

KOMPSAT-2 DIRECT SENSOR MODELING AND GEOMETRIC CALIBRATION/VALIDATION

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ABSTRACT:

The Korea Multi-Purpose Satellite-2 (KOMPSAT-2) was launched in July 2006 and the main mission of the KOMPSAT-2 is a high resolution imaging for the cartography of Korea peninsula by utilizing Multi Spectral Camera (MSC) images. The camera resolutions are 1 m in panchromatic scene and 4 m in multi-spectral imaging. This paper provides the geometric accuracy assessment of the KOMPSAT-2 high resolution image without ground control points, briefly introduces the sensor model, Rational Function Model and geometric calibration and validation of KOMPSAT-2. Also investigated and evaluated the obtained 3-dimensional terrain information using the MSC pass image and scene images acquired from the KOMPSAT-2 satellite.

1. INTRODUCTION

The Korea's first high resolution satellite, KOMPSAT-2, was successfully launched by the Rockot launch vehicle from Plesetsk Cosmodrome in Northern Russia on 28 July 2006.

The KOMPSAT-2 system consists of space segment, ground segment, and launch service segment, and various external interfaces including additional ground stations to support image data reception or launch and early operations. The space segment is a satellite consists of the spacecraft bus and payload.

The main payload of KOMPSAT-2 is MSC (Multi-Spectral Camera). The MSC is a high spatial resolution imaging sensor which collects visible image data of the earth's sunlit surface.

The MSC is a pushbroom-scanned sensor which incorporates a single nadir looking telescope. The sensor is submerged and rigidly attached to the spacecraft and the optical boresight of the telescope is aligned with the spacecraft +Z direction (nadir). The MSC collects PAN and MS monoscopic images of the earth. Stereoscopic images are made by ground processing of the images from multiple orbits. The MSC pointing is accomplished by rolling the spacecraft, as needed, so that the line of sight of the MSC may pass over the desired location or swath. The spacecraft has a roll capability of ± 56 degrees to support special imaging revisit cases.

At the nominal mission altitude with the spacecraft nadir pointing, the MSC collects data with a GSD of 1 meter for PAN and 4 meters for MS data and with a swath width of approximately 15 km. The MSC is designed to operate with a duty cycle of up to 20 % per orbit. All MSC electronics will provide full redundancies without a single point failure. Image telemetry data can be compressed on-board.

The Mission orbit of the KOMPSAT-2 is a sun-synchronous circular orbit with an altitude of 685.13 ± 1 km. The Orbit

inclination is 98.13 ± 0.05 degrees and the eccentricity from 0 to 0.001. The satellite operates with a nominal local time of ascending nodes of 10:50 AM $\pm 10/-15$ min. Figure 1 shows ascending passes (solid lines) of the KOMPSAT-2 for 28 day and a boundary of contact (circle) between the KOMPSAT-2 and the KARI site based on the minimum elevation for contact of 5 degrees. The satellite passes Korean region during the day along ascending orbits and during the night along descending orbits. The KOMPSAT-2 satellite is designed for an operational service life of 3 years on the mission orbit.

The horizontal geo-location accuracy of KOMPSAT-2, without GCPs (Ground Control Points) is 80 meters CE90 for monoscopic image of up to 26 degrees off-nadir angle, after processing including POD (Precise Orbit Determination), PAD (Precise Attitude Determination) and AOCS (Attitude and Orbit Control Subsystem) sensor calibration. In case of multiple stereo images, without GCPs, the vertical geometric accuracy is less than 22.4 meters LE 90 and the horizontal geometric accuracy is less than 25.4 meters.

The KOMPSAT-2 system provides surveillance of large scale disasters and their countermeasures, acquisition of independent high resolution images for GIS, and composition of printed maps and digitized image maps on domestic and overseas territories to users.

The major objective of this investigation is to check and verify the geometrical performance when KOMPSAT-2 images are employed and briefly introduce the sensor model of KOMPSAT-2.

