Correlation analysis between rotation parameters and attitude parameters in simulated satellite image

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Abstract

Physical sensor model in pushbroom satellite images can be made from sensor modeling by rotation parameters and attitude parameters on the satellite track. These parameters are determined by the information obtained from GPS, INS, or star tracker. Provided from satellite image, an auxiliary data error is connected directly with an error of rotation parameters and attitude parameters. This paper analyzed how obtaining satellite images influenced errors of rotation parameters and attitude parameters. Furthermore, for detailed analysis, this paper generated simulated satellite image, which was changed variously by rotation parameters and attitude parameters of satellite sensor model. Simulated satellite image is generated by using high-resolution digital aerial image and DEM (Digital Elevation Model) data. Moreover, this paper determined correlation of rotation parameter and attitude parameters through error analysis of simulated satellite image that was generated by various rotation parameters and attitude parameters.

Keyword : Simulated satellite image, Indirect method, exterior orientation, space intersection

1. Introduction

Physical sensor model in pushbroom satellite images can be made from sensor modeling by rotation parameters and attitude parameters on the satellite track. These parameters are determined by the information obtained from GPS, INS, or star tracker. Provided from satellite image, an auxiliary data error is connected directly with an error of rotation parameters and attitude parameters. Therefore, this paper generated simulated satellite image about obtaining image in high-resolution satellite using discretionary orbit information, exterior orientation parameters, and DEM data. As changing rotation parameters and attitude parameters of perspective center, this paper analyzed accuracy of simulated satellite image by using space intersection method and analyzed correlation between rotation parameters and attitude parameters through analyzing image accuracy.

2. Simulated satellite image

Simulated satellite image is previously a presupposed satellite image using aerial image, DEM data, and collinearity equation before satellite image is acquired in high-resolution satellite having discretionary rotation and attitude parameters. There are simulated satellite image generation methods applying digital differential rectification among digital ortho image generation methods. One is Direct-Indirect method, the other is Indirect-Indirect method(Byoung-Kil Lee, 1992). This paper generated simulated satellite image having various rotation and attitude parameters by using Indirect-Indirect method.

2.1 Indirect-Indirect method

Indirect-Indirect method is a simulated satellite image generation method applied to indirect method of digital differential rectification two times. First of all, this method applies indirect method between DEM data and aerial image one times and applies indirect method between DEM data and satellite image again. Indirect-Indirect method is now given the term of "IID method" and this principle is like Fig. 2.1.

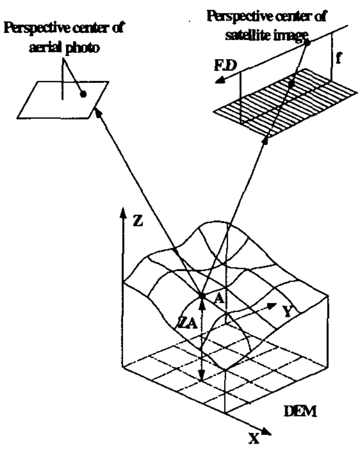


Fig.2.1 Indirect-Indirect Method

This paper supposed that the satellite sensor model extended from collinearity equations was represented by the six exterior orientation parameters in 1st order function of satellite image row and applied the satellite sensor model that was not changed the attitude parameter of pushbroom satellite while the satellite take a image(Bang, Ki In, 2001). To apply the exterior orientation parameter of perspective center considered satellite scan line that include the ground coordinates, this paper used Back-Tracing algorithm (Taejung Kim, Dongseok Shin, and Young-Ran Lee, 2001) changed satellite sensor model supposed in the above. The following equation 2.1 can be lead from collinearity equations in pushbroom satellite image to the following equation 2.2.

$$x_L = -f\frac{r}{q}$$
$$y_L = -f\frac{s}{q} = 0 \quad (y_L = -f_s = 0)$$
$$r = r_{11}(X - X_s) + r_{12}(Y - Y_s) + r_{13}(Z - Z_s)$$
$$s = r_{21}(X - X_s) + r_{22}(Y - Y_s) + r_{23}(Z - Z_s)$$
$$q = r_{31}(X - X_s) + r_{32}(Y - Y_s) + r_{33}(Z - Z_s) \qquad (2.1)$$

$$r_{21}(X - X_s) + r_{22}(Y - Y_s) + r_{23}(Z - Z_s) = 0 \qquad (2.2)$$

When input the following equation 2.1 into the following equation 2.2 and arrange, f(L) can be express to the following equation 2.3.

$$f(L) = -L(a_1 r_{12} + a_2 r_{22} + a_3 r_{32}) + r_{12}(X - X_0) + r_{22}(Y - Y_0) + r_{23}(Z - Z_0) \qquad (2.3)$$

Compute the applicable scan line by finding L satisfying the condition f(L)=zero. Another feature of IID method is that the rearrangement of DN value is performed one times while performing indirect method between DEM data and aerial image and is performed again while performing indirect method between DEM data and pushbroom satellite image because the perspective point of pushbroom satellite image pixel is not correctly reflected. Therefore, IID method performed many rearrangement processes two times. Also, IID method performed somewhat many processes while performing indirect method between DEM data and pushbroom satellite image because of Back-Tracing algorithm. The workflow of IID method is like Fig 2.2.

