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Accuracy Estimation of Electro-optical Camera (EOC) on KOMPSAT-1

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Abstract

Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation.[1)]

EOC (Electro -Optical Camera) sensor loaded on the KOMPSAT-1 (Korea Multi- Purpose Satellite-1) performs the earth remote sensing operation. EOC can get high-resolution images of ground distance 6.6m during photographing; it is possible to get a tilt image by tilting satellite body up to 45 degrees at maximum. Accordingly, the device developed in this study enables to obtain images by photographing one pair of tilt image for the same point from two different planes. KOMPSAT-1 aims to obtain a Korean map with a scale of 1:25,000 with high resolution. The KOMPSAT-1 developed automated feature extraction system based on stereo satellite image. It overcomes the limitations of sensor and difficulties associated with preprocessing quite effectively. In case of using 6, 7 and 9 ground control points, which are evenly spread in image, with 95% of reliability for horizontal and vertical position, 3-dimensional positioning was available with accuracy of 6.0752m and 9.8274m. Therefore, less than 10m of design accuracy in KOMPSAT-1 was achieved. Also the ground position error of ortho-image, with reliability of 95%, is 17.568m. And elevation error showing 36.82m was enhanced. The reason why elevation accuracy was not good compared with the positioning accuracy used stereo image was analyzed as a problem of image matching system.

Ortho-image system is advantageous if accurate altitude and production of digital elevation model are desired. The Korean map drawn on a scale of 1: 25,000 by using the new technique of KOMPSAT-1 EOC image adopted in the present study produces accurate result compared to existing mapping techniques involving high costs with less efficiency.

Keywords : KOMPSAT-1, Satellite Stereo Imagery, Ortho-image, DEM

1. Introduction

As a basic tool to establish a various policy of land development plan, resource management and national key industry field, geospatial information is seriously required. More recently, concern how to get the data more promptly and acutely, how to effectively manage and how to utilize the geospatial information is highly emphasized. Accordingly, it is true that a demand of map, which is the most systematic, effective indication, management and assistance tool about geospatial information, is in increasing trend. In order to satisfy these demands, we largely rely on mapping and surveying techniques, and eventually it is directly related to utilization of measuring method.

Remote sensing has an advantage enabling to handle an evenly observed image data by digital image device even though the desired target area is very vast. However, the technique has been restrictively used in the fields of extracting contour lines, and generating ortho-image due to relatively low resolution and complicated processing procedure during the last decades. However, together with the end of cold war and development in technology of measuring method, new satellite system and measuring equipment with high resolution were merged one by one. In line with this, geometrical application field such as 3-dimensional positioning, which requires a high resolution, is rapidly

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increasing trend.

In case of Korea, after the first Korean artificial satellite KITSAT-1 was launched in August of 1992, KITSAT -2 in 1993 and communication satellite KOREASAT-1 in 1995, and KOREASAT-2 were launched in 1996 respectively. In addition, multipurpose satellite series, namely KOMPSAT, has been developed. For example, KOMPSAT -1 was already orbited in 1999 and KOMPSAT-2 is under development now for purpose of launching.

2. System and Data of KOMPSAT-1

2.1 System of KOMPSAT-1

2.1.1 System Specification

KOMPSAT-1 consist of four platforms, such as EOC (Electro-Optical Camera), OSMI (Ocean Scanning Multispectral Imager), SPS (Space Physics Sensor)- IMS (Ionosphere Measurement Sensor), and HEPD (High Energy Particle Detector).

The following Table 1 summarizes performance and system component of KOMPSAT-1.

2.1.2 The Operation

The operation of KOMPSAT-1 is carried out according to the mission plan for the data collection to manufacture the Korean peninsula map, to measure the ocean, to study the space environment, and the status data collection of KOMPSTAT-1.

EOC is CCD (Charge Coupled Device) camera of high resolution to manufacture a Korean peninsula map of 1:25,000 and to have 3-dimensional image of Korean peninsula, which is a major mission of KOMPSAT-1. The time taken for one track is about 2 minutes.

