INITIAL GEOMETRIC ACCURACY OF KOMPSAT-2 HIGH RESOLUTION IMAGE

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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 an initial geometric accuracy assessment of the KOMPSAT-2 high resolution image without ground control points and briefly introduces the sensor model 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.

KEY WORDS: Geometric accuracy, KOMPSAT-2, High resolution image

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 satellite contains both a 1-meter 10 bit panchromatic sensor and a 4 band 4 meter 10 bit multi-spectral sensor. The satellite operates in a sun-synchronous orbit at on altitude of 685km and with an orbit inclination 98.13 degrees. It has a swath width of 15 km.

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 major objective of this investigation is to check and verify the geometrical performance when initial 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. 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 o function of the sampling time.

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

2.1 Direct Sensor Model

The direct sensor model basically uses the ephemeris data include satellite position, velocity and attitude data

Image point and the corresponding ground point are assumed to be on one straight line using eight 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.

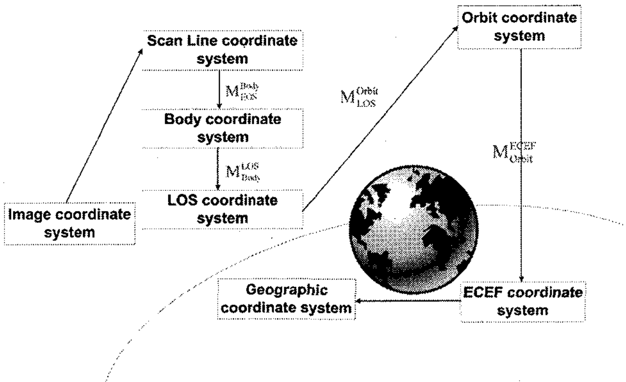

Figure 1. Coordinate system overview and coordinate transformations

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

$$\begin{bmatrix} X-X_S \\ Y-Y_S \\ Z-Z_S \end{bmatrix} = k\cdot M^{ECEF}_{Orbit}\cdot M^{Orbit}_{LOS}\cdot M^{LOS}_{Body}\cdot M^{Body}_{EOS}\cdot \begin{bmatrix} x \\ y \\ z \end{bmatrix} \quad (1)$$

where,

M^{ECEF}_{Orbit} : from Orbit coordinate system to ECEF

M^{Orbit}_{LOS} : from LOS(Line-Of-Sight) coordinate system to Orbit coordinate system

M_{Body}^{LOS} : from Body coordinate system to LOS coordinate system

M_{EOS}^{Body} : from Scan line 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

Rational Polynomial Coefficients (RPC) for the KOMPSAT-2 MSC sensor is generated from the Level 1G image using the Rational Function Model (RFM). The model uses a pair of rations of two polynomials, as shown in equation 2.

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

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.

$p1, p2, p3$ and $p4$: the polynomial coefficients

The determination method of RPCs in KOMPSAT-2 utilizes the satellite ephemeris data include interior orientation parameters, satellite position, velocity and attitude. There are two main steps in generation of RPCs ;

(1) The corresponding image coordinates for 3D object grid points are calculated by using KOMPSAT-2 direct sensor model (see Figure 2.)

(2) A least square fitting is applied to determine the RPCs from large number of the virtual ground control points.

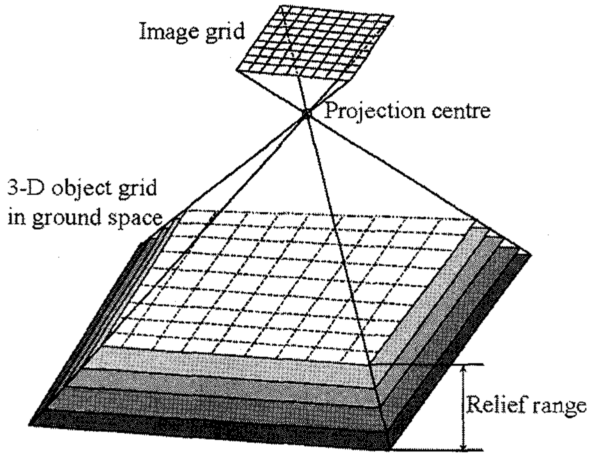

Figure 2. Use a 3-D object grid to solve for the RFM

3. EXPERIMENTS AND RESULTS

3.1 Data

The MSC data used in this study includes four orbit data of KOMPSAT-2 digital images.

