A Study on Producing Maps From Simulated KOMPSAT Ortho-Images

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Abstract

With high resolution capability, satellite images are expanding their roles from earth resource monitorings to map production. Until now, maps are produced from airborne photos, but as large as at 1:2,400 scale, low cost satellite ortho images will replace the airborne photos. However, there has been no standard for map productions with satellite images. In this paper, we study the process of map productions with the satellite images of SPOT, IRS-1C, KOMPSAT, the positional accuracy of map features extracted from the satellite images, and the relationship between the image resolution and the map scale.

Introduction

The KOMPSAT-1 will be the korea's first remote sensing satellite for commercial purpose. KOMPSAT-1 EOC(Electro Optical Camera) is designed for map production of 1:25,000 scale. Until now, map production is performed on aerial photo base stereo plotter through the process of photogrammetry. Using satellite for map production is recent work and not yet established in detail.

The SPOT is the first satellite for mapping purpose. It has cross track stereo capability

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that can produce DEM(Digital elevation Model) and topography map. Multiple satellites of SPOT are acting. After SPOT, several satellites goes up in the space like IRS-1C, MOMS.

Process of Map Production from Satellite Images

Fig. 1 shows the process of map production from satellite image. For map production the ortho image should be produced. The sensor model with the orbital parameters, satellite attitude, ground control points is used for precision geometric correction.

The first step is image aquisition. Season, aquisition date, time, resolution, incident angle, cloud coverage should be considered for good quality. After acquiring the image, image processing process is applied, image resampling, enhancement, and so on. The third step is satellite model computation. this process is very important to output accuracy. Satellite sensor geometry is computed in this process.

The next step is ortho rectification. In this process, the relief effect by terrain is corrected with DEM supplied. The DEM accuracy that used is not so critical factor. For example, if you use 5m DEM or 10m DEM, you cannot fill the difference of the DEM resolution. If this done with success, the produced images need mosaicking. After mosaicking, the features on images can be extracted to maps.