EOC (Electro-Optical Camera) sensor loaded on the KOMPSAT-1 (Korea Multi- Purpose SATellite-1) performs the earth remote sensing. EOC can get a high resolution images of 6.6m during photographing; it is possible to get a tilt image by tilting satellite body up to 45 degrees at maximum. Accordingly, the device developed in this study enables to obtain images by photographing one pair of tilt image for the same point from different two planes. KOMPSAT-1 aims to obtain a Korean map with a scale of 1: 25,000 with high resolution.

KOMPSAT-1 passes the repeated same orbit every 28 days with equator passing time at 10:50 AM local time. In addition, the satellite normally gets through the Korean peninsula twice a day (daytime and night), and its ground wheel track passing during daytime will place on a rising track where a satellite is progressing forward from the equator space to the Polar Regions.[2)]

2.2 EOC Sensor Characteristics

The major function of EOC is to take a satellite image, to generate Digital Elevation Model (DEM), and manufacture 3-dimentional map of the Korean territory. This 3-dimensional map is digitized and used as a data to make a digital map, and also it can be used as a managing tool of national land and to prevent a disaster being a basis of Geo-Spatial Information System (GSIS).

EOC collects a panchromatic ground image with 0.51

Table 1. KOMPSAT-1 specification

Mission period.	Three years and over	
Track	685km sun synchronous orbit, equator transit local time. local time AM 10:50 (south and north track)	
Ground control center of contact	2 or 3 times message exchanges available every 10 to 11 hours.	
Weight	510 kg	
Power consumption	636 W	
Track cycle	98.46 min	
Size	Body diameter 53inch, body height 98inch, solar battery plate 2.8×4.6m	
Satellite body	Honeycomb structure, mode of a manual heat controls, mode of a control of three axis, Hydrazine, Si solar battery plate	
Platform	EOC	Provide image enabling to manufacture the Korean peninsula map with 1:25,000 scale, resolution 6.6m, observation width 17km Panchromatic Band 0.51～0.73㎛
	OSMI	Resolution 1km, width 800km 6 band: 0.4～0.9㎛
	SPS	IMS, HEPD

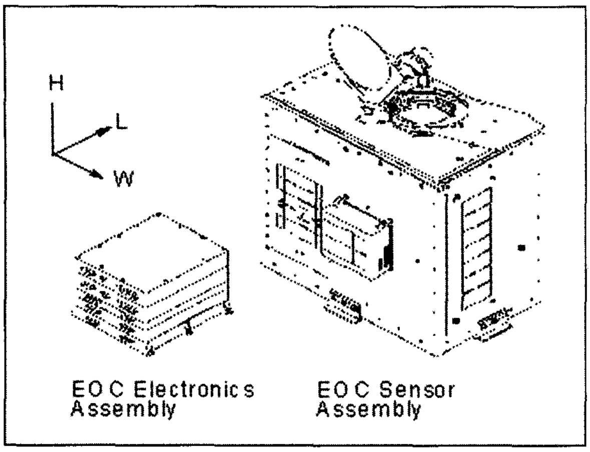

Fig. 1. Composition of EOC.

Table 2. Main characteristics of EOC

Resolution	6.6m ± 10%
Observation wavelength	0.51 ~ 0.73μm (Panchromatic)
FOV	1.42° (FOV : Field of View)
Camera MTF	>10 % at Frequency
SNR	≥ 50
Sensor/ Scanning method /Pixel	CCD/Push-bloom/2592 Pixels
Confidence	>0.9
Swath	17 km at 685 km (Nadir view)
Duty cycle	2 minutes (ground length 800 km)
Receiving cycle	39 times for 28 days
Correction	Area of observation, or GCP(Ground Control Point)
System components	Weight 34kg, Consumption electricity 46 W

~0.73μm wavelength proxy. In the mean time, the ground station provides stereo images by means of processing a number of images in different orbits. The ground resolution is 6.6m and swath is the 17km upon vertical photographing, and continuous photographing for approx. 800km-ground length per one track is also available. The orbital life is more than three years, and the reliability 0.9 for that period is guaranteed including Payload Data Transmission Subsystem (PDTS). It has a function of Programmable Gain, enabling to order from the ground a Gain of image signal according to the photographing condition.

