Geometric Modeling of Linear Pushbroom Images
: SPOT5 Images

Ja-Hyuck Koo
Chung-Ang Aero Survey
18 Kyonam-dong Chongro-gu Seoul 110-100, Korea
perrkoo@orgio.net

Hyung-Sup Jung
Chung-Ang Aero Survey
18 Kyonam-dong Chongro-gu Seoul 110-100, Korea
geohyung@yonsei.ac.kr

Ho-Nam Lee
Chung-Ang Aero Survey
18 Kyonam-dong Chongro-gu Seoul 110-100, Korea
yhnhan@chol.com

Abstract: Geometric corrections are required to compensate skew effects, earth rotation effects and so on. Parameters for geometric modeling can be acquired from the metadata information. These parameters allow to locate on ground every pixel of acquired images.
In this paper, we tested the precision of geometric modeling of linear pushbroom images, acquired by SPOT 3 and 5 using the satellite orbit information itself without additional external data. The result acquired from examination to recovery the geometry of image using 30 GCPs have about 650m RMSE in SPOT 3 and about 170m RMSE in SPOT 5.
Keywords: SPOT-5, Modeling, Pushbroom

1. Introduction

In order to compensate skew effects, earth rotation effects and so on, geometric correction is required. Parameters for geometric correction can be acquired from the metadata. These parameters include instrument geometry and position on board, Image dating, Satellite attitude in space, Satellite position in space and Earth shape and position. All those parameters allow to locate on ground every pixel of acquired images [1]. Namely, satellite information such as these parameters can help to acquire ground coordinates of each satellite image pixel.

But, using these satellite information didn't have a high accuracy. In this reason, additional information such as GCPs (Ground Control Points) must be used. Surely, It caused additional expenses.

If geometric modeling using the satellite information itself without additional external data is possible and has a high accuracy, it will help to extract GCPs automatically from them. And this is a purpose of this study.

2. SPOT-5 Platform

In this Study, we try to investigate a geometric modeling of SPOT-5 images. In the first place, we will introduce features of SPOT-5 platform briefly.

At first, SPOT-5 has two HRGs instruments. It can acquire higher resolution images: two panchromatic (5 m), one short-wave infrared (20 m), and three multi-spectral (10 m) images. And through Supermode processing, two panchromatic images are combined to generate a 2.5 meters product.

And SPOT-5 is equipped with a star tracker. This sophisticated instrument points at the stars and recognize constellations to position the satellite about its center of gravity with respect to the celestial sphere. It provides very accurate information about the satellite's attitude and, thus, about the exact location of points on the ground with using DORIS precise positioning instrument.

DIMAP is a new format for SPOT products. It is a two-part format comprising geo-tiff image data and metadata. DIMAP is an open format that supports products derived from other sources of satellite data distributed by Spot Image.

To display descriptive product information, users simply open the DIMAP file (METADATA.DIM). DIMAP metadata is using XML format. Advantages of

XML are that it can be read directly by standard Web browsers and supports style-sheets in XSL, which transforms and formats the information contained in an XML file.

3. Geometric Modeling of Linear Pushbroom Images

A purpose of a geometric modeling is acquiring geographic coordinates (λ, φ) from each pixel coordinate (i, j).
The geometric modeling process is shown in Fig. 1.

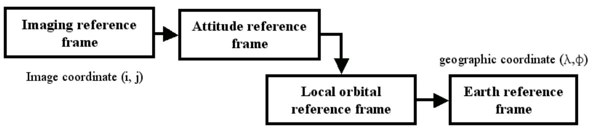

Fig. 1. A flow chart of the geometric modeling process

In this process, inertial reference frame (R_I) which will be used for the Keops system. It is defined by the star reference frame at the date: 2000-01-01, 12hr.
The earth reference frame (R_E) which will be used for the Keops system. At first approximation, coordinates expressed in R_E can be deduced from those expressed in R_I by a rotation around the pole axis of an angle. The local orbital reference frame (R_L) is defined by mass center of the satellite, yaw axis, roll axis and form a right-handed reference frame. The attitude reference frame (R_S) is linked to the satellite. It is identical to the local orbital reference frame when the spacecraft attitude angles are all zero. And the imaging reference frame (R_{im}) is linked to the instrument, and will be called R_{im}
From these definitions of reference frames, the geometric modeling process is expressed as Eq. (1).

$$(\vec{u}_i)_{R_E} = M_{R_L->R_E} . M_{R_S->R_L} . M_{R_{im}->R_S} . (\vec{u}_i)_{R_{im}} \quad (1)$$

$M_{R1->R2}$ is the passage matrix from reference frame 1 to frame 2.

For each pixel (i, j) of an image, the line number i corresponds to a certain acquisition date t and the column number i corresponds to a specific pixel which is characterized by its line of sight direction in the imaging reference frame.
In the Earth reference frame, this line of sight can be computed using an upper passage matrix.

$M_{Rim->RS}$ characterizes the position of the instrument on the satellite, $M_{RS->RL}$ is computed using attitude measurements, and $M_{RL->RE}$ is given by the orbital parameters with respect to the orbit model depending on time.
And satellite position (Xs, Ys, Zs)·R_I is given by the orbit model.

The sighted point (Eq. (2)) on Earth is then defined by the intersection of the line of sight thus defined, and the Earth ellipsoid.