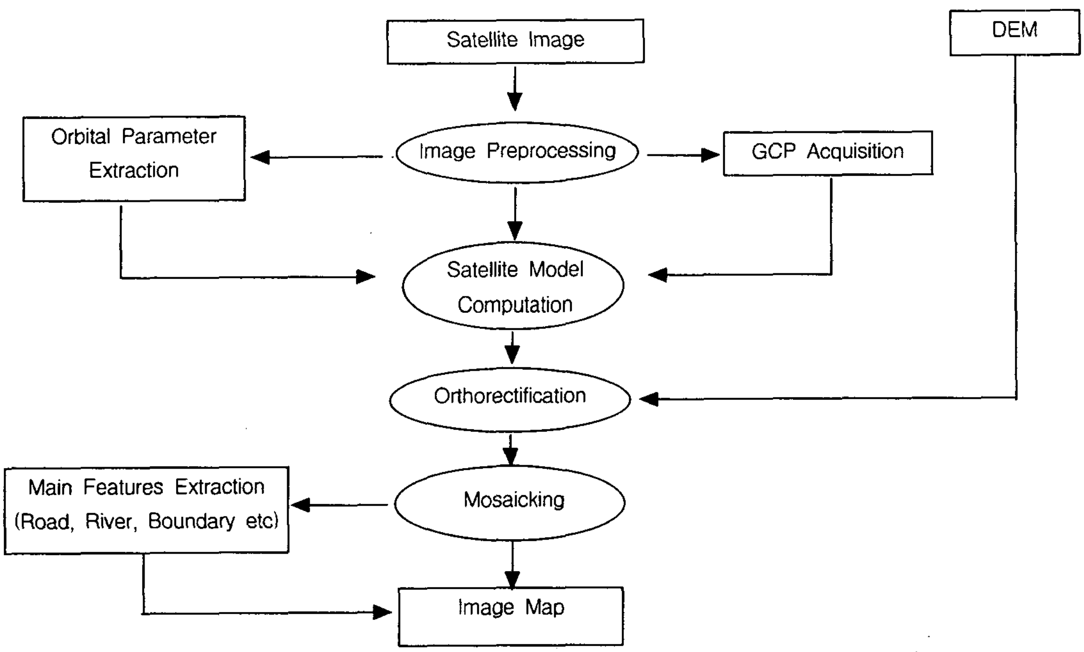

Fig. 1 The flowchart for Ortho-Image Map production

KOMPSAT-1 EOC Camera and Image Geometry

Sensor geometric model is very important for extract features on earth. More accurate the model, the images can be more accurately corrected. Due to complex characteristics of the sensor and earth geometry, images obtained from space have distortions that it cannot be superimposed on a map. The distortions are from earth curvature, scanning method, orbit, satellite attitude, relief and so on. Table 1 shows the KOMPSAT-1 EOC's specification.

Resolution	6.6m±10% (GSD : Ground Sample Distance)
Spectral range	510 ~ 730nm (Panchromatic)
FOV	1.25°
Swath Width	15km
Orbit	Height 685km, Sun synchronous, 98.13° Orbit cycle 98.46min
Rolling range	±45° Crosstrack

Table 1 KOMPSAT-1 EOC Specification

V. Pala and X. Pon(1995) calculated displacement for Landsat TM and Spot HRV assuming flat earth and spherical earth. The result is shown in table 2.

Assuming a flat earth the displacement for relief can be calculated with this equation

$$Dp=Lz/H$$

For a curved earth, we can calculate the displacement like this.

We assume that the earth radius is constant. The average radius can be calculated with the following equation:

$$R=[B^2+\cos^2(lat)\ (A^2-B^2)]^{1/2}$$

where A and B are the major and minor earth axes. The y axis is linked to satellite and the x axis crossing the earth center.

angle a is known from the distance L on earth surface

$$a=L/R$$

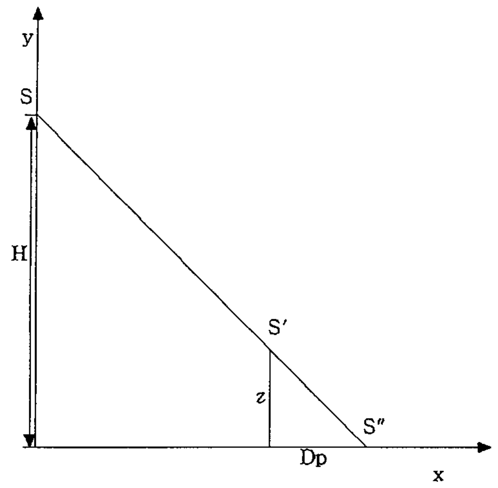

Fig. 2 The image geometry for flat earth

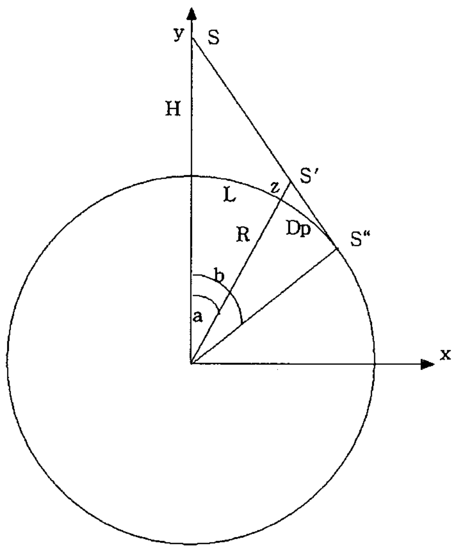

Fig. 3 The geometry for curved earth

The line equation that links S and S″ is

$$y=ex+f$$

where

$$e=\{[R+z]\cos(a)-[R+H]/\{[R+z]\sin(a)\}$$

$$f=R+H$$

Assume the arc Dp is rectilinear segment, the line including Dp is defined by

$$y=cx+d$$

letting (x_0,y_0) to be the base coordinates for the point S′ on the reference surface level

