A STUDY ON THE GENERATION OF EO STANDARD IMAGE PRODUCTS : SPOT

HYUNG-SUP JUNG
Department of Earth System Sciences, Yonsei University
134 Sinchon-dong, Seodaemun-gu, Seoul 120-749, Korea
geohyung@yonsei.ac.kr

MYUNG-HO KANG, YONG-WOONG LEE
Agency for Defense Development
35 Yusung, Daejeon 305-600, Korea

HO-NAM LEE
Imagery and Information Business Department
Chung-Ang Aerosurvey, 18 Kyonam-dong, Jongro-ku, Seoul, Korea 110-100

JOONG-SUN WON
Department of Earth System Sciences, Yonsei University

Abstract: In this study, the concept and techniques to generate the level 1A, 1B and 2A image products have been reviewed. In particular, radiometric and geometric corrections and bands registration used to generate level 1A, 1B and 2A products have been focused in this study. Radiometric correction is performed to take into account radiometric gain and offset calculated by compensating the detector response non-uniformity. And, in order to compensate satellite altitude, attitude, skew effects, earth rotation and earth curvature, some geometric parameters for geometric corrections are computed and applied. Bands registration process using the matching function between a geometry, which is called "reference geometry", and another one which is corresponds to the image to be registered is applied to images in case of multi-spectral imaging mode. In order to generate level-1A image products, a simple radiometric processing is applied to a level-0 image. Level-1B image has the same radiometry correction as a level-1A image, but is also issued from some geometric corrections in order to compensate skew effects, Earth rotation effects and spectral misregistration. Level-2A image is generated using some geo-referencing parameters computed by ephemeris data, orbit attitudes and sensor angles. Level 1A image is tested by visual analysis. The difference between distances calculated level 1B image and distances of real coordinate is tested. Level 2A image is tested Using checking points.

Keywords: radiometric correction, geometric correction, bands registration, 1A, 1B, 2A

1. Introduction

The images taken by satellite bring to us many benefits. We can find the changed area using two satellite images acquired in different times and same places, generate the DTM (Digital Terrain Model) from the geometry of the stereo image, and acquire the military intelligence about the world.

In order to use these satellite images, it is important to generate satellite image products with good quality. Current commercial satellites such as IRS-1C/1D, SPOT, IKONOS, and QuickBird generally use linear arrays in pushbroom mode. So, it is performed to compensate for the differences of sensitivities between the elementary detectors of the CCD. Also, Many people want to get geo-referenced image. In order to correct the geometry of satellite image, some geometric parameters for compensating satellite altitude, attitude, skew effects, earth rotation and earth curvature are computed and applied.

This paper explains and tests the processing algorithms to be implemented in order to generate Level-1A, 1B and 2A images from Level-0 data. It concerns radiometric equalization, geometric corrections and bands registration.

Level-1A image is issued from a simple radiometric processing on a Level-0 image which consists in taking into account radiometric gain and offset[1-3].

Level-1B image has the same radiometry correction as a level-1A image, but is also issued from some geometric corrections in order to compensate skew effects, Earth rotation effects and spectral misregistration[4,5]. Some geo-referencing parameters are also computed[4].

Level-2A image has the same radiometry correction as a level-1A image, but the parameters taken from instrument geometry and position on board, image dating, satellite attitude, satellite position and earth shape and position allow to locate on ground every pixels of acquired images[6].

The processing algorithm of level 1A image is presented in section 2. In Section 3, we show level 1B image processing algorithm. And the technique to generate level 2A image product is focused in section 4. Result and discussion follow them in section 5.

2. Level 1A products

In SPOT image product, level 1A product is generated by simple radiometric processing on a level-0 image using radiometric gain and offset.

The level-0 image is modeled as

$$X_B(i,j,k) = A_B \cdot G_B(i,k) \cdot \gamma_B(i,k) \cdot L_B(i,j) + C_B(i,j,k) \tag{1}$$

where, i and j are each other the number of the pixel and number of line in image, k is the number of the selected gain, B is a subscript for the considered spectral band, A_B is the absolute calibration coefficient of the considered spectral band, $G_B(i,k)$ is the detection chain gain without unit (it is 1 or $\sqrt{2}$), $\gamma_B(i,k)$ is the relative calibration coefficient, without unit. (it is normally 1, whatever B, i, or k), $L_B(i,j)$ is the input radiance level for the given pixel, $C_B(i,j,k)$ is the dark signal coefficient of detector i, in gain k, for spectral band B, at line j and $X_B(i,j,k)$ is the raw radiometric output signal from pixel i, in gain k, for spectral band B, at line j, in counts.