2. KOMPSAT-2 SENSOR MODEL

There are two types of sensor model for KOMPSAT-2, direct sensor model and Rational Function Model (RFM). In general, a sensor model relates object coordinates to image coordinates.

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The direct sensor model calculates the orbital parameters directly by using the position vector. Based on the collinearity condition, an image point corresponds to ground point using the employment of the orientation parameters, which are expressed as a function of the sampling time.

The RFM is a generalized sensor model that uses a pair of ratios of two polynomials to approximate the condition equation.

2.1 DIRECT SENSOR MODEL

The direct sensor model of KOMPSAT-2 MSC is realized on the co-linearity condition. The spacecraft perspective center, image point and the corresponding ground point are assumed to be on one straight line using six basic coordinate systems. The origin of sensor coordinate system is considering coincided with the origin of the spacecraft which is located at the spacecraft center of mass.

The Figure 1 gives a description of basic sensor model of KOMPSAT-2.

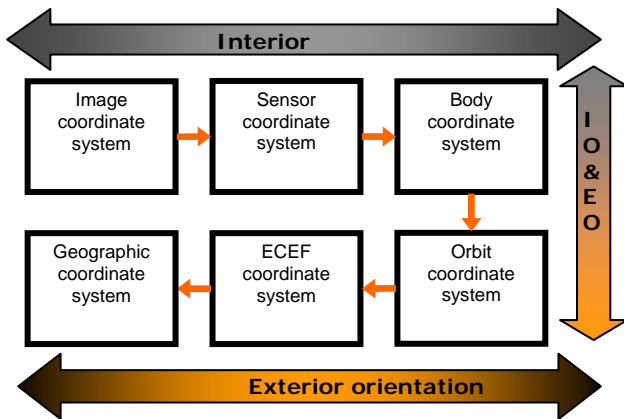


Figure 1. Direct sensor modelling for KOMPSAT-2 geometric calibration and validation

In from image coordinate system to sensor coordinate system, the main cal/val parameters consist of focal length, distortion which one is the LOD distortion the other is LOS distortion. After those distortion corrected using by GCP(Ground Control Point)/ICP(Image Control Point) with under 0.3 pixel accuracy and bundle adjustment, KOMPSAT-2 image data are provided to users. The cal/val items of from sensor coordinate system to body coordinate system compute to correct occurring misalignment come from between star tracker sensor and MSC. The Orbit Coordinate System as translation body coordinate System, the produced rotation angle of roll, pitch and yaw rotate and transfer the coordinate system from star tracker and gyro sensor of KOMPSAT-2. The measured attitude data are recorrected by the KPADS (KOMPAST-2 Precision Attitude Determination Subsystem). Earth-Centered Earth-Fixed Coordinate System(ECEF) is transfer from orbit coordinate system to ECEF as coordinate system, using satellite position and velocity vectors of the satellite measured from GPS sensors of KOMPSAT-2. The measured from GPS of the KOMPSAT-2 satellite system, the satellite of position, velocity and time information are transferred to the OBC, after this, that information is transferred to ground station through the S-band.

This ephemeris information through the KOMPSAT-2 POD system and the produced POD(Precision Orbit Data) .

The calculation of ground coordinates on an arbitrary image coordinate (u,v) is

$$\begin{bmatrix} X - X_s \\ Y - Y_s \\ Z - Z_s \end{bmatrix} = k \cdot M_{Orbit}^{ECEF} \cdot M_{Body}^{Orbit} \cdot M_{Sensor}^{Body} \cdot \begin{bmatrix} x \\ y \\ z \end{bmatrix} \quad (1)$$

where,

M_{Orbit}^{ECEF} : from orbit coordinate system to ECEF

M_{Body}^{Orbit} : from body coordinate system to orbit coordinate system

M_{Sensor}^{Body} : from sensor coordinate system to body coordinate system

$[x, y, z]^T$: Scan line coordinate

$[X_s, Y_s, Z_s]^T$: Satellite position from ephemeris data

$[X, Y, Z]^T$: Ground coordinate

k : scale factor

2.2 RFM

The RPC for the KOMPSAT-2 MSC sensor is generated from the resulted KOMPSAT-2 direct sensor model using the RFM. The RPC generation in KOMPSAT-2 IRPE system consists of 4 main parts as shown in Figure 2.

