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A Study on the GCP Disposition of KOMPSAT-1

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Abstract

There are invisible wars going on to preoccupy required satellite information for national defense, industry and living in the out space. Therefore, Korea has developed and successfully launched KOMPSAT (Korea Multi-Purpose SATellite), Korea's first multi-pur pose applications satellite, on December 21, 1999. In the course of geometric corrections with KOMPSAT-1 images, an accuracy of GCP collections is analyzed by the coordinated of digital map respective and an accuracy according to the GCP disposition was analyzed as well. For disposition of GCP, it turned out that even distribution on the whole screen contributes to promote accuracy. These are expected to used as basic data in putting the KOMPSAT-1 geometric correction into practical use.

Keywords : ground control point (GCP), geometric correction, resampling, EOC, GCP disposition positioning

1. Introduction

Nowadays, every country has been competitively at the invisible war in the space so as to get the information necessary for national defense, industry and living. Korea also has opened the Satellite Age since the satellites such as the scientific research satellite, KITSAT-1 (Korea Institute of Technology Satellite-1), and KITSAT-2 and the broadcasting & communication satellite, KORSAT-1 and KORSAT-2 were launched. And Korea developed the first Korea Multi-Purpose Satellite, KOMPSAT was launched on December 21, 1999 and successfully received the practical information from the satellite.[1)]

KOMPSAT-1 is the remote sensing satellite for the earth like Landsat or SPOT, since it is equipped with EOC (Electro Optical Camera), which has the resolution with the ground sample distance (GSD) of 6.6 m, and two ground photographing LRC's (Low Resolution Camera), which has the resolution with 1km GSD, it can observe Korean Peninsula real-time and epochally contribute to the cartography, prevention of calamities, management of national land and development of vegetation and forest field.[2)]

This study analyzed the accuracy according to GCP (Ground Control Point). Disposition using KOMPSAT-1's EOC images, and it has the study goal that this can be used as the basic data for improving the geometric correction accuracy with KOMPSAT.

2. KOMPSAT-1

2.1 Necessity of KOMPSAT-1

It is considered that the necessity for developing Multi-Purpose Satellite has a very important meaning in aspects of industry and technology nationally.[3)]

First, as the national necessity for developing it, there are aspects of securing the space in the earth orbit and extraterrestrial territory, and reinforcing aerospace technology competitiveness such as exploring the national land resources, forecasting weather, communication, broadcasting and science, and the national security for military strategy by using satellites, and second, as the technological and industrial necessity for developing it, since it is the high value-added industry combined with high-tech, it can accomplish the advanced structure of industry, and it contributes to satisfy the domestic demand for satellites by securing the ability to manufacture satellites in domestic, and it takes a role of bridgehead in advancing into foreign

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aerospace markets, Finally, as the social and cultural necessity for developing it, there is the use of satellites for securing digitalized societies mass media such as satellite mobile communication and video conference, culture zone and the extension of independent cultural territory.

2.2 KOMPSAT-1's Equipments on Board

KOMPSAT's system configuration includes the spacecraft combined with sensors and satellite main body, launch vehicle and ground station. Sensors among them are loaded with Electro-Optical Camera (EOC), Ocean Scanning Multispectral Imager (OSMI), and Space Physics Sensor (SPS).

2.2.1. Electro-optical camera (EOC)[4)]

The main mission of EOC is to remote photographing Korean Peninsula and then to make digital elevation model of the national land and produce a stereo map. The stereo map is digitalized and used as data for making an electronic map, and it becomes the basis of GIS and can be used for national land management and preventing disasters. EOC collects panchromatic ground images at the wavelength range of 510~730 nm, and the ground station mixes and treat the images of various orbits and gets the stereo images.

The resolution for ground is 6.6 m, and the swath width at nadir view is 17 km, and 800 km image per orbit is possible continuously to photograph, and EOC's specifications is as shown in Table 1.

2.2.2 Ocean scanning multispectral imager[5)]

For the purpose of observing marine resources & environment around the world, OSMI (Ocean Scanning Multispectral Imager) draws biological oceanography based on the observed data of seawater color.

