E-1 (CE-1) obiter is the first lunar probe of China. CE-1 CCD camera is a three-line pushbroom camera which has a ground resolution of 120m and a swath width of 60km. It is implemented on an area array CCD sensor and uses only the 11th, 512th and 1013th rows to generate the forward-, nadir-, and backward-looking images simultaneously in the flight direction. Chang’E-2 (CE-2) obiter is the follow-up orbiter of CE-1 and is part of the second phase of the Chinese Lunar Exploration Program. The CCD camera carried by CE-2 is a two-line pushbroom sensor which acquires forward- and backward-looking images with a swath width of 13km. CE-2 CCD images have ground resolution of 7m globally and 1.5m at Sinus Iridum, the pre-selected landing site of Chang’E-3 lunar rover.
In this research, we developed rigorous sensor models of CE-1 and CE-2 CCD cameras based on push-broom imaging principle and exterior orientation parameters (EOPs) derived from spacecraft trajectory (position and orientation) data. The image coordinates are transformed to the focal-plane coordinates centered at the principal point according to the calibrated camera interior orientation parameters. Transformation between focal-plane coordinates and lunar-body fixed (LBF) coordinates are represented as collinearity equations based on EOPs. Three order polynomials and Lagrange polynomials are used in our experiment to calculate EOPs from the original telemetry data. Based on the rigorous sensor model, the 3D coordinate of a ground point in LBF can be calculated by space intersection from the images coordinates of conjugate points in stereo images, and the image coordinate can be calculated from 3D coordinate by back-projection. Ideally, using the 3D coordinate from space intersection, the back-projected image position should be the same as the measured image points which are used in space intersection. However, due to the orbit uncertainty, the back-projected image points are different from the measured point. The differences are called back-projection residuals. Using the original EOPs, the back-projection residuals among the images of the same orbit are up to 1.5 pixels, the back-projection residuals among the images of neighboring orbits are around 2.5 pixels. In order to reduce these inconsistencies and improve precision, we have developed two methods to refine the rigorous sensor model: (1) correcting the attitude angle bias of different looking images within the same orbit, (2) eliminating the inconsistencies among the images from different orbits using bundle adjustment. Preliminary experimental results show that the back-projection residuals can be reduced to 1/100 pixel level for images of the same orbit and subpixel level for images of neighboring orbits after model refinement. A multi-level image matching method is adopted for dense stereo image matching. Consequently, high precision DEM (Digital Elevation Model) and DOM (Digital Ortho Map) are automatically generated.

Keywords: Planetary, Topographic Mapping, Rigorous Sensor Model, Chang’E-1, Chang’E-2, CCD image, Model Refinement