EOC consists of sensor and electronics assembly as shown in Fig. 1 and it weighs approximately 35kg with maximum power consumption of 50W and image data transmission ratio of 25Mbps.[3]

An order from the ground station, and sending and receiving of status information are carried out through S-band. For 2 minutes of duty cycle, approximately 800km distance will be photographed, and the observed data will be transmitted to the ground station at real-time or transmitted after being stored in the memory device of Data Transmission Subsystem. Here, X-band is used.

The received data are passed by radiometric wave and geometric correction, and correction is made by photographing a basic observation area such as desert or ground control point (GCP), and test area. From the satellite body, ancillary data such as time required to process EOC data, satellite position and attitude and

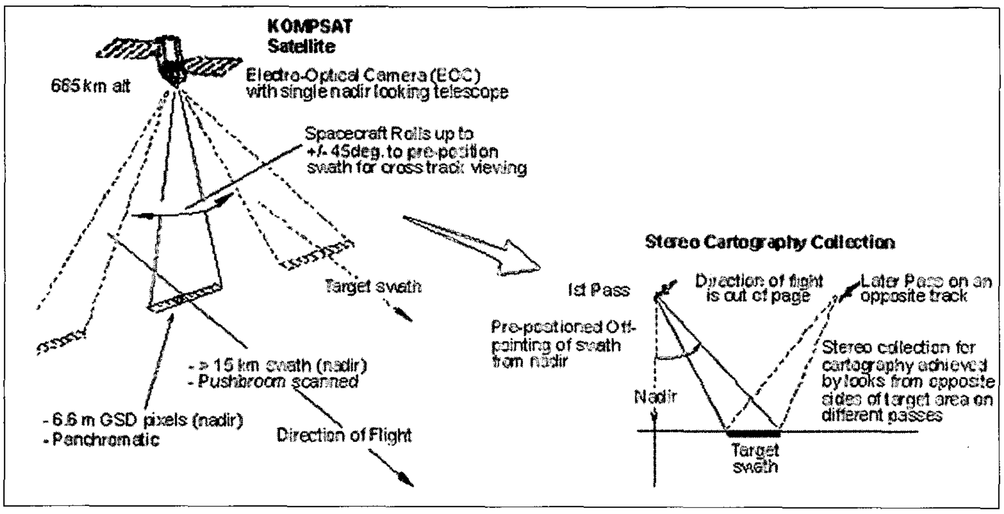

Fig. 2. General concept of EOC.

so on are supplied.

Fig. 2 illustrates EOC sensor concept.

The same ground target is photographed at two different orbits rolling satellite body up to ±45° at maximum, and 3-dimensional map is manufactured combining (during data processing) the image obtained from two orbits at ground station. During daytime for every 28 days, re-visit cycle of the satellite, 39 times of X-band reception is made. And considering rolling of up to ± 30°, 20 times of image acquisition of EOC map manufacturing is available out of 30 times. The below Fig. 2 shows a concept of EOC sensor.

2.3 EOC Data

For EOC image data received from satellite body of KOMPSTAT-1, its processing level is defined as below table according to the processing procedure. The media of standard image is provided as CD, DLT, 8mm/4mm Tape, etc. according to the user requirement.