Table 1. Specification of four orbit data

Orbit	Date	Tilt angle	Target location
508	06. 9. 1	-1.969	Goheung
770	06. 9. 19	-21.828	Daejeon
799	06. 9. 21	7.497	Daegu
843	06. 9. 24	-24.002	Daegu

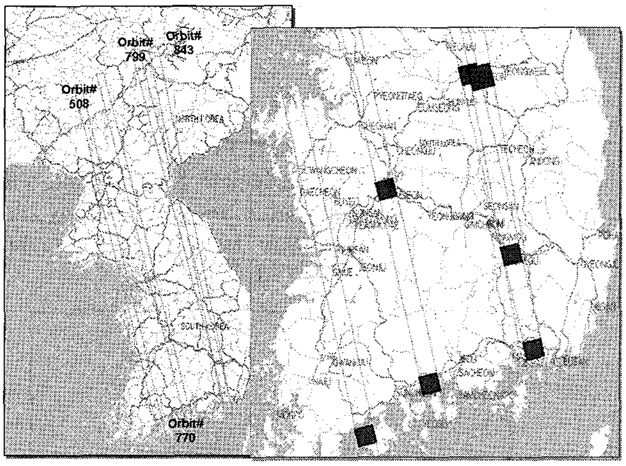

Figure 3. The location of test image

KOMPSAT-2 Level 1A product consists of the image data in standard TIFF or HDF format and the meta data in TIFF/HDF format. The following information is;

(1) the ephemeris data containing position, velocity and attitude data from measured satellite sensor or POD, PAD which are calculated by MCE(Mission Control Element) and KPAS(KOMPSAT-2 Precise Attitude Determination Syatem)

(2) the instrument data are consist of the NUC, compression, TDI, electrical gain and offset information.

(3) the auxiliary data contain tilt angle, map projection, KGRS location, imaging time etc.

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", Lagrangian interpolation of the ephemeris and attitude data are used to calculate data set for every scan line.

3.2 Ground Control Points

To check and verify the initial geometric accuracy of KOMPSAT-2, 6 regions in the south KOREA were selected. The elevations range from about 1 meter to 700 meters. The ground control points data chosen for this test areas are the following;

(1) Goheung, Daejeon and Gwangyang in Orbit # 508, 770: About 52 ~ 150 points distributed around the entire image. The 3D coordinates were surveyed by using DGPS. Especially, the artificially GCP targets were installed on the public building in this test site. The image coordinates were determined images by using cubic spline method.

(2) Changwon, Daegu, Jecheon in Orbit # 799, 843: About 30 ~ 50 points distributed around the entire image.

The 3D ground coordinates for GCPs were captured by CAD system from 1:5,000-scale national digital maps in 1995. These captured rectangular planimetric coordinates and height on a geoid were transformed to the Earth-fixed Cartesian coordinates of the World Geodetic System 1984(WGS84) using Bursa-Wolf model of 7-parameters and EGM96 model.

3.3 Initial Geometric Accuracy

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 geometric accuracy was examined during KOMPSAT-2 CAL/VAL Phase I.