OSMI has the ground swath of 800 km and ground sample distance of 1 km, and it collects ocean color data in 6 spectral bands by whisky-broom scanning method at the altitude of 685 km, and performs the function to transform this into electronic signals and transmit them to the ground station through PDTS. And OSMIs specifications are as shown in Table 2.

2.2.3 Space physics sensor[6)]

Space Physics Sensor (SPS) is consisted two scientific instruments, High Energy Particle Detector (HEPD) and Ionosphere Measurement Sensor (IMS).

HEPD is carried out to measure the low altitude high energy particle and particles maps.

3. Geometric Correction

3.1 Basic Concept of Geometric Correction

The image data acquired by remote sensing includes the considerable distortion portion made by the earths curved surface. In order to overlap this distorted image with the existing topographical map, which exists on the plane, we should go through the process to transform the satellites image into the same size and projection value as the topographical map. We call this transformation process geometric correction, and only after going through this process, we can get the stable images as the form that we can generally see can study the effects on the micro through maps.

electronics due to these high energy and particles, and IMS is used for the whole earth characteristics search of

Table 1. Specifications of EOC

Item	Description	Item	Description
Spectral distance	6.6 m	F/Number	8.3
Swath width	17 km	Scanner	1 μm pixel, 2592 linear array 0
Duty cycle for image collection	2 m	Signal generation rate	1024 Hz
Image generation method	Push-broom method	Image data transmission rate	25 Mbps
Observation wave length width	510~730 nm	Dimensions of sensor assembly	540 × 660 × 330 (mm) : ESA
Mission life time/reliability	3 year/0.94 over	Dimensions of electronics assembly	230 × 170 × 250 (mm) : EEA
Total weight	35 kg	Average power consumption	Below 50 wat

Table 2. Specifications of OSMI

Item	Description	Item	Description
GSD	85 km at Nadir	F/Number	6
Swath width	800 km	Focal length	128.94 mm
Duty cycle	19.6 min	MTF	20%
Sensor/Scanning method	CCD/Whisk-bloom Scan	SNR	350~450
Spectral band	400~900 nm	Dimensions of sensor assembly	301 × 473 503 (mm) : LSA
FOV	6.83°	Dimensions of electronics assembly	229 × 253 × 141 (mm) : LEA
Total weight	15 kg	Average power consumption	Below 30 wat

Table 3. Capability & Specifications of SPS

	High Energy Partical Detector : HEPD	Ionosphere Measurement Sensor : IMS
Configuration	Proton/Electron Spectrometer (PES) LET Spectrometer (LET) Total Dose Monitor (TDM) Single Event Monitor (SEM)	Electron density measuring assembly Electron temperature measuring assembly
Measurement range	Proton (3 channels : 6.4~38 MeV) Electron (3 channels : 0.25~2 MeV) Alpha particle (1 channel : 15~60 MeV)	Electron density 10~106 Electron/cm^3, Electron temperature 0~1 eV
Data transmission rate	365.4 bps	4984 bps

ionosphere in Arirang Satellites orbit through measuring electron density and electron temperature of the earth ionosphere. The capability and specifications of SPS are as shown in Table 3.

Generally, the methods of geometric correction can be divided into two, Systematic correction and GCP correction.

The systematic correction is the method that after analyzing all the causes of geometric errors that we have observed on the above, we find the reversed transformation system, which transforms the dis torted image into the original one, and then we make correction on distortion.

On the other hand, the GCP correction is the method that without considering the cause of distortion, it analyzes just the distortion degree and find the correction formula, which can connect the collected images with the digitalized map, and then corrects the image distortion. That is, when we suppose GCPs coordinate on the map is (x_n, y_n) and the image coordinate is (u_n, v_n), the goal is to find the related formula between them by connecting two coordinates, and generally it does not use over cubic.

The correction formula using GCP and the transformation formula between these coordinates are as shown is Formula 1.[7)]

$$x_n = a_1 u_n + a_2 v_n + a_3$$
$$y_n = b_1 u_n + b_2 v_n + b_3 \quad (1)$$

In this case, we should find total 6 unknowns in order to determine the transformation formula of Formula 1, and accordingly we should select the exact GCPs at least not less than 6.

