Rigorous Photogrammetric Push-Broom Sensor Modeling for Lunar and Planetary Image Processing

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Abstract : Accurate geometric relation algorithms are imperative in Earth and planetary satellite and aerial image processing, particularly for high-resolution images that are used for topographic mapping. Most of these satellites carry push-broom sensors. These sensors are optical scanners equipped with linear arrays of CCDs. These sensors have been deployed on most EOSs. In addition, the LROC is equipped with two push NACs that provide 0.5 meter-scale panchromatic images over a 5 km swath of the Moon. The HiRISE carried by the MRO and the HRSC carried by MEX are examples of push-broom sensor that produces images of the surface of Mars. Sensor models developed in photogrammetry relate image space coordinates in two or more images with the 3D coordinates of ground features. Rigorous sensor models use the actual interior orientation parameters and exterior orientation parameters of the camera, unlike approximate models. In this research, we generate a generic push-broom sensor model to process imageries acquired through linear array cameras and investigate its performance, advantages, and disadvantages in generating topographic models for the Earth, Mars, and the Moon. We also compare and contrast the utilization, effectiveness, and applicability of available photogrammetric techniques and softcopies with the developed model. We start by defining an image reference coordinate system to unify image coordinates from all three arrays. The transformation from an image coordinate system to a reference coordinate system involves a translation and three rotations. For any image point within the linear array, its image reference coordinates, the coordinates of the exposure center of the array in the ground coordinate system at the imaging epoch (t), and the corresponding ground point coordinates are related through the collinearity condition that states that all these three points must be on the same line. The rotation angles for each CCD array at the epoch t are defined and included in the transformation model. The exterior orientation parameters of an image line, i.e., coordinates of exposure station and rotation angles, are computed by a polynomial interpolation function in time (t). The parameter (t) is the time at a certain epoch from a certain orbit position. Depending on the types of observations, coordinates, and parameters may be treated as knowns or unknowns differently in various situations. The unknown coefficients are determined in a bundle adjustment. The orientation process starts by extracting the sensor position and, orientation and raw images from the PDS. The parameters of each image line are then estimated and imported into the push-broom sensor model. We also define tie points between image pairs to aid the bundle adjustment model, determine the refined camera parameters, and generate highly accurate topographic maps. The model was tested on different satellite images such as IKONOS, QuickBird, and WorldView-2, HiRISE. It was found that the accuracy of our model is comparable to those of commercial and open-source software, the computational efficiency of the developed model is high, the model could be used in different environments with various sensors, and the implementation process is much more cost-and effort-consuming.

Keywords : photogrammetry, push-broom sensors, IKONOS, HiRISE, collinearity condition
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