Table 3. The level of EOC image

Image Level	Substance
Raw Data	Unformatted serial data
Level 0	Frame formatted
Level 1A	The image which a supplementary data is separated by the frame and Ancillary Data
Level 1R	Radiometric correction
Level 1GR	Geo-referenced
Level 1GC	Geo-coded
Level 1GC_P	Geometric correction(using GCP)
Level 1GC_D	DEM
Level 4	Mosaic

Basically, the data is formatted as HDF. As for data processing software, OPEN 2000 software developed by Datron Inc. is normally used for level 1A, level 1R and level 1GR

In case of level 1R, the radiometric correction is performed usually by detector normalization and MTF, whereas in the geometric correction for more than level 1GR, various methods are applied by each level.[4] Table 3 shows a processing level of EOC standard image.

3. The Image Processing and Analysis

3.1 An Observation Object Area Selection

The target area of this research is set to the western part of Busan City, and the dimension of the target area is limited to a part overlapped in one pair of stereo image. The stereo images of KOMPSAT-1 EOC in this study were taken on 9th October 2000 (left image) and on 6th October 2000(right image) respectively. In addition, the inclination angles are -14° and -16°, as shown in Fig. 3 and 4. It should be necessary to be noted that both images were processed as Level 1R carrying out only radiometric correction.

At the beginning, the image header information of KOMPSAT-1 were supplied with text file of extension with HDF (Hierarchical Data Format) and RPT (RePorT), but now it is supplied only with HDF file format. However, it is also available to supply in various kinds of widely used image format such as TIFF (Tag Image File Format) according to users requirement. A focal length of EOC sensor is 1045mm, scan time per scan line is 1/1024 seconds, and one pixel size is 10㎛.

Table 4 summarizes the header information in the EOC image used in this research.

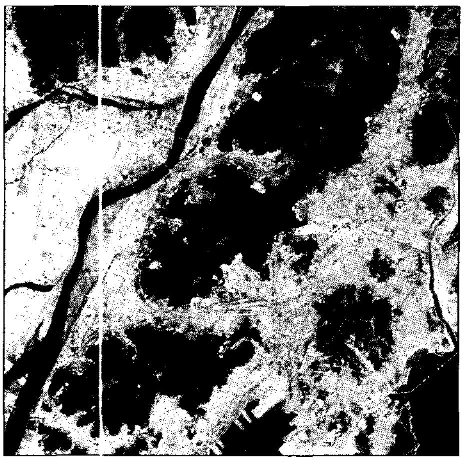

Fig. 3. Left image.

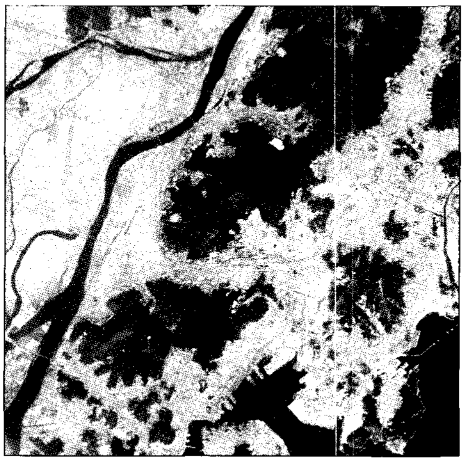

Fig. 4. Right image.

Table 4. Header Information of left image

Contents	Substance
Sensor Name	EOC
Scene ID	EOC_09361313200010090158I4N14_1R
Grid Reference System(GRS)	(936, 1313)
Acquisition Date/Time(UTC)	2000/10/09/ 01:58:14
Processing Level	Level 1R Product
Look Angle	N14
Ground Spatial Distance(GRD)	X: 6.6m, Y: 6.6m
Bits per pixel	8bits
Pixels per line	2592
Lines per image	2799
Minimum Value	0
Maximum Value	255
Mean Value	47.7090
Std. Dev. Value	15.1536
MTF Convolution Kernel	Size=9
Signal/Noise	5.000000