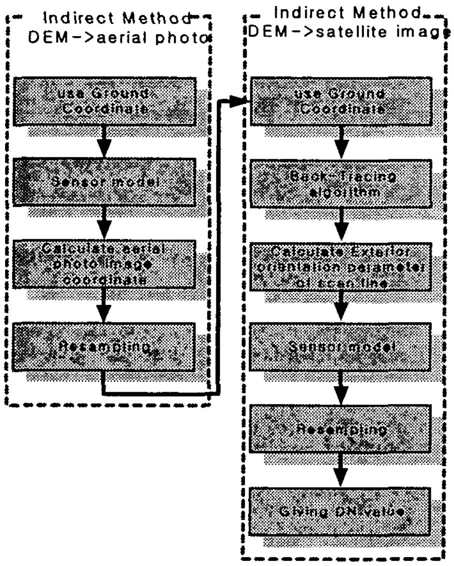


Fig.2.2 IID Method workflow

3. The generation and analysis of simulated satellite image

This paper generated simulated satellite image having discretionary orbit information and exterior orientation parameters applied IID method. Also, this paper generated each simulated satellite image having different each rotation and attitude parameter of pushbroom satellite and analyzed correlation of rotation parameters and attitude parameters using error analysis.

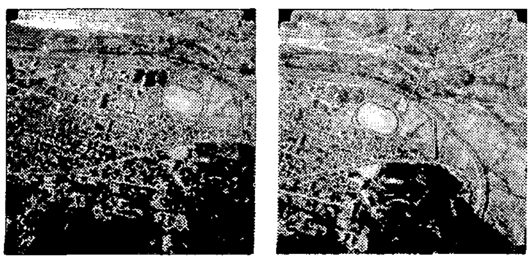


Fig.3.1 Yanggu aerial stereo image

Table.3.1 Aerial image specification

Division	Left	Right
Camera	RC10	RC10
Date	1989. 4. 29	1989. 4. 29
Focal Length	153.3mm	153.3mm
Height	1000.0m	1000.0m
Image size	9056×9063	9114×9037
Scale	1:5,000	1:5,000
Scanning resolution	25μm	25μm

Fig.3.1 is study area aerial stereo image. And Table3.1 is aerial image specification.

DEM data was generated automatically by using digital photogrammetry system 'Imagestation SSK Pro' of Intergraph cooperation at 50cm intervals. In the generation of simulated satellite image, this paper controlled darkly the discretionary DN value of any area getting out of DEM data. To generate simulated satellite image, used exterior orientation parameters of aerial image are like table 3.2. Used orbit information and exterior orientation parameters of pushbroom satellite are like table 3.3.

Table.3.2 Aerial image exterior orientation

	Left	Right
X(m)	286522.934	286360.860
Y(m)	512113.116	512465.159
Z(m)	953.670	956.435
ω(rad)	0.02991494338	-0.005044001538
φ(rad)	-0.01811651764	0.01356120829
κ(rad)	1.864674866	1.927314733

Table.3.3 Exterior orientation for simulating satellite image

Height	681km
Focal lenght	10m
ω(rad)	0.0
φ(rad)	0.0
κ(rad)	0.0
X(m)	286468.00
Y(m)	512072.00
Z(m)	685000.00
Spatial resolution(m)	0.82

3.1 Image comparison on the exterior orientation parameter change

To differently apply rotation and attitude parameters of pushbroom satellite, this paper used about 20 degree of φ angle, rotation angle of the Y-axis direction. The following Fig. 3.2 shown these processes and generated simulated satellite image changed about 20 degree in rotation parameters like table. 3.4.

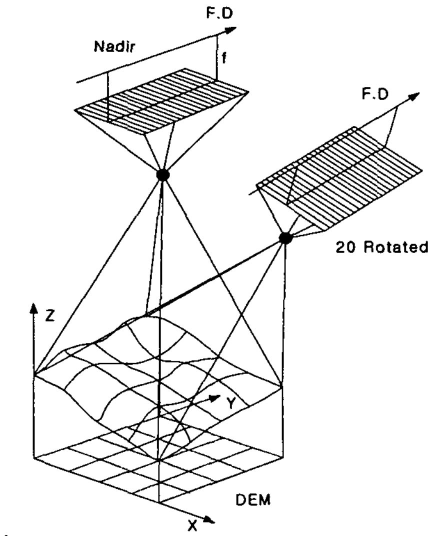


Fig.3.2 Changed Orientation Parameters

Table.3.4 Test configuration of attitude parameter

Case	Omega	Phi	Kappa
Case 1	○	×	×
Case 2	×	○	×
Case 3	○	×	○
Case 4	×	○	○

Also, we analyzed the accuracy of simulated satellite image by using both the image fitted rotation parameters and the image changed rotation and attitude parameters.