$$x_0=R\sin(a)$$

$$y_0=R\cos(a)$$

c and d becomes

$$c=-\tan(a)$$

$$d=y_0-cx_0$$

The coordinates (xi,yi) of S″ can be calculated with the expressions

$$ex+f=cx+d$$

The displacement value can be finally calculated with

$$Dp=[(x_i-x_0)^2+(y_i-y_0)^2]$$

Satellite	Incident Angle	H(km)	L(km)	z(km)	Dp-flat (m)	Dp-flat (pixel)	Dp-curved (m)	Dp-Curved (pixel)
LANDSAT TM	0	705	90	3	383.0	13	427.6	14.3
	0			2	255.3	9	284.7	9.5
	0			1	127.7	4	142.1	4.7
IRS-1C	0	817	35	3	128.5	26	145.6	29.1
	0			2	85.7	17	96.9	19.4
	0			1	42.8	9	48.4	9.7
SPOT HRV	0	822	29.6	3	108.0	11	122.4	12.2
	0			2	72.0	7	81.5	8.2
	5.1		103.7	3	378.6	38	429.5	42.9
	10		175.7	3	641.1	64	728.8	72.9
	20		333.2	3	1215.9	122	1393.9	139.4
	27		456.8	3	1667.2	167	1931.2	193.1
	27			2	1111.5	111	1285.9	128.6
	27			1	555.7	56	642.1	64.2

Table 2 The displacements for Landsat TM, SPOT and IRS-1C

Satellite	Incident Angle	H(km)	L(km)	z(km)	Dp-flat (m)	Dp-flat (pixel)	Dp-curved (m)	Dp-Curved (pixel)
KOMPSAT-1	0	685	7.5	3	32.7	5	36.4	5.5
	0			2	21.8	3	24.2	3.7
	0			1	10.9	2	12.1	1.8
	10		128.5	3	562.8	85	627.3	95.1
	10			2	375.2	57	417.6	63.3
	10			1	187.6	28	208.5	31.6
	20		257.8	3	1129.1	171	1266.4	191.9
	20			2	752.7	114	843.0	127.7
	20			1	376.4	57	420.9	63.8
	30		405.5	3	1776.0	269	2016.5	305.5
	30			2	1184.0	179	1342.3	203.4
	30			1	592.0	90	670.2	101.5
	45		700.1	3	3066.2	465	3630.6	550.1
	45			2	2044.1	310	2416.6	366.2
	45			1	1022.1	155	1206.4	182.8

Table 3 The displacements for KOMPSAT-1 EOC

The table 2 shows the displacements for Landsat, SPOT and IRS-1C. The table 3 shows the same calculations for KOMPSAT-1 EOC. For flat region where there are no mountains higher than 1,000m the displacement by relief is negligible when the incident angle is 0. In this case we do not need DEM or ortho rectification. Polynomial rectification is sufficient. But, the incident angle increases, the displacement increase very fast. So, we should ortho-rectify the image.

Accuracy of Vector Map extracted from Simulated KOMPSAT-1 Images

For KOMPSAT-1 EOC simulated image we use a IRC-1C image. The IRS-1C satellite has pushbroom scanner similar to KOMPSAT-1 EOC camera and it's image have the 5.8m ground resolution. We resampled a IRS-1C image to 6.6m.

We used two different methods for geometric correction and compare the results. The first method is general polynomial geometric correction. We use the third-order polynomial equation and cubic convolution for resampling. GCPs are from the 1:5,000 scale map. As we shown, the relief effects are increasing with the height(z) and distance(L) from the image center. The polynomial geometric correction method cannot correct all these effects by relief though it can reduce them.

The second method is ortho-rectification. Ortho-rectification is to eliminate the relief effect. Ortho-rectification is done with DEM made from 1:5,000 contour map. The DEM spacing is 5m x 5m. ortho image has same scale in every point