Above all, the most important thing in selecting GCP is whether that point is rational as a reference point. Since GCP become a reference point in transforming between image coordinate and map coordinate, their positions should have no change always. As a point for this, crossroad has the highest reliability, and in addition, edge of bank or top of mountain is used more.

And, since the basic concept of GCP correction is that it artificially adjusts the reference points to the corresponding positions on the map and it determines the positions of the points between them by interpolation, if GCPs are not distributed evenly throughout the area, we may have possibility that the distortion can appear more largely rather than before the transformation in the area where it has no GCP or few.

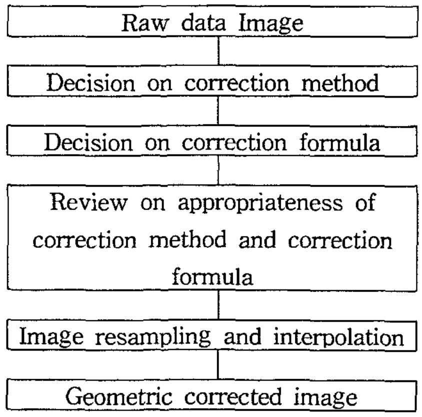


Fig. 1. The General Procedure of Geometric Correction.[7)]

3.2. Procedure of Geometric Correction

The general procedure of geometric correction is as following Fig. 1.

3.2.1. Decision on correction method and correction formula

Correction method and correction formula should be decided by judging the characteristics of geometric distortion and the data available for correction or the distribution chart of reference point data. And about 3 correction methods are generalized and the correction formula corresponding to them are expressed also.

First, the systematic correction is often used for focal distance, position and posture on sensor structure, and correction formula uses collinearity equation.

Second, non-systematic correction is used only when we use the corresponding relation between image coordinate and map coordinate at reference points for the coordinate transformation formula between image coordinate system and map coordinate system, and linear, quadratic isogonal transformation formulas and the higher polynomial are used as correction formulas as shown in formula 2. and formula 3.

Third, combined correction is the correction formula that determines by using theoretical correction formula and reference point.[8)]

· Linear transformation formula is

$$X = a + cX - dY, Y = b + cY - dX \quad (2)$$

· Conformal transformation formula is

$$X = a + cX - dY + e(X^2 - Y^2) - 2fXY$$
$$Y = b + cY + dX + 2eXY + f(X^2 - Y^2) \quad (3)$$

3.2.2. Review on appropriateness of correction method and correction formula

Review of appropriateness of correction method and correction formula is a very difficult part. We don't have clear standard about the number of GCP and the range of RMSE value of position accuracy. The correlation formula between the number of GCP and the grade of polynomial necessary for the image size which we acquired in this study is expressed in the formula 4.[9)]

$$K = [(N + 1)(N + 2)]/2 \quad (4)$$

K : Number of GCP
N : Grade number of polynomial

In using RMSE (Root Mean Square Error) that expresses the position accuracy, it defines the range of allowable error by scale in Digitalized Mapping Bylaws, Section 10 (Accuracy), and it is expressed as the standard deviation of plane position by 1/25,000 is 5.0 m and the maximum deviation is 10.0 m.

Accordingly, since SPOT, IRS and Korea Multi-purpose Satellite (Arirang1) has the GSD that can draw digitalized maps on a scale of 1/25,000, the allowable error is set by 0.5~2.0 Pixel.[10)]

3.2.3 Image resampling and interpolation

If the coordinate transformation formula for geometric correction is decided, the new image data can be output after the data is transformed by the formula. At this time the newly decided coordinate is expressed as not integer but real number, and in this case the method is called as Resampling that we decide the pixel value, that the new coordinate will have by supposing the continuity that each pixel value makes.