3.2 Accuracy analysis of each attitude changes

Fig.3.3 shows the relation of each exterior orientation parameter in linear CCD(Couple Charged Device) images.

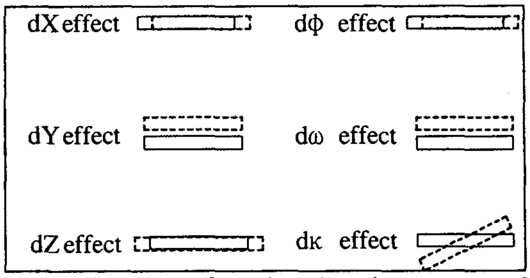


Fig.3.3 The effects of exterior orientation parameters in Linear CCD image

The change of both the X-axis direction movement and φ rotation angle in perspective center and the change of both Y-axis direction movement and ω rotation angle have the similar effect in simulated satellite image. In the linear CCD image, rotation and attitude parameters of perspective center have generally dependent features each other(Ahmet Bahadir Orun, Krishnaier Natarajan, 1994). To analyze these features how to represent in simulated satellite image, we generated each simulated satellite image having various rotation and attitude parameters and fixable rotation and attitude parameters. We checked the accuracy of simulated satellite image made by GCPs(Ground Control Points) and space intersection method. Used GCPs are like Fig.3.4 and those of coordinates are like table.3.5.

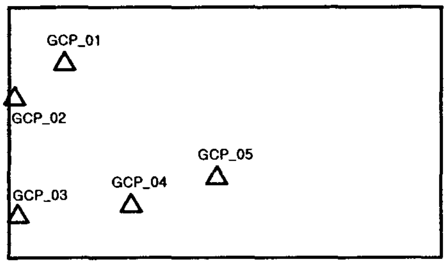


Fig.3.4 Position of GCPs

Table.3.5 Coordinate of GCPs

	Ground Control Point		
	X(m)	Y(m)	Z(m)
GCP_01	286674.57092	512127.39399	184.77774
GCP_02	286642.33945	512170.90401	184.84625
GCP_03	286776.85363	512130.17181	187.19428
GCP_04	286767.55215	512226.96917	187.73188
GCP_05	286745.48766	512300.14653	189.07568

To analyze the relation of rotation and attitude parameters in simulated satellite image, this paper performed the process of space intersection to know what to change RMSE(Root Mean Squares Error) of GCPs. The following table.3.6 and Fig.3.5 represent each RMSE of cases.

Table.3.6 RMSE result of each case

Case	Vx(m)	Vy(m)	Vz(m)	RMSE(m)
case 1(W)	1.0090	0.5999	3.3317	2.4978
case 2(P)	0.9299	0.4000	2.1449	1.6771
case 3(W,K)	0.8607	0.5999	3.9830	2.9124
case 4(P,K)	0.9298	0.6799	2.7910	2.1350

Like the above results, the case 2 just changed by φ angle and fitted by ω, κ angle showed more exacted accuracy than any other cases. In attitude change of simulated satellite image, the accuracy of each case represented comparatively exacted accuracy of fewer 3m in sequence of case 2, case 4, case 1, and case 3. In case 1 and case 3, it is closely related to the X-axis direction movement and φ rotation angle in perspective center.

Totally, the accuracy of each case in simulated satellite image represented about fewer 1m to the X and Y-axis direction. However, the accuracy of the Z-axis direction represented somewhat badly.

In the case 2, the distortion of scan line represented somewhat more exacted result than any other cases. Like the above tables, these results reflected more exacted accuracy than any other cases in the X and Y-axis.

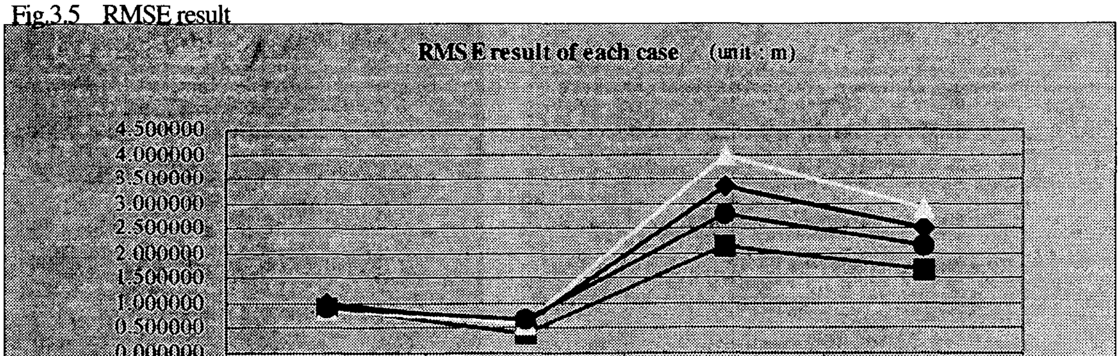
4. Conclusion

There are simulated satellite image generation methods applying digital differential rectification among digital ortho image generation methods.

