

# Suitable Type of Ground Control Point for High-resolution Satellite Imagery

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**Abstract.** Highly accurate geometric correction is necessary for high-resolution data. Then, it is important to acquire the high accuracy Ground Control Point (GCP) and corresponded Image Control Points (ICPs) for geometric correction. The objective of this study is evaluation of GCP type for high-resolution satellite image. In this study, following two types of GCP was selected:

- 1) Polygon in field surveying using GPS
- 2) Template image using aerial photograph

Accuracy was evaluated using Root Mean Square Error (RMSE) which was calculated by comparing around GCP and validation points. In this study, IKONOS was used as high resolution imagery. 3D affine transform was carried out for the geometric correction of the IKONOS imagery. GCP polygon such as agricultural field were surveyed by kinematic method of GPS. Then, a center of gravity was calculated using the polygon data. The corresponded ICP polygon image was extracted from the IKONOS image by visual interpretation. A center of gravity was also calculated using the polygon image. Then geometric corrections were carried out using control points obtained from GCP polygon and ICP polygon. In the result, RMSE showed less than 0.56 pixels. GCP from gravity point became enough accuracy. For image matching using aerial photograph, ortho image was established using aerial photograph and DSM. And, template image was generated from the ortho image. Land cover in the image was much different between aerial photograph and IKONOS image. Therefore, the classified image was generated by normalized Euclidian distance from training data of road. Image matching was carried out by using the classified template image and IKONOS image. Classification image can be adapted for image matching, which showed 0.08 correlation and 0.189 pixel error. The original color image showed 0.07 correlation and 14.06 pixels error, for image matching. Image matching with classification image made reliable result rather than original color image.

Keywords: High resolution satellite image, GCP, Image Matching

## 1. Introduction

High-resolution satellite images are expected to be overlaid with other GIS data, and for updating existing map. Therefore, highly accurate geometric correction is necessary to rectify the high-resolution data. Then it is important to acquire the high accuracy Ground Control Points (GCPs) and corresponded Image Control Points (ICPs) for geometric correction. Usually GCPs can be surveyed by Global Positioning System (GPS) as point data. However, it was difficult to pick up the corresponded ICP by visual interpretation.

Kadota (2002) carried out the geometric correction of using point based GCPs for IKONOS image. GCPs were selected the place where it can be surveyed safely and easily in field surveying. The error had occurred 0.5 to 0.9 pixels with eight GCPs. Yamakawa (2002) used circle type GCPs to proceed high accurate geometric correction. However, it is difficult to prepare circle type GCPs in various field. Therefore, other types of GCPs such as polygon of agricultural field, shape of road or aerial photograph should be evaluated.

## 2. Objectives

The objective of this study is evaluation of GCP type for high-resolution satellite image. In this study, following two types of GCP was selected.

- Polygon by field surveying using GPS
- Template image using aerial photograph

Accuracy was evaluated by Root Mean Square Error (RMSE) which was calculated around GCP and validation points.

### 3. Data used

In this study, IKONOS was used as high resolution imagery. It was the digital-geo image which was corrected distortion by the roundness of the earth. Table 3.1 shows the specification of IKONOS imagery used. Test area around Tosayamada-cho, KOCHI prefecture, JAPAN was selected (Fig 3.1). The Image was covered about 11km x 11km. There were several small towns, deep forest, wide river, many farm lands, port and few buildings.



Fig 3.1 Test Area, IKONOS Image

Table 3.1 Specification of Used IKONOS Imagery

Item	Detail
Cross Scan	0.86m
Along Scan	0.84m
Scan Direction	0°
Nominal Collection Azimuth	263.9600°
Nominal Collection Elevation	76.68608°
Acquisition Data/Time	2000/6/15
Photography Area	Tosayamada Kochi JAPAN
Area (km <sup>2</sup> )	134.848
Product Level	Digital-Geo Image
Sensor Type	Pan-Sharpen (4 Bands)
Map Projective Method	Transverse Mercator
Ellipsoid	Bessel
Datum	Tokyo

### 4. Geometric Transformation Equation

In this study, 3D affine transform was applied (4.1). The 3D affine transform can be adapted for geometric correction for high-resolution satellite imagery by Dowman (2000), Yamakawa (2002) and Kadota (2002).

$$\begin{aligned}
 u &= a_1x + a_2y + a_3z + a_4 \\
 v &= b_1x + b_2y + b_3z + b_4
 \end{aligned}
 \tag{4.1}$$

Where  $u, v$  = ICP  
 $x, y, z$  = GCP  
 $a_1 \sim a_4$  = Transformed coefficient  
 $b_1 \sim b_4$  = Transformed coefficient

Unknown coefficient were calculated by least square method using GCP (x, y, z) and ICP (u, v).