Table 5. EOC Ephemeris of left image

REC	UTC (days)	UTC (seconds)	Position X (km)	Position Y (km)	Position Z (km)	Velocity X (km/sec)	Velocity Y (km/sec)	Velocity Z (km/sec)
1	18544	7099.001	-3502.57	4617.39	4035.37	3.9332	-2.3363	6.0679
2	18544	7098.001	-3506.5	4619.72	4029.30	3.9296	-2.3305	6.0724
3	18544	7097.001	-3510.43	4622.05	4023.22	3.9260	-2.3248	6.0770
4	18544	7096.001	-3514.35	4624.37	4017.14	3.9224	-2.319	6.0816
5	18544	7095.001	-3518.27	4626.69	4011.06	3.9188	-2.3132	6.0861
6	18544	7094.001	-3522.19	4629.00	4004.97	3.9152	-2.3075	6.0906
7	18544	7093.001	-3526.1	4631.31	3998.88	3.9115	-2.3017	6.0952
8	18544	7092.001	-3530.01	4633.61	3992.78	3.9079	-2.2959	6.0997
9	18544	7091.001	-3533.92	4635.9	3986.68	3.9043	-2.2901	6.1042
10	18544	7090.001	-3537.82	4638.19	3980.57	3.9006	-2.2844	6.1087
11	18544	7089.001	-3541.71	4640.47	3974.46	3.8970	-2.2786	6.1132

Scene ID (identification) of KOMPSAT-1 contains plenty of information, it varies according to image processing level and photographing time. Standard format is EOC_ kkkkjjjjyyyymmddttmmssN16_1R.hdf according to the image level and photographing time. Here, kkkk and jjjj stands for an area contained in the image expressed in KOMPSAT-1 Grid Reference System (GRS), while yyyy, mm, and dd represents date, and tt, mm, ss is the time when the image is taken. N16, presenting direction of photographing, means this image is tilted about 16 degree to the left of direction of satellite flight.

As ephemeris data of the left image, Table 5 indicates the satellite position and velocity upon photographing each tilting line. In telemetry, satellite position and velocity is recorded by every 1/4 second by geocentric coordinate system (ECEF), and therefore, this value is gained by calculating satellite position and velocity upon photographing the tilting line.

Table 6 shows the ephemeris of the right image and the attitude information.

As the ephemeris on left image, Table 6, shows roll (rotation quantity for X-axis), pitch (rotation quantity for X-axis) and yaw (rotation quantity for Z-axis) for

Table 6. EOC Ephemeris of left image

REC	UTC (days)	UTC (seconds)	Position X (km)	Position Y (km)	Position Z (km)	Velocity X (km/sec)	Velocity Y (km/sec)	Velocity Z (km/sec)
1	18541	6102.0040	-3787.6500	4327.1300	4099.2900	4.1351	-2.0997	6.0189
2	18541	6101.0040	-3791.7800	4329.2200	4093.2700	4.1311	-2.0942	6.0235
3	18541	6100.0040	-3795.9100	4331.3100	4087.2400	4.1272	-2.0888	6.0282
4	18541	6099.0040	-3800.0400	4333.4000	4081.2100	4.1232	-2.0833	6.0328
5	18541	6098.0040	-3804.1600	4335.4800	4075.1800	4.1192	-2.0778	6.0374
6	18541	6097.0040	-3808.2800	4337.5500	4069.1400	4.1152	-2.0723	6.0420
7	18541	6096.0040	-3812.3900	4339.6200	4063.1000	4.1113	-2.0668	6.0466
8	18541	6095.0040	-3816.5000	4341.6900	4057.0500	4.1072	-2.0614	6.0513
9	18541	6094.0040	-3820.6100	4343.7400	4051.0000	4.1033	-2.0559	6.0559
10	18541	6093.0040	-3824.7100	4345.8000	4044.9400	4.0992	-2.0504	6.0604
11	18541	6092.0040	-3828.8100	4347.8400	4038.8800	4.0952	-2.0449	6.0650
12	18541	6091.0040	-3832.9000	4349.8900	4032.8100	4.0912	-2.0394	6.0690

UTC (Universal Time Coordinated), and provided in radian unit.