Corrected radiometry taken by this radiometric model is

$$Y_B(i,j,k) = \frac{X_B(i,j,k) - C_B(i,j,k)}{A_B \cdot G_B(i,k) \cdot \gamma_B(i,k)} \tag{2}$$

The radiometric correction coefficients A_B , $G_B(i,k)$ and $\gamma_B(i,k)$ and the dark signal coefficients $C_B(i,j,k)$ shall be provided to the ground station after ground calibration. These coefficients must be updated using paneling effect and odd and even correction algorithm.

Paneling effect is divided into two effects by the method of correction. Desert paneling effects of multiplicative corrections are corrected by updating radiometric gain parameter, $G_B(i,k)$. But, Additive corrections are performed by refining dark signal coefficients, $C_B(i,j,k)$.

Imagery acquired by sensors using CCD linear arrays sometimes suffers form strip-type defects due to the nature of the sensor. This phenomenon are corrected by Odd and even correction algorithm.

In generally, band registration is performed by onboard processing. However, SWIR band in SPOT 4 must be corrected using band registration processing. Registration processing consists in computing the geometric deformation model between the reference image and the one to be registered. The output data is a matching grid which is sampled in order to overlap the reference geometry. Each node of this grid gives some parameters which allow to compute the corresponding point in the image to be registered.

Fig. 1 shows SPOT image acquired by satellite. This image has strip-type defects due to the nature of the sensor (Fig. 1(A)). Level 1A image products are generated using radiometric correction such as paneling effect and odd and even correction (Fig. 1(B)). Because Level 1A products are used to product DEM(Digital Elevation Model), it is very important to remove strip-type defects.

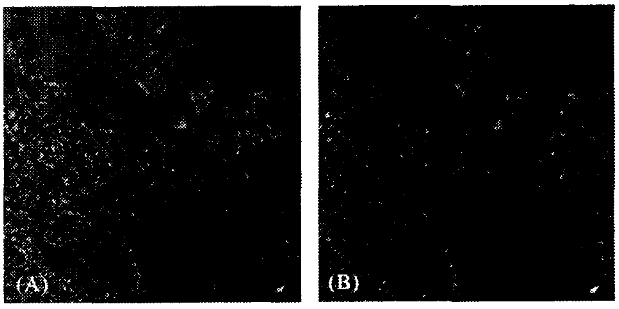

Fig. 1. The comparison between level 0 image(A) and level 1A image(B). level 1A image is generated by radiometric processing. Strip-type defects in (A) exist, but in (B) do not exist.

3. Level 1B products

Level-1B image has the same radiometry correction as a level-1A image, but is also issued from some geometric corrections in order to compensate skew effects, Earth rotation effects and spectral misregistration. Some geo-referencing parameters are also computed.

Level-1B image is generated using deformation model.

Direct model is

$$i' = I(l') \tag{3}$$

$$j' = \frac{J(p') + B(i')}{A(i')} \tag{4}$$

Inverse model is

$$l' = L(i')$$

$$p' = P(A(i') \cdot j' - B(i'))$$

where, I , L , J , P , A and B are polynomials and i', j', l' and p' are centerd and normalized values of i , j , l and p . i and j are the count of lines and pixels in corrected image, and l and p are the count of lines and pixels in original image.

The variable of V is centered and normalized as

$$v' = \frac{(V - V_m)}{DV} \tag{5}$$

where, V_m is mean of maximum and minimum values of V over grid points, and DV is half-width of the range represented as

$$DV = \frac{(V_{\max} - V_{\min})}{2} \tag{6}$$

Level 1B images is produced using deformation model. The calculation methods of this model are as follow

1) Select the nodes of 10x4 grid from data strip
2) For 40 nodes, change image coordinate points of strip data into geographic coordinate points
3) Calculate geodetic distance and bearing, and calculate point (x,y) in plat grid.
4) Transform (x,y) into (i,j).

Fig 2. displays level 1B images acquired by deformation model.