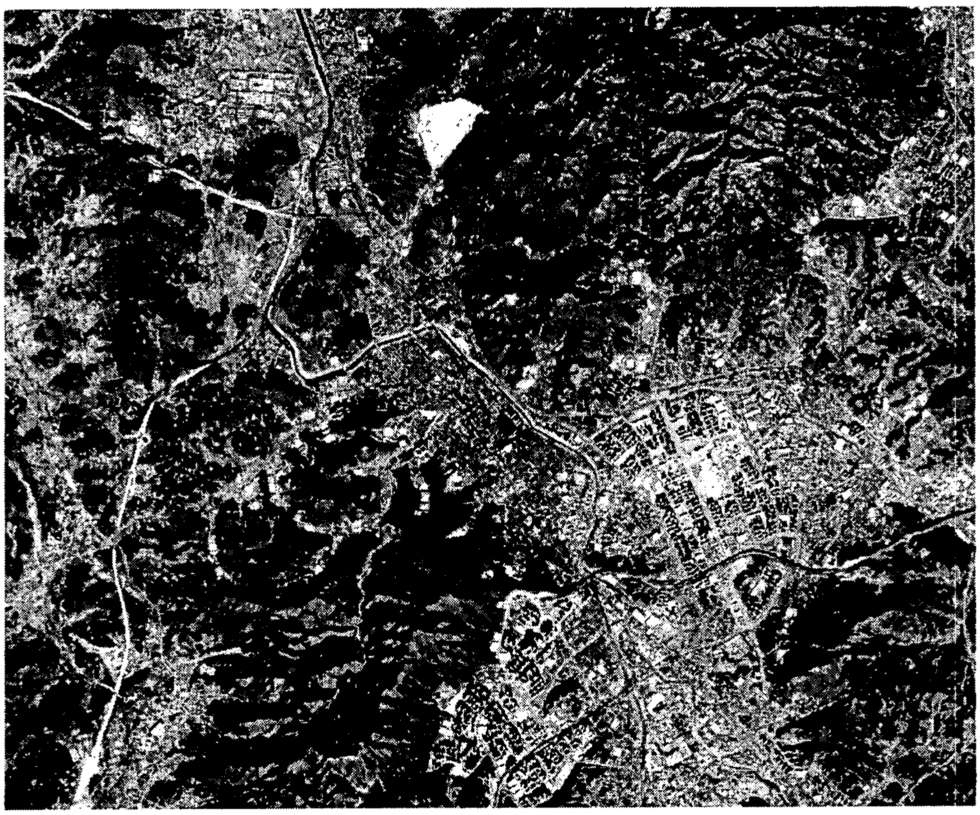

Fig. 4 KOMPSAT-1 EOC simulated Image for interest area

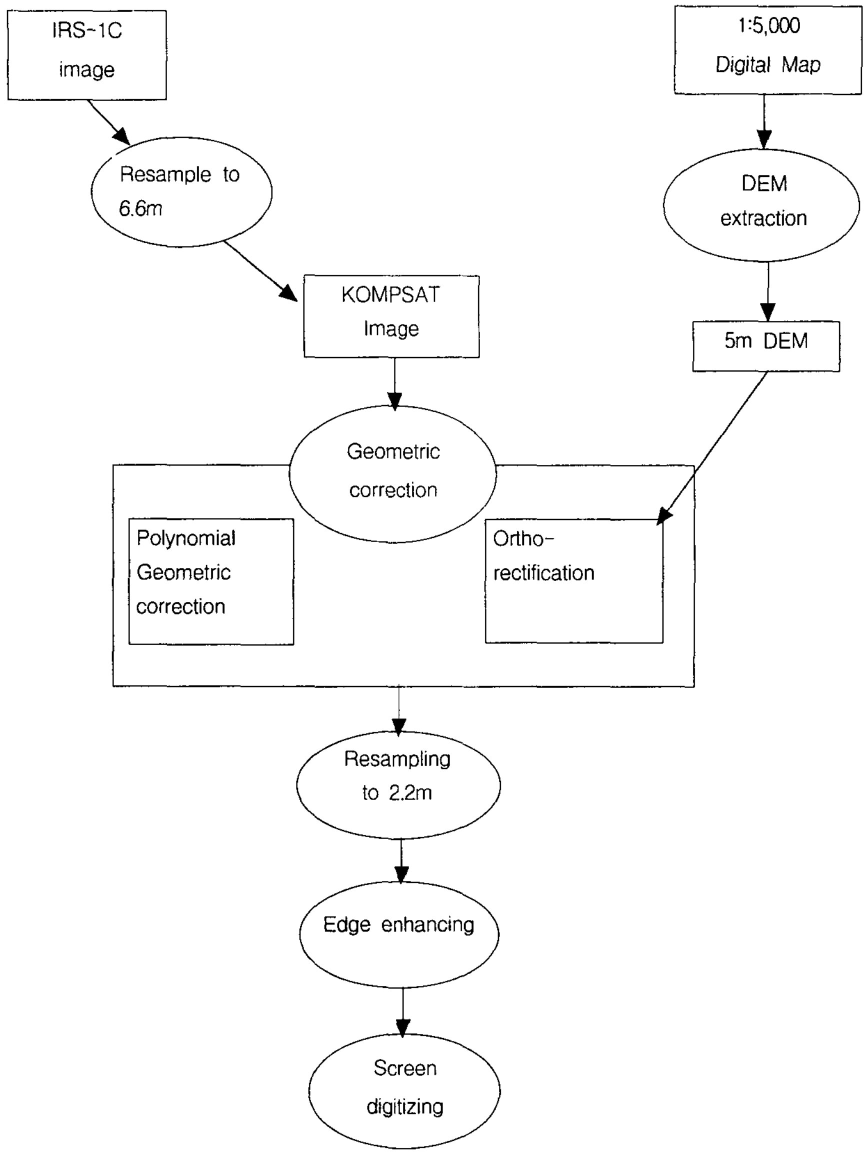

Fig. 5 flowchart for data processing

After geometric correction we resampled image to 2.2m to increase precision for screen digitizing. This method is suggested by Rachida Jazouli(1994). A pixel is divided into 9 pixels. Another method is selected to increase precision. it is edge enhancing filtering. we use 3 x 3 filter and stretch the histogram. Fig. 5 shows this process. After the resampling each 9 cells have different value