3.2 Ground Control Point

Ground Control Point (GCP) is required to implement modeling, which interprets the geometrical relationship between 3-D position and satellite image. In this research, after preoccupying 32 ground survey points from stereo image, 3-D position was decided through GPS surveying Besides, we intended to use some as a ground control point, and the rest as a checkpoint. The ground control position point was arranged to widely spread to all images and not focused on some part.

For GPS surveying, static DGPS surveying method was applied. The position of base station was gained by DGPS treatment after receipt of GPS signal for 24 hours. Receiving signal was received setting to carrier phase mode, and GPS signal was received for more than 1 hour with an interval of 5 seconds per 1 point. On the other hand, the corrected carrier phase measurement was processed with respect to a know point, namely Dong-A university GPS reference point (DUGPS). To obtain maximum accuracy, three dimensional network adjustments were performed as well with due consideration to covariance values from GPS data processing and the network adjustment. The obtained results are of the order of 1～2cm level. Fig. 5 illustrates distribution of the ground control points.

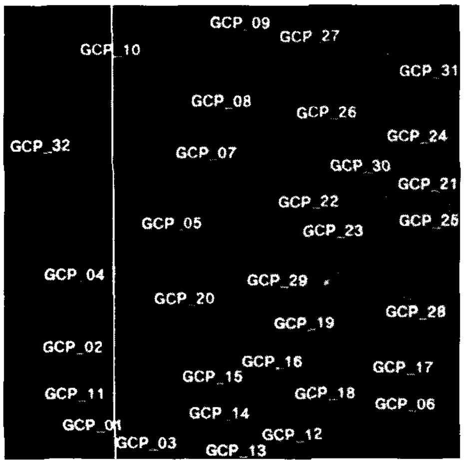

Fig. 5. Ground Control Point.

Among 32 points observed by GPS surveying, 6, 7 and 9 points were used as GCPs, and the other points used as checkpoints to assess the modeling accuracy. Modeling can be stable with many GCPs, whereas using so many GCPs, it is difficult to apply to the actual practice since it does not guarantee economic problem.

The remaining ground points excluding those are used as ground check points were set as checkpoints. Check points can be a guideline to evaluate modeling accuracy, and joint point was established for a stable calculation.

In order to study the relation between the change in the number of ground control points and modeling accuracy, location accuracy for 14 checkpoints was analyzed by changing the number of GCPs to 6, 7 and 9 point. Also, it was analyzed with different arrangement of GCPs, such as Type I, Type II and Type III, since accuracy shows different according to the accuracy of GCPs and block format. And, we transformed WGS 84 to UTM coordinate system.

Table 7～9 shows modeling accuracy of x, y, and z.

Table 7. The X RMSE direction of Modeling

	Type I	Type II	Type III
GCP 6	2.886	2.731	2.783
GCP 7	2.632	2.545	2.796
GCP 9	2.594	2.422	2.654

Table 8. The Y RMSE direction of Modeling

	Type I	Type II	Type III
GCP 6	3.121	2.943	3.001
GCP 7	2.944	3.011	3.639
GCP 9	3.021	2.542	2.899

Table 9. The Z RMSE direction of Modeling

	Type I	Type II	Type III
GCP 6	7.353	6.432	8.213
GCP 7	7.298	6.121	7.262
GCP 9	6.622	5.014	6.429

Studying this, it is found generally that the location accuracy increases with increasing number of reference points. It is foreseen that the accuracy of *y* coordinate is influenced upon block formulation of ground control points.

Fig. 6~7 and Fig. 8 represent horizontal and vertical components accuracy of GCP depending on its number.

From the figure, it is seen that 9 GCPs become the most stable modeling, and the case of Type II shows the least RMSE value.