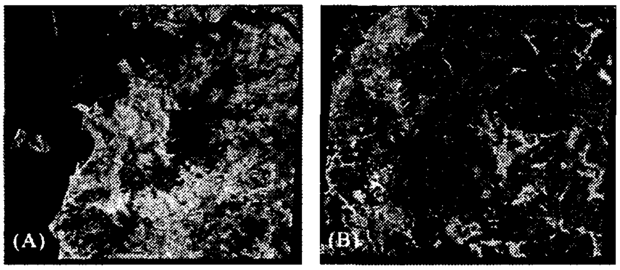

Fig. 2. level 1B products. (A) is SPOT 4 mono image and (B) is SPOT4 XI image.

The difference of distance in the corrected image and real distance is tested using 5 GCPs and equation as follow,

$$\frac{D-D'}{D}\times 100(\%) \qquad (7)$$

where, D is the distance of real world and D' is the measured distance using corrected image.

Table 1. represents the result of test about calculated values of 10 distances. Because of below the 0.5 percents in all distances, it is known that the result is very good.

Table 1. The ratio of distance in the corrected image(level 1B image) and distance in real world. The values are calculated by equation (7).

Distance ratio (%)				
0.3461	0.2942	0.1637	0.0354	0.1139
0.2281	0.0663	0.1310	0.0481	0.3969

4. Level 2A products

Level-2A image has the same radiometry correction as a level-1A image, but the parameters taken from instrument geometry and position on board, image dating, satellite attitude, satellite position and earth shape and position allow to locate on ground every pixels of acquired images.

Image dating allow to link all dynamic parameters together such as image lines, orbit, attitude and Earth position. It is given by the knowledge of each line acquisition date, which is given by three parameters of T_0 (reference date), i_0 (reference line) and T_s (line sampling period).

We can get time corresponding to the line number i

$$t(i) = T_0 + (i - i_0)\cdot T_S \qquad (8)$$

Because the ephemeris for given time is computed, We must use orbit model. In first approximation, the satellite trajectory is a Keplerian trajectory. In this approximation we consider that the Earth is spherical, and that its force of gravity is directed towards its mass center. This trajectory is characterized by a set of 4 constant parameters represented in Fig. 3.

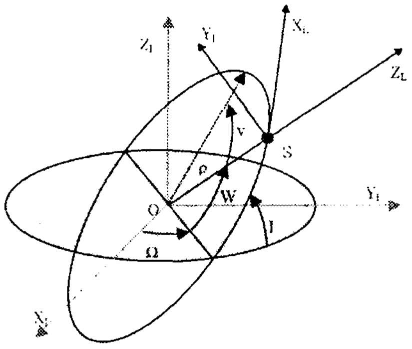

Fig. 3. Orbit parameters definition. Ω is longitude of the ascending node, I is inclination of the orbit plan, W is latitude argument of the satellite and ρ is the distance between earth center and satellite. S is the position of satellite and O is earth's mass center.

At a given time, satellite position can calculated as follow,

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix}_{R_I} = \begin{pmatrix} \cos\Omega & -\sin\Omega & 0 \\ \sin\Omega & \cos\Omega & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos I & -\sin I \\ 0 & \sin I & \cos I \end{pmatrix}$$

$$\begin{pmatrix} \cos W & -\sin W & 0 \\ \sin W & \cos W & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix} \begin{pmatrix} 0 \\ 0 \\ \rho \end{pmatrix}_{R_L} = M \begin{pmatrix} 0 \\ 0 \\ \rho \end{pmatrix} \qquad (8)$$

Orbit parameters calculated from an ephemeris is given by the following formulas:

$$\vec{C} = \vec{r} \times \vec{v} = \begin{pmatrix} C_x \\ C_y \\ C_z \end{pmatrix} \qquad (9)$$

$$C = \left\| \vec{C} \right\| \qquad (10)$$

$$\rho = \left\| r \right\| \qquad (11)$$

$$\cos I = \frac{C_z}{C} \qquad (12)$$

$$\tan\Omega = -\frac{C_x}{C_y} \qquad (13)$$

$$\sin W = \frac{z}{\rho.\sin I} \qquad (14)$$

where, $\vec{r}$ is satellite's position vector and $\vec{v}$ is satellite's velocity vector.