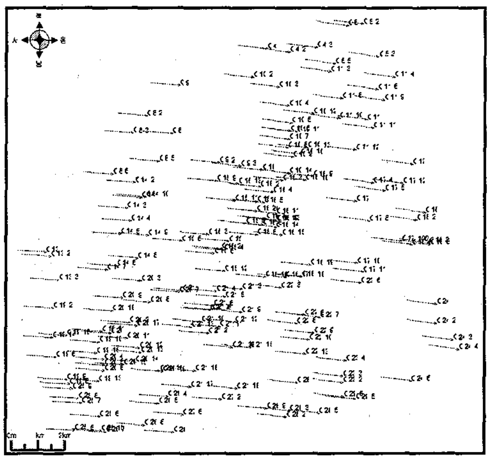

Figure 4. Horizontal residuals with ground points for Goheung test area, Orbit #508

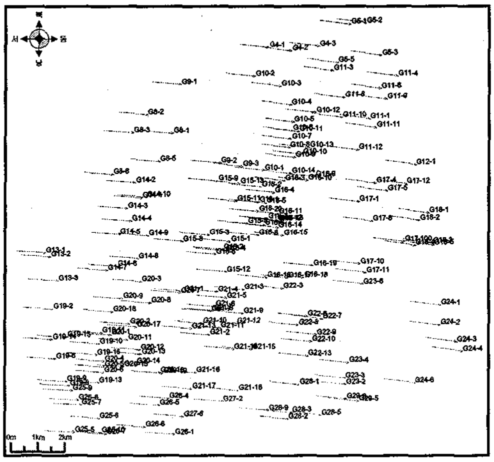

Figure 5. Horizontal residuals with ground points for Gwangyang test area, Orbit #770

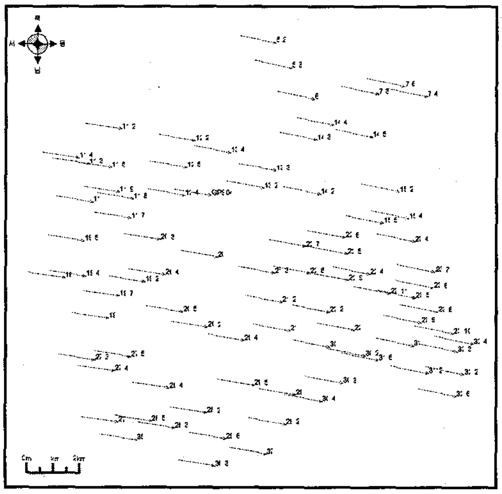

Figure 6. Horizontal residuals with ground points for Daejeon test area, Orbit #770

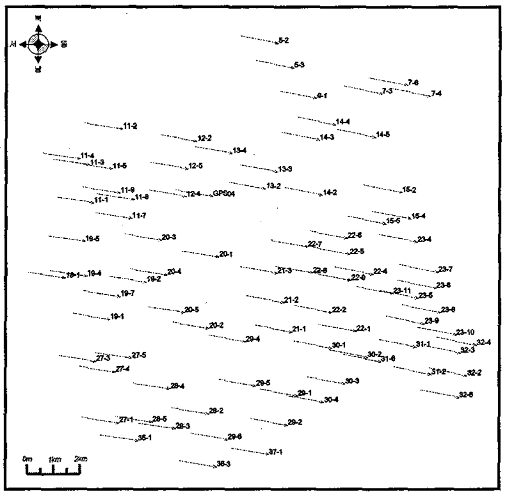

Figure 7. Horizontal residuals with ground points for Daegu test area, Orbit #799

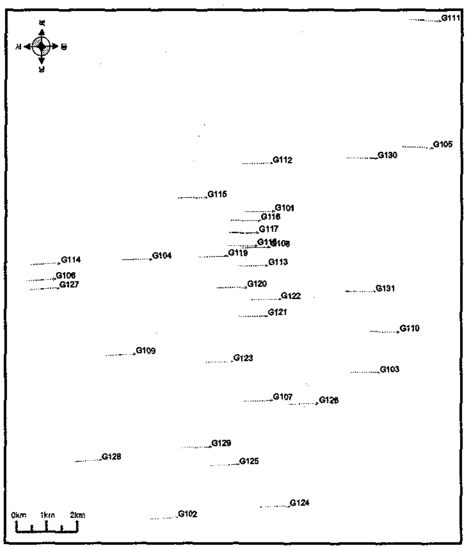

Figure 8. Horizontal residuals with ground points for Jaecheon test area, Orbit #799