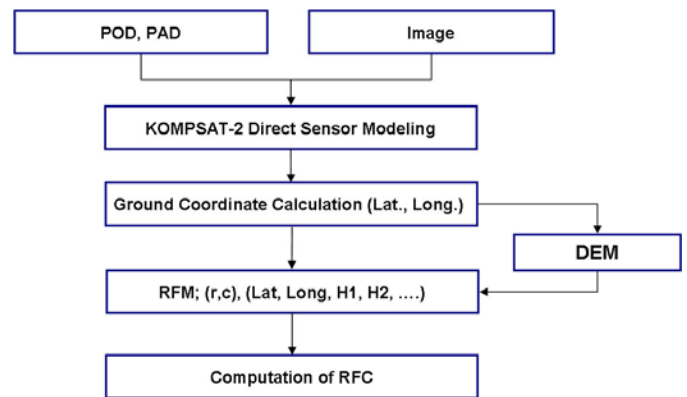


Figure 2. KOMPSAT-2 RPC generation workflow

The model uses a pair of ratios of two polynomials, as shown in equation 2.

$$r_n = \frac{p1(X_n, Y_n, Z_n)}{p2(X_n, Y_n, Z_n)}, \quad c_n = \frac{p3(X_n, Y_n, Z_n)}{p4(X_n, Y_n, Z_n)} \quad (2)$$

where,

r_n, c_n : the normalized row and column index of pixels in image.

X_n, Y_n, Z_n : the normalized coordinate value of object points in ground space.

p_1, p_2, p_3 and p_4 : the polynomial coefficients

$$p_l(X_n, Y_n, Z_n) = a_0 + a_1X + a_2Y + a_3Z + a_4X^2 + a_5XY + a_6XZ + a_7Y^2 + a_8YZ + a_9Z^2 + a_{10}X^3 + a_{11}X^2Y + a_{12}X^2Z + a_{13}XY^2 + a_{14}XYZ + a_{15}XZ^2 + a_{16}Y^3 + a_{17}Y^2Z + a_{18}YZ^2 + a_{19}Z^3$$

KOMPSAT-2 RFM is forward method which can be calculated from ground coordinate (Latitude, Longitude, Height) to image coordinate (Column, Row). Auxiliary file(***.rpc) gives RPC parameters for “ground to image” location model.

A least-squares approach is utilized to determine the RPC a_n, b_n and d_n from a three-dimensional ground coordinates generated using the KOMPSAT-2 MSC camera model. The basic relationship of the KOMPSAT-2 MSC camera model that describes the ground coordinates in term of sensor coordinates is realized by the co-linearity condition in which the KOMPSAT-2 MSC perspective center, an image point and the corresponding ground point are assumed to be on one straight line. The 3D ground coordinates of object points in RFM are generated by intersecting the rays emanating from a 2-D grid of image with a number of constant elevation planes.

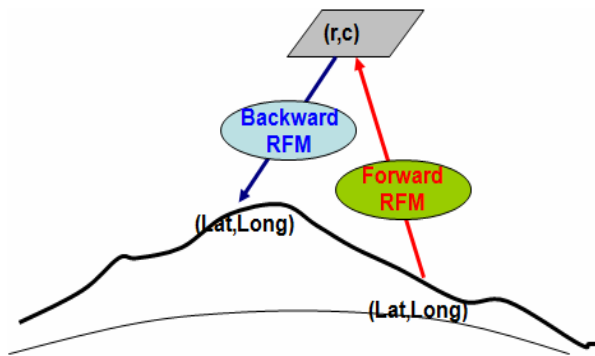


Figure 3. RFM

3. EXPERIMENTS AND RESULTS

3.1 Test Data

The experiments were conducted on a Level 1G panchromatic KOMPSAT-2 image of worldwide area. (See, Figure 3) The KOMPSAT-2 Level 1G imagery acquired on February 17, 2007 to February 9, 2008. The total number of test images data set is 121.