This resampling method has three cases according to interpolation method. First, this is Nearest Neighbor (NN) method that it takes the nearest pixel value to a new pixel position as a new pixel value, and second, this is Bi-Linear (BL) method that it calculates the pixel value by using 4 pixel values surrounding a new pixel, And third, this is Cubic Convolution (CC) method that it interpolates, based on the assumption that 16 pixels around a pixel form the surface consisting of cubic polynomial, and they are correlated with one another. Therefore, the first method is usually used in case of analyzing the object images contrast feature or image classification, and the second & third methods are used in case of the data that we can fully antic-

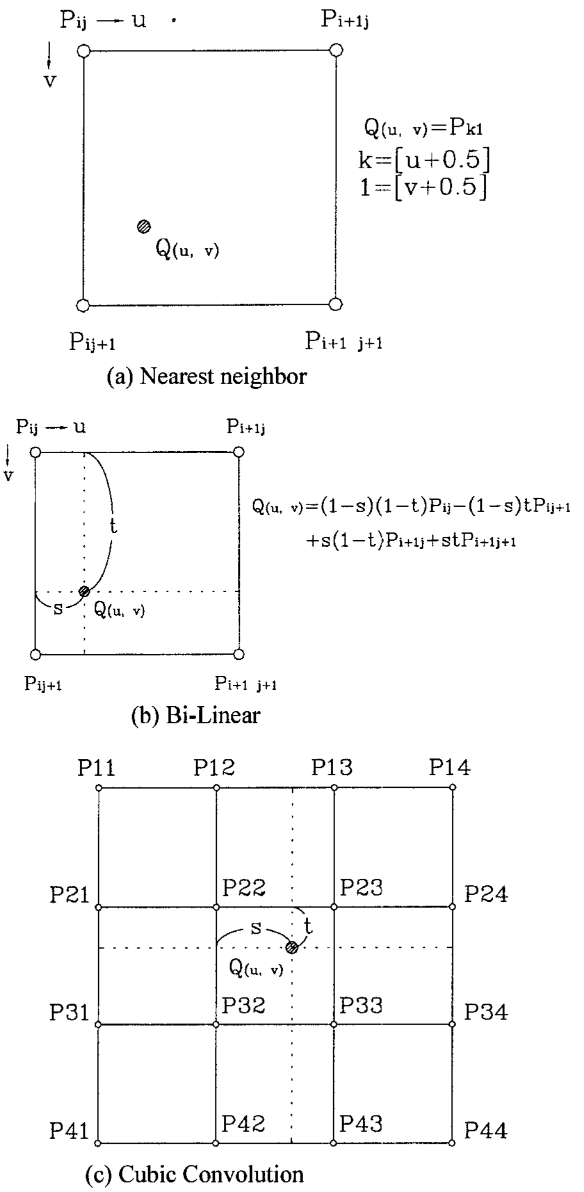


Fig. 2. Interpolation Method for this Image Resampling.

ipate the pixel values continuity in the partial areas such as data for visual analysis, altitude data or temperature data. Each interpolation method for this image resampling is expressed in Fig. 2.[7]

4. Experiment and Analysis

The object area of experiment in this study is the vicinity of Nam-Ku, Pusan, Korea, we used the high resolution camera image provided by Korea Multi-purpose Satellite

Table 4. The Specifications of Image

Nam-Ku, Pusan, Korea,	
Date : 2000. 5. 29	Path No : 1183
Time : a.m. 10:29	TiltAngle : 30.12°

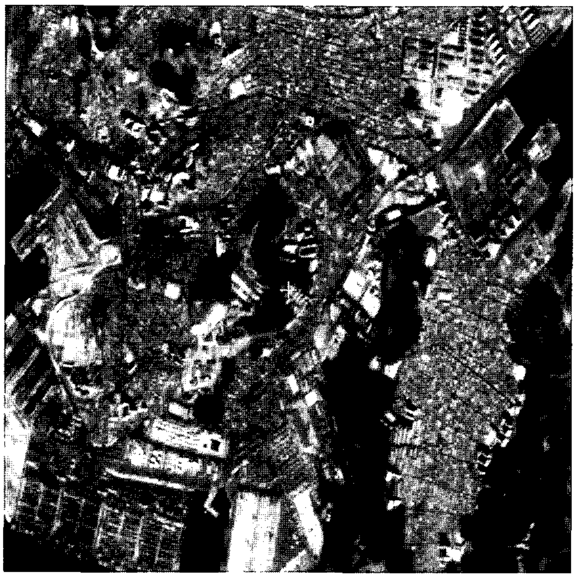


Fig. 3. Shows a Raw Image by KOMPSTAT.