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} X_S \\ Y_S \\ Z_S \end{pmatrix} + \mu.(\vec{u}_i)_{R_I} \quad (2)$$

We could compute the value of μ by intersection with earth ellipsoid. (Eq. (3), Fig. 2)

$$\frac{X^2 + Y^2}{(a+h)^2} + \frac{Z^2}{(b+h)^2} = 1 \quad (3)$$

The second order equation gives two solutions and we must choose the one, which has the smallest absolute value.

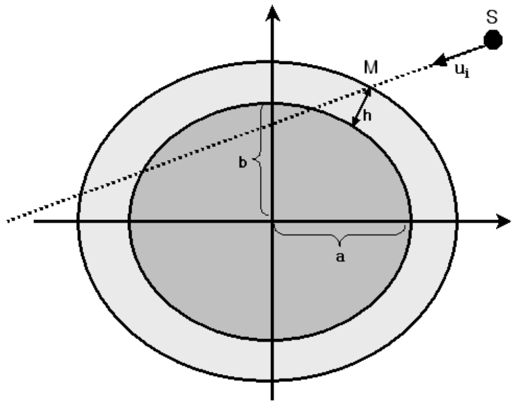

Fig. 2. Intersection of the line of sight with the earth ellipsoid

Passage to the geographic coordinates is given by Eq. (4), (5).

$$\lambda = a\tan(Y, X) \quad (4)$$

$$\varphi = a\sin\left(\frac{Z}{\sqrt{X^2+Y^2+Z^2}}\right) \quad (5)$$

4. Data and Method

To examine the geometric modeling accuracy, SPOT-3 and SPOT-5 scenes were used. And for this processing, we tested the geometric modeling algorithm using 30 GCPs respectively. The detail information of these data is shown in Table 1.

Table 1. Data list used in this study

ID	Satellite	Detail
D1	SPOT-3	Path/Row 305/277 DaeJeon Area Center Time : 16529 9581.806 Line period : 0.001504 Look angles : PSI X first 0:37:11; PSI X last 0:36:31 PSI Y first 22:3:13; PSI Y last 17:55:55
D2	SPOT-3	Path/Row 305/277 DaeJeon Area Center Time : 16530 8424.744 Line period : 0.001504 Look angles : PSI X first 0:34:2; PSI X last 0:34:33 PSI Y first 5:32:36; PSI Y last 9:40:4
D3	SPOT-5	Path/Row 308/279 JinJu Area Center Time : 19395 9330.202640; Line period : 0.0003760 Look angles : PSI X first 0:32:0; PSI X last 0:32:44 PSI Y first 15:48:45; PSI Y last 19:56:28

First of all, the satellite information from SPOT-3 Leader files [2] and SPOT-5 DIMAP [3] was extracted. To extract the data from SPOT-5 DIMAP, a new XSL file was made using XSL (eXtensible Stylesheets Language). By using this file, the important information could be acquired from DIMAP file easily and be displayed via Web browser (Fig. 3).

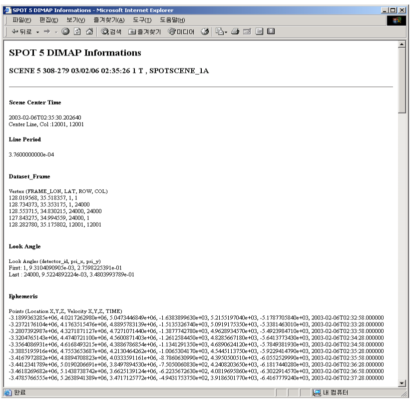

Fig. 3. SPOT-5 DIMAP Information using XSL

Secondly, software for this processing was made using C++ language. This software needs the satellite information such as: ephemeris data, satellite center time, line period, image rows/columns, attitude data, look angles, and so on. From these data, image coordinates (i, j) is converted to geographic coordinates (λ, φ).

Finally, to examine accuracy and precision of the result data, we compared between result coordinates and 30 GCP data respectively. And these comparison results are explained in next paragraph.

5. Result

Using the method mentioned above, geographic coordinates were acquired from image points that are coupled with ground control points in the study area. And these results were compared with GCPs. These results are shown in Table 2.

Table 2. Results compared with GCPs

ID	RMSE (m)			
	Longitude	Latitude	Total	σ
D1	622.383	266.783	677.152	45.543
D2	620.936	192.558	650.108	18.516
D3	49.371	160.605	168.023	17.976

On the assumption that GCPs are correct, points acquired were compared with them. RMSE of points used in D1 was 677.152m and RMSE in D2 was 650.108m. On the other side, RMSE in D3 was 168.023m.

This can be explained that SPOT-5 geometric modeling process just using the satellite information is higher accuracy than SPOT-3.

And if the value of standard deviation in the table is considered, we can get satisfactory results using just a few GCPs.

6. Conclusions

As mentioned above, the satellite information for geometric modeling in SPOT-5 has a good accuracy and precision.

Because the result have low values of standard deviation, a little additional data will help the geometric correction with high accuracy and precision.

If digital elevation models (heights data) are used, more accurate results can be acquired.

References

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[2] SPOT IMAGE, 1997. *The SPOT Scene Standard Digital Product Format*

[3] **URL:** DIMAP (Digital Image Map): dimap 1.1 05/2003. Available at: http://www.spotimage.fr/spot5/ensavoirplus/dimap/spec/dimap.htm