In case of the plane location accuracy of 2.422~3.121m, it is less than KOMPSAT-1 satellite image resolution of 6.6m; but on the other hand, the accuracy of vertical location of 5.014~8.214m is considered to be selected and used only value included in 6.6m.

Considering the case of Busan, it can be deduced that the RMSE values of three dimensional positioning using KOMPSAT-1 satellite stereo imagery could be less than 6.6m corresponding to the ground distance of one pixel size in each three dimensional axes with about 9 GCPs evenly distributed. The entire image is used.

National Standard for Spatial Data Accuracy of Geospatial Positioning Accuracy Standards Part 3, FGDC (Federal Geographic Data Committee) USA, proposes a statistical testing method for position accuracy on maps and digital geospatial data, with respect to georeferenced ground positions of higher accuracy (FGDC, 1998). This guideline estimates position accuracy from RMSE with observed points surveyed by independent method with high accuracy, and proposes vertical and horizontal position accuracy for 95% reliability as follows.5)

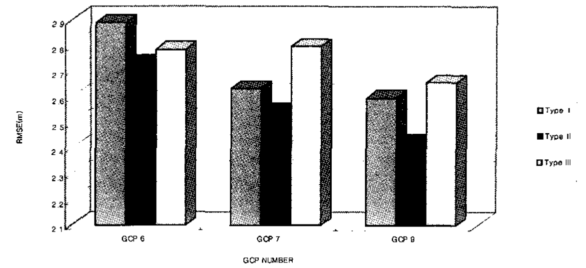

Fig. 6. The X RMSE direction of Modeling.

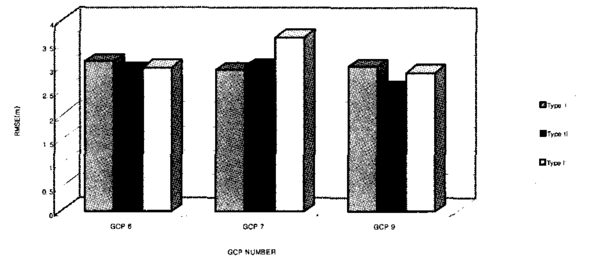

Fig. 7. The Y RMSE direction of Modeling.

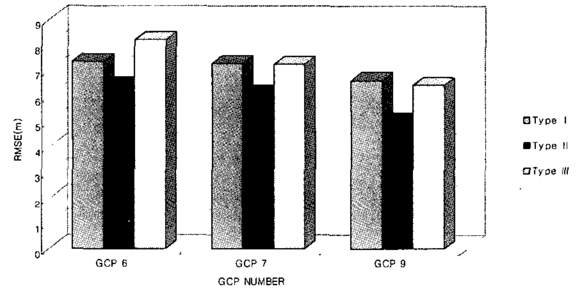

Fig. 8. The Z RMSE direction of Modeling.

Also, vertical accuracy with 95% reliability is as follows,

$$Accuracy\ r = 2.4477 \times 0.5 \times (RMSEx + RMSEy)$$
$$Accuracy\ z = 1.9600 \times RMSEz$$

If this applies, in case the number of GCPs of Type II is 9, horizontal position accuracy becomes 9.8274m and vertical position accuracy becomes 6.0752m.

This shows that it satisfies both horizontal and vertical position deciding accuracy of 10m(1 σ), which applied in the design of KOMPSAT-1. On the contrary, in order to satisfy to 10m of horizontal and vertical position accuracy, it is found that *x*, *y* RMSE of GCPs should be limited below value of *x*, *y* RMSE of 4.0855m, and *z* RMSE of 5.1020m.6)

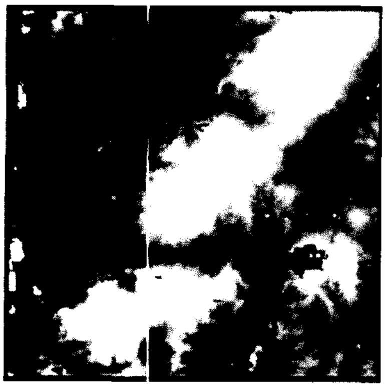

Fig. 9. Automatic DEM.