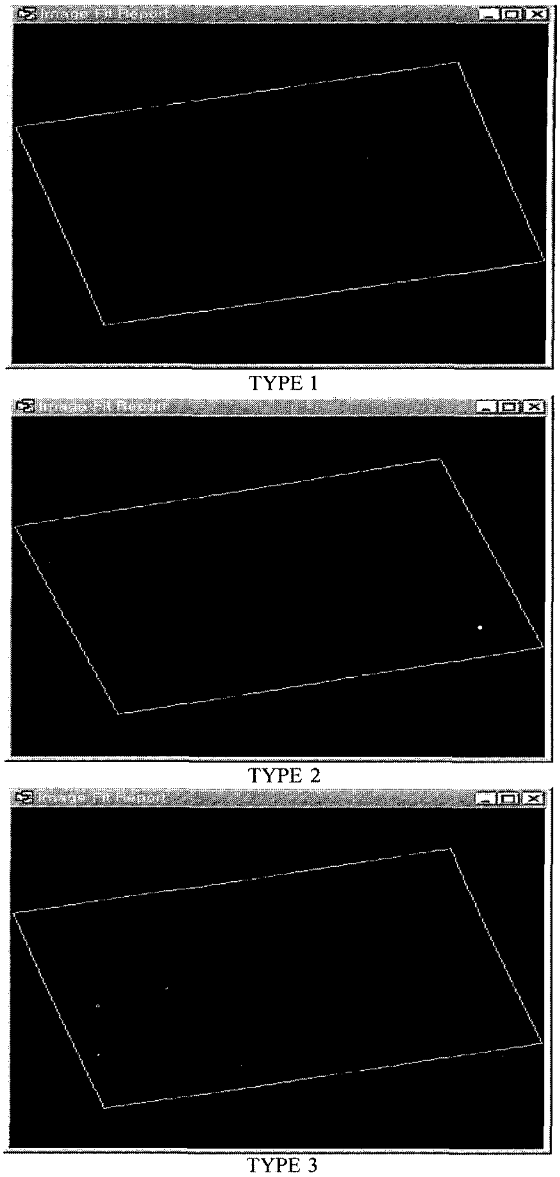


Fig. 4. The Disposition for Each GCP by Type is Shown.

Table 5. Using Digital Map and the Coordinate is Shown

No	Coordinate			No	Coordinate		
	X	Y	Z		X	Y	Z
1	206176.3193	180739.4240	2.27	14	206604.1600	180343.3800	2.72
2	206282.0900	179913.0800	2.67	15	207596.3580	181551.4210	5.75
3	206779.5000	178285.5300	3.03	16	207327.0600	180319.0000	2.65
4	208272.1180	178772.4010	2.26	17	206984.7621	181150.8506	4.23
5	210495.0260	179220.8490	61.61	18	208733.8650	179961.5460	18.18
6	210465.8400	181023.8900	51.24	19	208173.1350	179874.1860	80.85
7	210303.5326	182055.0760	30.12	20	209123.7270	180146.0840	34.72
8	208309.8419	181768.6444	21.27	21	208993.8170	180206.3040	21.89
9	208418.1550	179817.8160	54.75	22	208905.8070	180308.2840	16.64
10	208331.2633	181134.3971	70.12	23	208971.4370	180308.3240	15.64
11	208665.3200	180823.9320	4.21	24	207780.5550	179983.0960	69.78
12	207114.0136	180601.4466	3.57	25	208033.5950	180215.0960	68.54
13	208081.9847	181227.0047	44.73	26	208255.2171	179887.0119	97.79