In this study geometric accuracy of KOMPSAT-2 images have been thoroughly examined based on KOMPSAT-2 direct sensor model results from KOMPSAT-2 IRPE system. For ground coordinate calculation from satellite data, we need the ephemeris data every scan line but KOMPSAT-2 meta data contains the ephemeris data every 1 second with respect to the WGS 84. According to, “KOMPSAT-2 Users Manual”, Lagrange interpolation of the ephemeris and attitude data are used to calculate data set for every scan line.

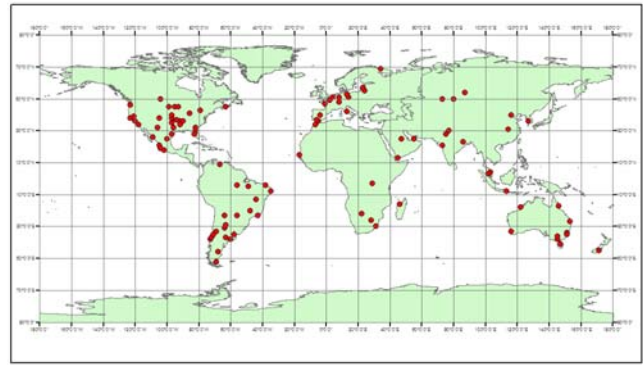


Figure 4. The location map of KOMPSAT-2 geometric accuracy test area.

The GCPs were extracted from IKONOS ortho-rectified image data by Google Earth. GCPs were features in imagery such as cross road and the corners of buildings. In each test image, used GCP number is about 16 GCPs.

3.2 Geometric Accuracy without GCPs

The ground coordinates of KOMPSAT-2 PAN using ephemeris data which are calculate from satellite GPS, star tracker and Gyro sensor were calculated by direct sensor model. The Figure 5 shows the results of implemented KOMPSAT-2 direct sensor models.

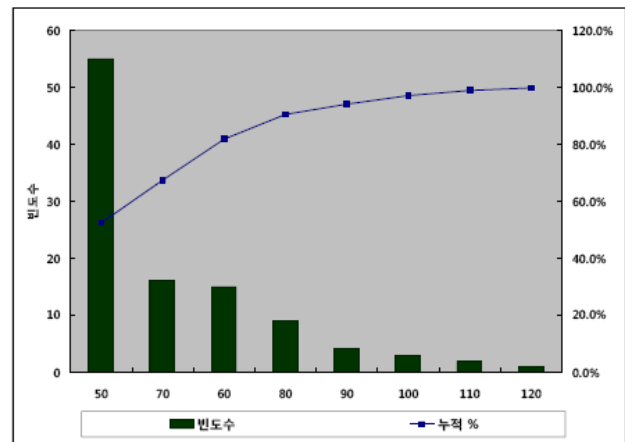


Figure 5. Summary of geometric accuracy

Figure 5 shows the 90% Circular Error measurements for the KOMPSAT-2 Level 1 product from IRPE for the February 2007 and the February 2008 data sets. Figure 5 shows the geometric accuracy in KOMPSAT-2 from just using provided ephemeris, attitude and time data. The average of geometric accuracy is 51.65 m(CE90). This accuracy met the KOMPSAT-2 system specification of 80m CE90 for both panchromatic and multispectral imagery.