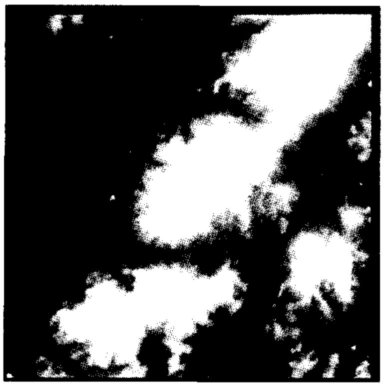

Fig. 10. DEM of correction.

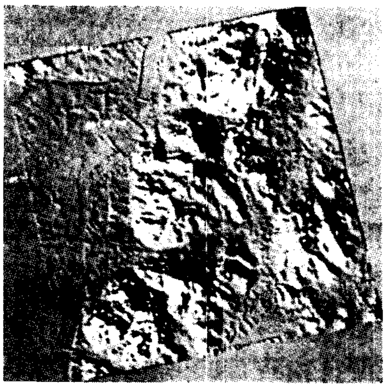

Fig. 11. Shaded relief map.

Fig. 12. Ortho image.

3.3 DEM and Ortho Rectification Image

To improve velocity and accuracy of matching, epipolar resampling process was performed. With an image where all parallax error was removed, parallax in two epipolar images was used by matching identical point, and it was possible to calculate elevation from base level by this parallax. Relative digital elevation model is also made from this. When the generation of the digital elevation model, before proved conjugate point, if we observe the parallax of a right and left of image. Fig. 9 is automatically generated DEM. Fig. 10 and 11 illustrates modified DEM and shaded relief map respectively.

Based on the digital elevation model (DEM), an ortho-image was generated through ortho revision as shown in Fig. 12. An accuracy of the DEM usually depends on numerical modeling accuracy with respect to satellite geometry. In the ortho-image generated in this study, horizontal accuracy corresponds to 17.568m, whereas that of vertical component is 36.8m.

4. Conclusion

In this study, using stereo satellite image of EOC loaded on KOMPSAT-1, feature extraction to be automated, to increase readability with decreased sensor effect and pre-treatment of noise removal, to manufacture an ortho-image, and to evaluate its accuracy were carried out. Through this, it aimed an adequacy of manufacturing an ortho-image through KOMPSAT-1 EOC image can to be justified. The following conclusions are made through these researches.

1. In case of using the 9 ground control points evenly spread in image, it was found that less than 10m of design accuracy of KOMPSAT-1 was achieved with 95% reliability, since 3-dimensional positioning was available with accuracy of 6.0752m and 9,8274m for horizontal and vertical position respectively.
2. In order to satisfy 10m of horizontal and vertical position accuracy, which was applied to KOMPSAT-1 design, it was found that the value of less than x, y RMSE of 4.0855m and z RMSE of 5.1020m should be limited.
3. The ground position accuracy of ortho-image, with 95% reliability, 36.8m of vertical position accuracy was enhanced. And it was analyzed that the accuracy of altitude cannot be enhanced compared to the modeling accuracy of positioning using stereo image. This turned out as a problem of image matching system.
4. For the accuracy development of ortho-image, it is considered that the exact attitude of satellite image and research on manufacturing of Digital Elevation Model (DEM) should continuously proceed in future.

The new high technology carrying out manufacturing the Korean peninsula map with a scale of 1:25,000 using KOMPSAT-1 EOC image will bring a good result avoiding high expensive and low efficiency in the existing map manufacturing and renovation process. If panchromatic image of 1m resolution in high-resolution camera (Multi-spectral camera: MSC) - a satellite body of KOMPSAT-2, which will be launched in 2004 is used, more effective management support of the national land and more accurate and various forms of the national territory information can be supplied promptly.

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