INVESTIGATION ON RATIONAL FUNCTION MODELS FOR MULTIPLE LUNAR AND MARS ORBITER IMAGES

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ABSTRACT:

Planetary orbiter imagery plays critical roles in planetary exploration missions, in applications such as topographic mapping, morphology analysis of planetary surface, geodetic parameters determination, landing site selection, and localization of lander or rover, etc. All these applications demand high-precision geometric processing of the orbiter images, such as co-registration, geometric rectification, stereo mapping, and orthophoto generation. Establishing the geometric models of the images is the basis of these geometric processing tasks. So far, most studies of extra-terrestrial mapping (such as lunar and Mars mapping) use rigorous physical sensor model based on the collinearity equations. Owing to the features of push-broom image principle, the ephemerides and attitudes of orbital sensors used in the rigorous sensor model are functions of time. The rigorous sensor model is extremely complex for planetary scientists who don not specialize in photogrammetry. Moreover, because different orbital sensors have different geometric characteristics, the physical sensor models always differ from each other. Thus, a new corresponding physical sensor model should be developed whenever a new sensor is launched. It is usually difficult to implement the complex physical sensor models in general digital photogrammetric workstations, and it is especially challenging to process orbital images from different missions together.

A flood of high spatial, temporal and spectral resolution lunar and Mars orbiter images have been and are being acquired by missions from several space agencies. To obtain the maximal value of these data, integrated processing of multi-mission images is necessary. Due to the aforementioned disadvantages of physical sensor model, finding a generalized geometric model which is independent of sensors and mathematically simple, to replace the rigorous physical sensor model, is very meaningful. Rational Function Model (RFM) is one of the generic geometric models that has been widely used in geometric processing of high-resolution earth-observation satellite images, especially when the rigorous physical sensor models are not supplied and internal geometric parameters are not disclosed.

RFM uses two rational functions with 78 rational polynomial coefficients (RPCs) to express the geometric relationship between a ground point and its corresponding image point. It has excellent capability of fitting complex rigorous sensor models. The RPCs of the RFM can be solved under terrain-independent or terrain-dependent scenarios which distinguish whether the control points generated from rigorous physical sensor model or other source (reference map etc.). Many studies have investigated the accuracy of RFM as a replacement of rigorous physical sensor models when applied to aerial frame images, push-broom images and Synthetic Aperture Radar (SAR) images. A variety of researches investigated the issues on practical applications of RFM in geometric processing, such as refinement of the existing RFMs using ground control points (GCPs), geopositioning and image rectification, block adjustment, and 3D reconstruction. However, So far, to the best of our knowledge, there are few studies on feasibility and application of RFM in extra-terrestrial mapping.

A systematic investigation on the feasibility and precision of RFMs for Lunar and Mars orbiter images is presented in this paper. First, we establish the rigorous physical sensor models of some mainstream extra-terrestrial orbiter sensors, including Lunar Reconnaissance Orbiter Camera (LROC) Narrow Angle Cameras (NACs), Chang'E-1 (CE-1), Chang'E-2 (CE-2), high-resolution stereo camera (HRSC) on Mars Express, and Mars Reconnaissance Orbiter's High Resolution Imaging Science Experiment (HiRISE). Then RFM models are computed by fitting the rigorous physical sensor models with virtual control points generated from the rigorous sensor models . In order to solve the integral time hopping problem in Chang'E-2 and HRSC, a time-based rational function model is also proposed. The experimental results show that traditional FRM can be used to describe the imaging geometry of CE-1, LROC, HiRISE images with the accuracy comparable to the rigorous sensor model, i.e., RFM can precisely fit the rigorous sensor model of these pushbroom images with a RMS residual error of 1/100 pixel level. With the time based RFM, the low fitting precision of CE-2 and HRSC with traditional scanline based RFM can be solved effectively, with the RMS residual error reducing from 9 pixels to 1/100 pixel level.

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