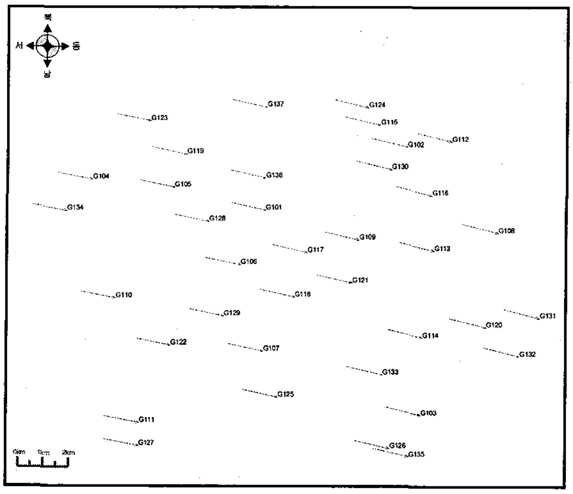

Figure 9. Horizontal residuals with ground points for Changwon test area, Orbit #843

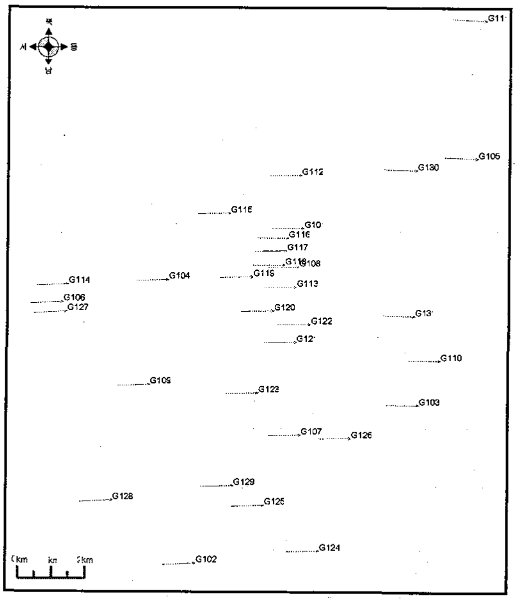

Figure 10. Horizontal residuals with ground points for Jaecheon test area, Orbit #843

Figure 4 to Figure 10 plots the horizontal residual error with ground control points for the various test area. The accuracy of west-east direction is about 1.2km and south-north direction is about 0.25km and Table 2 summarizes these results in the ground space with GCP residuals (root mean square error; RMSE).

Table 2. Direct sensor model results in the ground space for each test areas.

Orbit	Tilt angle	Date	Path-Row	RMSE (m)	
				W-E	S-N
508	-1.969°	06.9.1	1076-1258	1145.7	121.2
770	-21.828°	06.9.19	1081-1261	1398.4	257.1
			1082-1272	1429.4	267.0
799	7.497°	06.9.21	1090-1269	1020.4	32.5
			1090-1278	991.4	28.9
843	-24.002°	06.9.24	1090-1264	1406.0	314.5
			1091-1278	1524.6	287.7

The error pattern is seen to have similar characteristic. This is, systematic error is shown. (See Figure 4 to Figure 10). We determined the correction of systematic error from the Orbit # 508. Table 3 summarizes these results with the correction of systematic error.

Table 3. Direct sensor model results in the ground space for each test areas

Orbit	Tilt angle	Date	Path-Row	RMSE(m)	
				W-E	S-N
508	-1.969°	06.9.1	1076-1258	13.0	32.3
770	-21.828°	06.9.19	1081-1261	52.7	127.6
			1082-1272	81.3	135.3
799	7.497°	06.9.21	1090-1269	128.5	145.1
			1090-1278	157.7	139.9
843	-24.002°	06.9.24	1090-1264	15.7	174.3
			1091-1278	131.3	141.4

4. CONCLUSIONS

This paper investigation is to check and verify the geometrical performance when initial KOMPSAT-2 images are employed and briefly introduce the sensor model of KOMPSAT-2. The ephemeris data from KOMPSAT-2 sensor data could yield 35 m to 210 m geometric error on the 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 result can be come out.

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