and after filtering and histogram stretching the edge is enhanced and can be discriminated easily. in this process the ambiguity for screen digitizing decreases. Fig. 9 is the output image of this process.

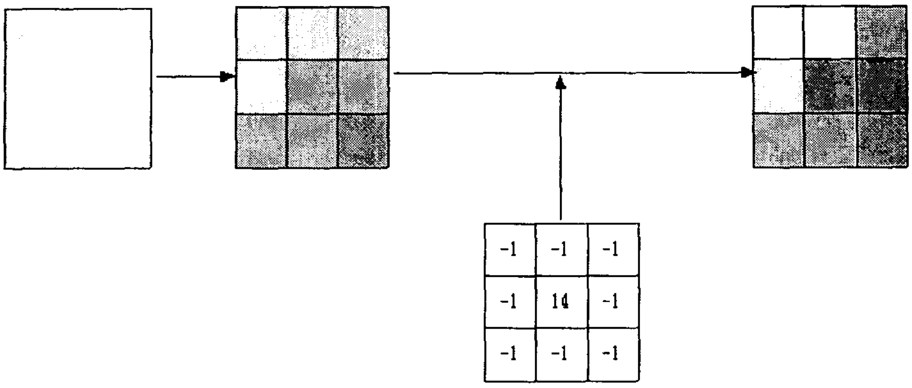

Fig. 6 Image resampling and filtering

Fig. 7 SPOT Ortho image

Fig. 8 KOMPSAT-1 simulated image

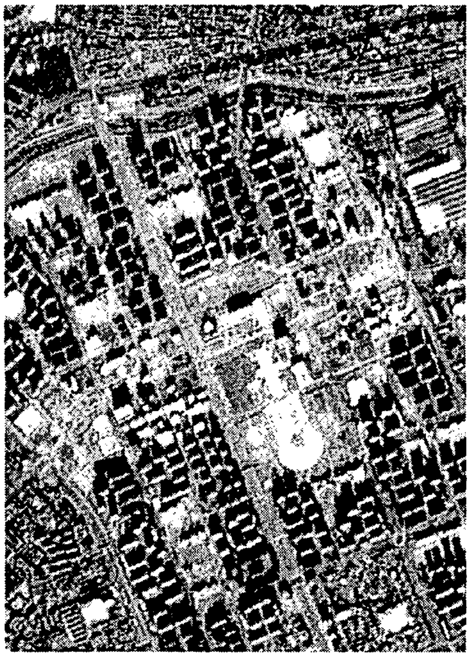

Fig. 9 Resampled and filtered Image

Image	Residual		Check Point		Number of GCP
	x	y	x	y	
KOMPSAT Ortho rectified	0.99	0.95	1.33	1.16	35
SPOT Ortho rectified	0.80	0.64	1.23	1.28	30