Table 6. The Error for Each GCP by Type

Units: pixel

Type 1			Type 2			Type 3		
No	Residual		No	Residual		No	Residual	
	X	Y		X	Y		X	Y
1	0.17	0.01	9	0.39	–0.04	1	0.00	0.00
2	0.01	–0.09	11	–0.04	0.00	2	0.18	–0.17
3	–0.11	–0.03	18	–0.56	0.06	8	–0.01	0.00
4	0.17	0.05	19	–0.03	0.00	9	1.47	1.24
5	–0.07	–0.02	20	0.20	–0.02	10	–0.02	0.01
6	0.31	–0.17	21	–0.73	0.07	12	–0.04	0.01
7	0.06	0.02	22	–0.91	0.09	13	0.05	–0.02
8	–0.14	0.35	23	–1.15	0.12	14	0.01	0.00
9	0.04	0.01	24	–0.18	0.02	15	–0.06	–0.03
10	–0.17	–0.05	25	0.21	–0.02	16	0.01	0.00
Avg	0.02	0.01	Avg	–0.25	0.03	Avg	0.14	0.09

(Arirang-1), and the specifications are as shown in Table 4 and Fig. 3. shows a raw image by KOMPSAT.

And in this study, we selected a subset of raw image and experimented it with 500×500 pixel image, and we acquired the coordinate for reference point by using Digital Map (1:1,000) and the coordinate is shown in Table 5, and we made geometric correction with 10 GCPs, and we set 3 check points and examined them.

We disposed GCPs by 3 types, and the disposition is shown in Fig. 4, and as shown in the figure, Type 1 evenly disposed GCPs, and Type 2 disposed GCPs densely concentrated in the center of image, and Type 3 divided image into 4 sectors and disposed GCPs in one sector.

The errors for each GCP by Type are shown in Table 6, and Fig. 5, and here the check point for Type 1 is No. 2, 6, 8 and the check point for Type 2 is No. 21, 22, 23 and the check point for Type 3 is No. 2, 9, 15. Finding each RMSE by Type, we could find that RMSE in Type 1 is $X = 0.29$ (pixel) $Y = 0.08$(pixel), RMSE in Type 2 is $X = 0.77$(pixel) $Y = 0.08$(pixel) and RMSE in Type 3 is $X = 0.06$(pixel) $Y =$ 0.02(pixel). The distortion in the type 2 is shown on all sides but the distortion in the type 3 is occurred on the three

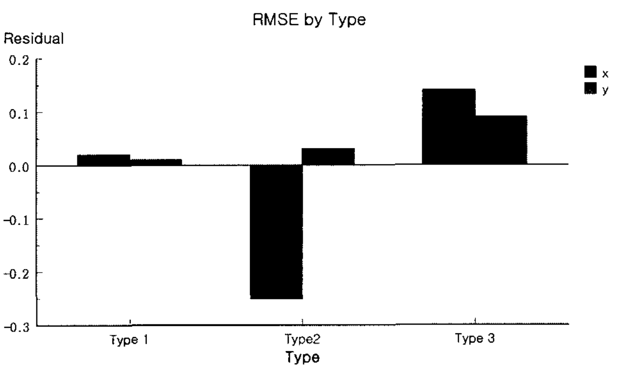
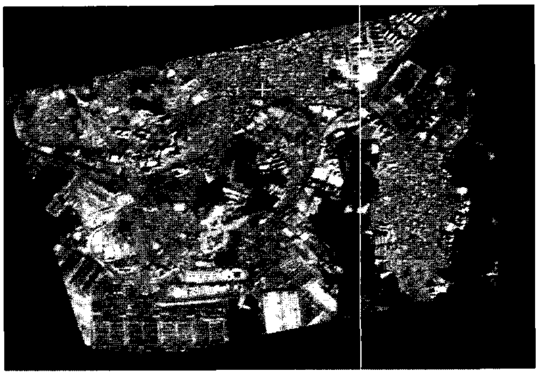
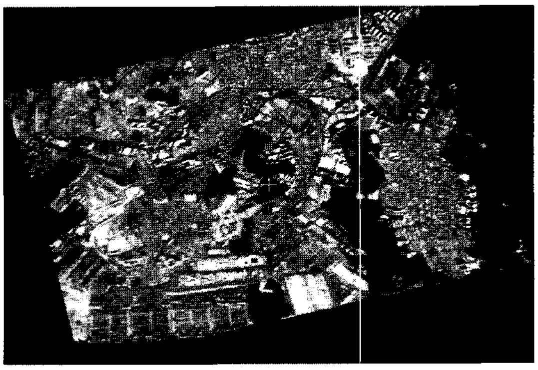


