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RESOURCESAT-1 LISS-4 MX bands onground co-registration by in-flight calibration and attitude refinement

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Abstract

RESOURCESAT-1 satellite was launched in October of 2003. Since then it has been consistently providing high quality 5 m monochromatic and multispectral images of same resolution. LISS-4 MX sensor has complex acquisition geometry. It operates in three spectral bands imaged by 3 CCD arrays, which are separated by a finite time in imaging along the satellite track direction. Individual band data is acquired at different times while the satellite is driven by a pre-determined yaw profile. In addition, the odd–even pixels are too shifted by a small fixed delay in time. A unique challenge in LISS-4 MX Level-2 data processing sub-system is to autonomously rectify and additionally co-register the three bands data because of the influence of orbit and attitude in the time gap in the imaging sequence. In this paper, authors bring out details of in-flight calibration arrived for LISS-4 MX sensor. It addresses parameterization of co-registration problem by doing sensitivity analysis of the geometric model parameters to achieve co-registration among all bands. This approach can also be used for other sensor system having similar imaging geometry to achieve improved image co-registration among bands.

Keywords: RESOURCESAT-1 LISS-4 MX; Geometric correction; Co-registration; In-flight calibration

1. Introduction

Emerging engineering designs of high-resolution satellite cameras and their geometric descriptions are complex. The increasing variety and complexity of camera models presents an implementation challenge to software developers and data users. Camera model of a sensor describe the viewing geometry mathematically. The major advantages of physical modeling is mainly due to the fact that the mathematical functions correspond to the physical reality and take into account all the distortions generated in the image formation. When the parameters have a physical meaning, bad or erroneous results are easy to find and interpret. In the subsequent sections details on the payload geometry of LISS-4 camera, pre-flight calibration, Level-2 processing steps and co-registration procedure and its performance are given.

2. RESOURCESAT-1 LISS-4 MX sensor geometry

LISS-4 is one of the payloads onboard IRS P6 spacecraft. The optical design features an off axis unobscured three-mirror telescope similar to IRS-1C/1D PAN telescope (Joseph et al., 1996). LISS-4 payload contains 3 CCD configurations corresponding to three spectral bands (B2–B4) placed in focal plane separated by angles across and along the axis of the CCDs. LISS-4

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camera has off nadir viewing capability wherein it can be steered to look at across-track direction with $\pm 26^\circ$. Swath of LISS-4 camera in monochrome mode is 70 km whereas in MX mode is only 23 km due to the constraints of date rate transmission. In LISS-4 MX mode out of 12,000 pixels per scan line only 4200 selected pixels from a start pixel are transmitted to the ground (ISRO, 2003). Individual band data is acquired at different times while the satellite is driven by a pre-determined yaw profile. In addition, the odd–even pixels are too shifted by a small fixed delay in time. Liss-4 has 5.8 m nominal resolution. Camera geometric parameters measured at laboratory before launch comprises mission critical data set, which are used by Level-2 processing sub-system.

2.1. Pre-flight camera geometric model calibration

The LISS-4 pre-flight calibration activity results in a group of measurements, which are called pre-flight camera geometric model (CGM). The general definition of CGM is a mathematical expression that gives an arbitrary pixel's viewing direction, in an appropriate coordinate system, as a function of several variables. The objectives of the pre-flight camera geometric model calibration are to characterize those variables. This satisfies the two requirements of mission namely instrument science and providing input to in-flight geometric calibration. Some of the parameters can be measured simply by inspection or set at specified values during assembly.

3. Level-2 processing steps for RESOURCESAT-1 imagery

Level-2 correction involves modeling all systematic errors in the imagery (IRS data processing terminology Level-2 indicates no usage of GCPs). Pre-flight and in-flight calibration data are put to use for constructing the look point equation. A complete mapping between the corrected images coordinates and the radiometrically conditioned input image is established using geometric model that includes CGM. Input to this procedure is the orbit, attitude, mission constants and CGM parameters. RESOURCESAT-1 orbit and attitude accuracies and their specifications can be found in user handbook (ISRO, 2003).

The basic geometric correction procedure performs a set of coordinate transformations that takes scan, pixel coordinates of radiometrically corrected data to map projected coordinates. Thus we have corrected image coordinates (in a map projected space) for radiometrically corrected image scan, pixel coordinates at a regular interval. This is known as so-called output space input space grid mapping or simply correction grid (ISRO, 2002; Moorthi et al., 2005). For LISS-4 camera, every band data has their individual correction grids computed.

4. Additional procedures to ensure co-registration of LISS-4 MX bands

The geometric correction procedure for generation of co-registered LISS-4 MX product is a two-step process. First step is the generation of correction grids for the scene of interest. Second step is to register all band data by a scene-based approach after collecting image correspondences through grid mapping and image matching. It would be an ideal condition to expect correction grids to be enough to generate systematically corrected product with co-registered bands by the first step alone due to the uncertainties in the orbit, attitude knowledge and non-usage of terrain relief. The additional procedure is aimed at achieving all LISS-4 MX bands co-registered with each other. It is to be noted that multi-band co-registration is only relative and B3 is chosen as reference band.

There are two types of co-registration methods implemented. The first method is image-based registration, which is not sensitive to the regular geometry of satellite image acquisition and the other is model based. The band-to-band registration assessment or accuracy is carried out always by an image-based registration method. Both methods are complementary to each other and hence provision is kept for both image- and model-based co-registration methods in RESOURCESAT-1data processing system. It will be discussed how in-flight calibration data and a local scene wise attitude refinement is used to arrive at a model-based co-registration. Attitude refinement model uses imaging geometry whereas image-based method uses only image correspondences. Later this transformation of choice is used to adjust the correction grid for bands other than the reference band. These regenerated correction grids are used for resampling the radiometrically conditioned but not registered LISS-4 MX data set into a corrected and co-registered data set.

The performance of an image registration algorithm depends on (1) the performance of its image correspondence step and (2) the performance of the transformation function that uses information about the correspondences to warp one image to the other (Ramakrishnan et al., 2004). Selection of points in