3.3 RPC characteristic

KOMPSAT-2 data is provided RPC with NITF format also. The main purpose of provided RPC has been used to replace the KOMPSAT-2 direct sensor model results with ephemeris, attitude and time data and also users can make the ortho-

rectified image with RPCs, DEM and GCPs. For ortho-rectified image produce, the RPCs has to effect to change the distance depending on height. (See Figure 6)

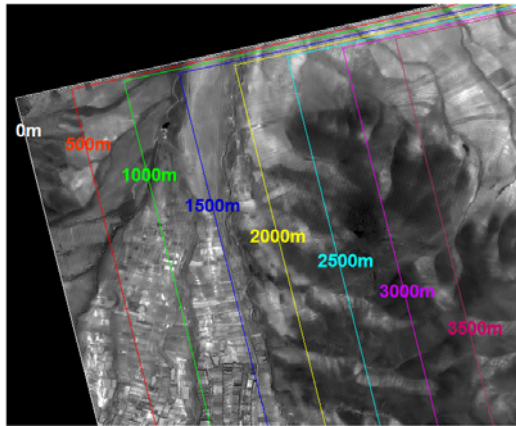


Figure 6. Height influence according to different height.

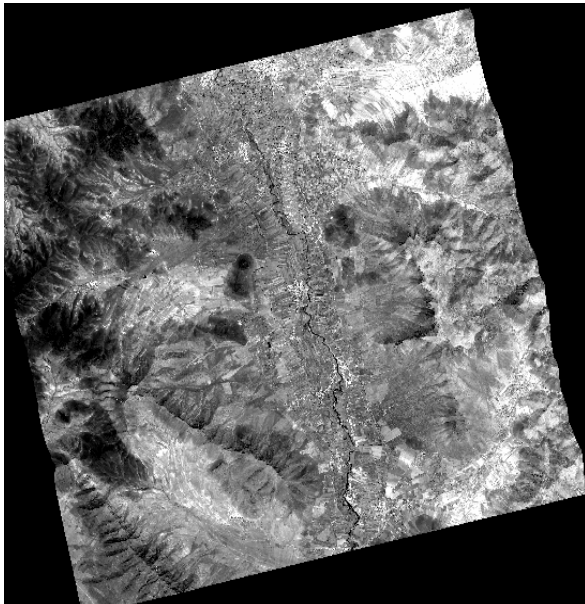


Figure 7. Generated ortho-rectified image using RPCs, GCP and DEM

We also tested ortho-rectified image, the step of ortho-rectified image is as following

- Step 1: Open a L1R product using commercially available software (PCI, ENVI)
; ENVI S/W was used
- Step 2: Select RPC tool and read K2 RPC file
; The RPC has different denominators with 3rd-order polynomial from KOMPSAT-2
- Step 3: Refined RFM with GCPs ; choose different Z values for each GCP: check if RMS is consistent with the true Z error.

Used GCPs number for refined KOMPSAT-2 is 8 points and 90m SRTM DEM was used to ortho-rectified image. The generated product is Figure 5. To evaluate ortho-rectified image

by RPC, we compare the resulted direct sensor model with RPC result.

In Figure 6 and Figure 7, it is possible to use KOMPSAT-2 RPC instead of KOMPSAT-2 DSM for 3D processes like ortho-rectification, stereo restitution or correlation.

4. CONCLUSION

The KOMPSAT-2 geometric accuracy verification was successfully evaluated from 2007 through 2008. The 121 test sites provided excellent condition for geometric verification due to its flat terrain and a very good grid infrastructure.

This paper investigation is to check and verify the geometrical performance when KOMPSAT-2 images data with precision orbit data, precision attitude data are employed and briefly introduce the direct sensor model and rational function model of KOMPSAT-2. The ephemeris, attitude, time and image data from KOMPSAT-2 acquired and direct sensor model or RFM could be met 51.65m (CE90) geometric accuracy on the flat ground. For the future research work, we should continue the calibration and validation of KOMPSAT-2, after KOMPSAT-2 Cal/Val Phase II, more excellent and accurate results can be come out.

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