This paper analyzed how obtaining satellite images influenced errors of rotation parameters and attitude parameters. Furthermore, for detailed analysis, this paper generated simulated satellite image, which was changed variously by rotation parameters and attitude parameters of satellite sensor model. Also, the quality and accuracy for the simulated satellite image were analyzed by space intersection using GCPs.

As a result of the accuracy analysis, we knew that the relation of each exterior orientation parameter in linear CCD image has very similar results. Similarly, X-axis variation of perspective center and φ variation of rotated parameter, and Y-axis variation of perspective center and ω variation of rotated parameter were similar to the relation of exterior orientation parameter in linear CCD image.

Fig.3.5 RMSE result



	Vx	Vy	Vz	Total RMSE
Case 1(W)	1.009028	0.599863	3.331685	2.497809
Case 2(P)	0.929919	0.400047	2.144887	1.677100
Case 3(W, K)	0.860665	0.599863	3.982966	2.912439
Case 4(P, K)	0.929800	0.679867	2.791004	2.135000

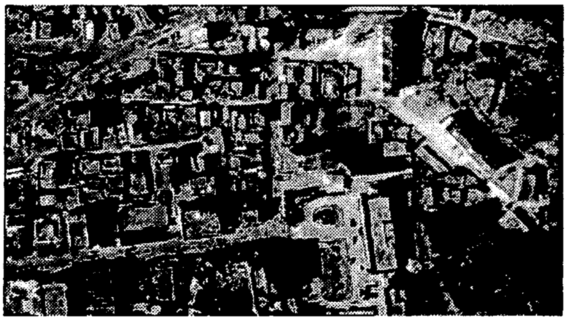


Fig.3.6 ω 20° rotated simulated image

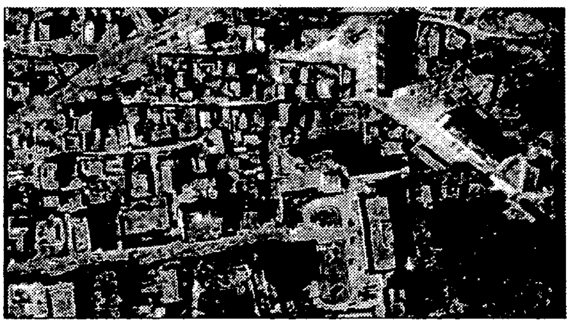


Fig.3.7 φ 20° rotated simulated image

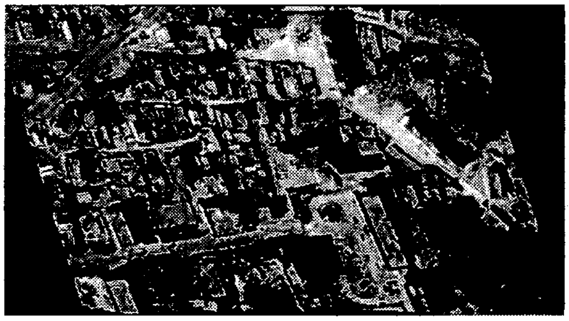


Fig.3.8 ω-κ 20° rotated simulated image

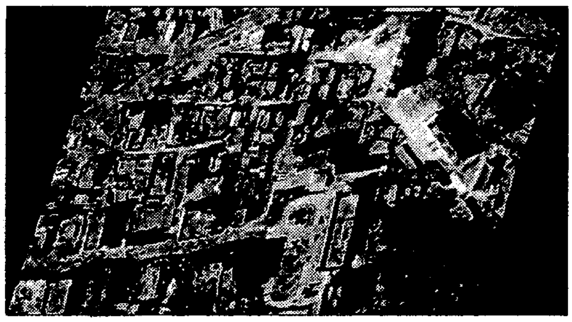


Fig.3.9 φ-κ 20° rotated simulated image

From the result that analyzes accuracy, we knew that the linear CCD image had the dependent features related to the movement and change of rotation parameters in the perspective center.

As a result, these results can be used in correcting the error of exterior orientation parameters using the relation of rotation and attitude information in pushbroom satellite.

5. Reference

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