Table 4 Residual error for geometric correction

Result and conclusion

We compared extracted vector map with the 1:5,000 scale map. We can reduce the average of errors from 6.3m to 4.9m and standard deviation from 5.2 to 4.1 using ortho-rectification. 90% of error is within 10.2m. This almost satisfies the korean map production standards for 1:25,000 scale map. According to the korean map production standard, the maximum error is 0.4mm on maps, 10m on real world.

Image	Average	Stdev	90% Value	95% Value
KOMPSAT polynomial	6.3m	5.2m	13.0m	14.8m
KOMPSAT Ortho image	4.9m	4.1m	10.2m	11.7m
SPOT Ortho image	9.96m	5.32m	16.8m	18.7m

Table 5 Measured errors

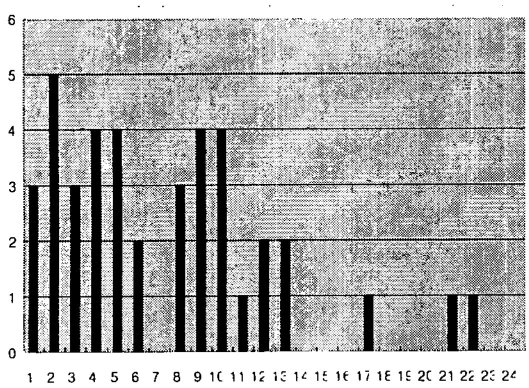

Fig. 10 Error distribution after Polynomial Method

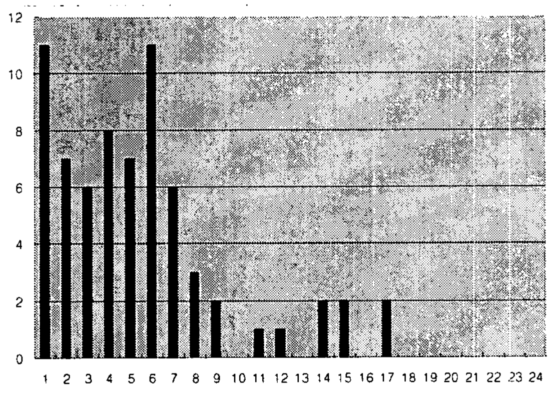

Fig 11 Error distribution after Ortho rectification

Fig. 10 and Fig. 11 show the distributions of the result errors. The errors are measured from extracted vectors and 1:5,000 reference map. We can see that the errors near the 10m are eliminated. And many parts of errors lie within 7m, the resolution of Kompsat-1 EOC. But Kompsat-1's image map is not enough to be used as 1:25,000 base map due to the errors more than 10m. It is useful for updating the existing map.

In measuring the image map's accuracy, the RMSE of check points is used in this paper. But selected chech point's accuracy is not accurate. Other precise evaluation method is needed.

Table 6. shows the relationship between satellite, resolution and available map scale. Though the map scale standards are different country by country, this table shows a rule of thumb for map production.

Satellite	Resolution	Map scale	Allowable error (Korean standard)
Landsat TM	30m	1:150,000	60m
SPOT HRV	10m	1:50,000	20m
IRS-1C KOMPSAT-1	5m 6.6m	1:25,000	10m
SPIN-2	1.56m	1:8,000	3.2m
Orview3,4 EROS B IKONOS-1 Resurs-DK	1m	1:5,000	2m
QuickBird	0.82m		

Table 6 Satellites and map scale

If KOMPSAT-1 will launch successfully, its image can be used for 1:25,000 map production and renewal of existing vector map, and have a great role to supply a high resolution satellite image in low costs.

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