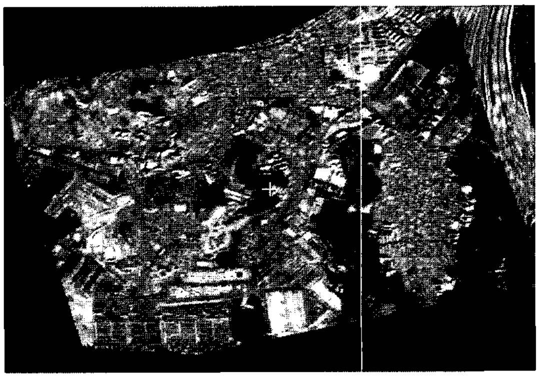
Fig 5. The Error for Each GCP by Type.



TYPE 1



TYPE 2



TYPE 3

Fig. 6. Shown of Image After Geometric Correction.

sides much more than the type 1 and 2.

It satisfied the range of allowable error by scale of digitalized mapping which sets in Digitalized Mapping Bylaws.

The image is geometrically corrected by using the most popularized method, Nearest Neighbor among the resamplings, which is the next step after geometric correction, is as shown in Fig. 6.

5. Conclusion

As a result we studied by means of disposing GCPs by 3 Types for the purpose of improving geometric correction accuracy according to the disposition of GCPs of Korea Multi-purpose Satellite in this study, we could get the following conclusions.

1. Finding each RMSE by Type, we could find that RMSE in Type 1 is $X = 0.29$(pixel) $Y = 0.08$(pixel), RMSE in Type 2 is $X = 0.77$(pixel) $Y = 0.08$(pixel) and RMSE in Type 3 is $X = 0.06$(pixel) $Y = 0.02$(pixel). The distortion in the type 2 is occurred on all sides but the distortion in the type 3 is occurred on the three sides much more than the type 1 and 2.

2. In case we disposed GCPs in only one sector like Type 3 that divided image into 4 sectors, it showed the result that the image had much displacement after resampling.

3. We could make relatively exact and easy geometric correction at the stage of practically using Korea Multi-purpose Satellite, and the result of this study is expected to be used as the basic data for geometric correction in the future.

Reference

1. Choi, G.H. *et al.* (1999). "Establishing Application System of KOMPSAT-1", Journal of the Korean Society Sensing, Vol. 15, No. 4, pp. 349-356.
2. Whitley, Robert, *et al.* (1998). "Final Acceptance Test Report on KOMPSAT EOC", TRW.
3. Ryoo, J.S. *et al.* (2000). "The Development and application of KOMPSAT series", The Korean Society for Aeronautical and Space Sciences, Vol. 28, No. 5, pp. 164-165.
4. Lee, S.H. *et al.* (1998). "Characteristics of the Electro-Optical Cammera(EOC)", KOMPSAT Workshop 2nd.
5. Chung, H.S. *et al.* (1998). "Study on the possibility of the aerosol and/or Yellow dust detection in the atmosphere by Ocean Scanning Multispectral Imager (OSMI)", KOMPSAT Workshop 2nd.
6. Min, K.W. *et al.* (1998). "Space Physics Sensor on KOMPSAT-1", KOMPSAT Workshop 2nd.
7. 日本リ モートャソシソ グ研究會. (1998). "Remote sensing note", pp. 201-205.
8. Jensen. (1996). "Introductory digital image processing : a remote sensing perspective", second edition, p.128.
9. Schowengerdt. (1997). "Remote Sensing : Models and methods for image processing", second edition, p.337.
10. Randy Crane. (1997). "Simplified approach to Image Processing (Prentice Hall)", pp. 18-24.
11. Korea Aerospace Research Institute. (1999). "KOMPSAT EOC User's Guide", p.11.