In fact, the satellite is subject to other forces than the only force of gravity (gravitational perturbations, solar and lunar attractions, atmospheric friction, etc...). Those forces depend on satellite position, velocity and time, and then orbital parameters are not constant. But it is possible to have a local model of this variation using polynomial expressions depending on time as follow,

$$I(t) = I_0 + I_1 \cdot t + I_2 \cdot t^2 + I_3 \cdot t^3 \qquad (15)$$

$$\Omega(t) = \Omega_0 + \Omega_1 \cdot t + \Omega_2 \cdot t^2 \qquad (16)$$

$$W(t) = W_0 + W_1 \cdot t + W_2 \cdot t^2 + W_3 \cdot t^3 \qquad (17)$$

$$\rho(t) = \rho_0 + \rho_1 \cdot t + \rho_2 \cdot t^2 + \rho_3 \cdot t^3 \qquad (18)$$

These parameters are computed for each image, using measured ephemeris around the image acquisition date. The polynomial coefficients of the orbit model can be computed by inversion of the following equations, using least square method.

The sighted point on earth is then defined by the intersection of the LOS(Line Of Sight) thus defined, and the earth ellipsoid(Fig. 4).

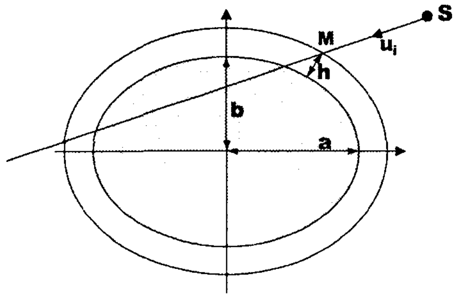

Fig. 4. Intersection of the line of sight with the earth ellipsoid.

We write the relationship between satellite and earth as

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} X_S \\ Y_S \\ Z_S \end{pmatrix} + \mu \cdot M \cdot M_A \cdot \vec{u} \qquad (20)$$

where, X, Y and Z are the point on earth, X_S, Y_S and Z_S are the position of satellite, $\vec{u}$ is LOS vector, M_A is rotation matrix for satellite's attitude and μ is arbitrary factor.

We could take point on earth by intersection with earth ellipsoid defined as

$$\frac{X^2 + Y^2}{(a+h)^2} + \frac{Z^2}{(b+h)^2} = 1 \qquad (21)$$

Passage to the geographic coordinates is given by

$$\lambda = a\tan(Y, X) \qquad (22)$$

$$\varphi = a\sin\left(\frac{Z}{\sqrt{X^2 + Y^2 + Z^2}}\right) \qquad (23)$$

The two order polynomial function consist of 12 parameters using relationship between image point (i, j) and geographic coordinates (λ, φ).

Fig 5. shows level 2A images acquired by deformation model. The generated level 2A image is tested by 20 checking points. It is the result of test that the RMSE of 20 checking points are 614.8m.

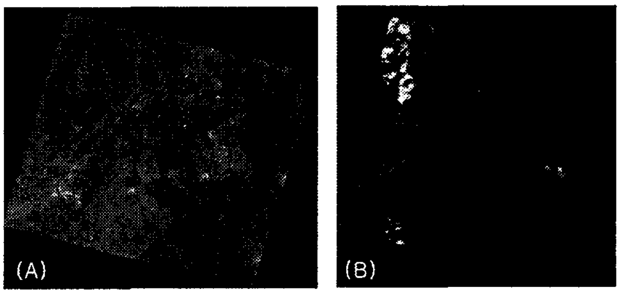

Fig. 5. level 2A products. (A) is SPOT 4 mono image and (B) is SPOT4 XI image.

5. Results and Discussions

The concept and techniques to generate the level 1A, 1B and 2A image products have been reviewed. Using radiometric correction algorithm, the strip-type defects was removed, and the image coordinates using the method of geometric correction is transformed into geographic coordinates.

References

[1] KUBIK, 1997, Radiometric corrections, technical note, CNES, C047-ST-73-106-SI.

[2] Philippe DELCLAUX, 1994, Paneling effect correction algorithm, technical note, CNES, S-NT-0-10-SI.

[3] P. KUBIC, 1997, Technical note for corrections of odd/even-pixel effects, , technical note, CNES, C047-ST-73-109-SI.

[4] Marc PERE, 1997, Level-1B HRV(IR) location model for data strip correction, technical note, CNES and SPOT IMAGE, C047.ST.73.103.SI.

[5] Gleyzes J. P., P. Gigord and E. Breton, 1997, Specification for additional SWIR registration, technical note, CNES and IGN, C040-ST-73-100-SI.

[6]. CNES and SPOT IMAGE, 1997, Specification for simplified SPOT location model, technical note, CNES and SPOT IMAGE, C047-ST-73-104-SI.