### 5. GCP using Gravity Point in Polygon by Field Surveying using GPS

#### 5.1. Flow of Geometric Correction using Gravity Point in polygon

Figure 5.1 shows the flow of geometric correction using center of gravity in polygon (Fig 5.1). GCP polygons such as agricultural fields were surveyed by kinematic method of GPS. Table 5.1 shows specification of used GPS in this study. Then, a center of gravity in the polygon data was calculated. Some errors of GCP by field surveying will decrease by calculating center of gravity in the polygon. The calculated center of gravity in the polygon was used as GCP. ICP polygon image was extracted from the IKONOS image by visual interpretation. Then, a center of gravity was also calculated from the polygon image. The calculated a center of gravity in the image was used as ICP. Finally, geometric correction was carried out.

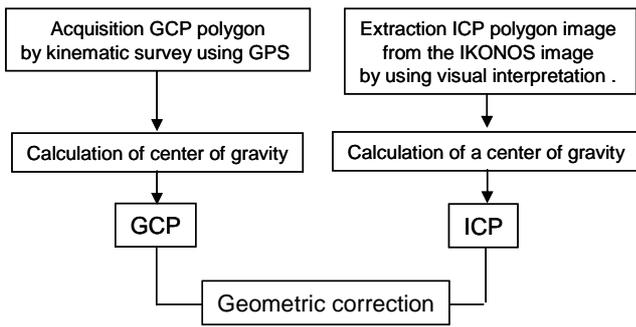


Fig 5.1 Flow of Geometric Correction using Center of Gravity Calculation

Table 5.1 Specification of Used GPS

Item	Detail
Maker	TOPCON
Name of an article	GP-SX1
Tracking channels	12 channels (parallel processing)
Tracking	L1 C/A code and L1 full-cycle carrier
<b>Accuracy</b>	
<b>Static Survey &amp; Quick Static Performance</b>	
Horizontal:	5mm + 1ppm (times baseline length) ( $\leq 10\text{km}$ ) 5mm + 2ppm (times baseline length) ( $> 10\text{km}$ )
Vertical:	10mm + 2ppm (times baseline length)
<b>Kinematic Survey</b>	
Horizontal:	20mm + 2ppm (times baseline length) (Cross dipole antenna: Standard accs.)
Vertical:	40mm + 2ppm (times baseline length) (Cross dipole antenna: Standard accs.)

## 5.2. Calculation Method of Center of Gravity in Polygon

### 5.2.1. GCP Polygon

Firstly, origin point  $(X_0, Y_0)$  was set temporally (Fig 5.2). GCP polygon data were divided into many small triangles using the origin point. A center of gravity  $(x_{gi}, y_{gi})$  in each triangulated area were calculated. Finally, a center of gravity in whole polygon can be calculated following equation.

$$X_g = X_0 + \sum_{i=1}^n S_i \times (x_{gi} - X_0) / \sum_{i=1}^n S_i \quad \dots \dots (5.1)$$

$$Y_g = Y_0 + \sum_{i=1}^n S_i \times (y_{gi} - Y_0) / \sum_{i=1}^n S_i$$

$(X_g, Y_g)$  : Center of gravity       $(x_{gi}, y_{gi})$  : Center of gravity       $S_i$  : Area of each triangle  
 $(X_0, Y_0)$  : Temporally origin      in each triangle       $n$  : Number of triangles

### 5.2.2. ICP Polygon

ICP polygon image were extracted from the IKONOS image by visual interpretation. ICP polygon image was binarized for calculating a center of gravity (Fig 5.3). A center of gravity was calculated average of all coordinates in GCP polygon image by following equations.

$$U_g = \sum_{i=1}^n U_i / n \quad \dots \dots (5.2)$$

$$V_g = \sum_{i=1}^n V_i / n$$

$(U_g, V_g)$  : Center of gravity       $(U_i, V_i)$  : Image coordinate       $n$  : number of pixel

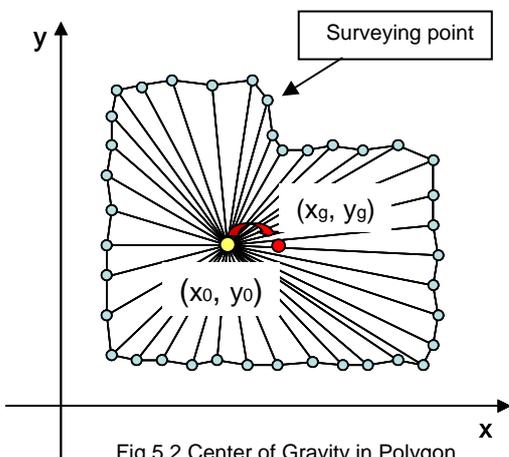


Fig 5.2 Center of Gravity in Polygon

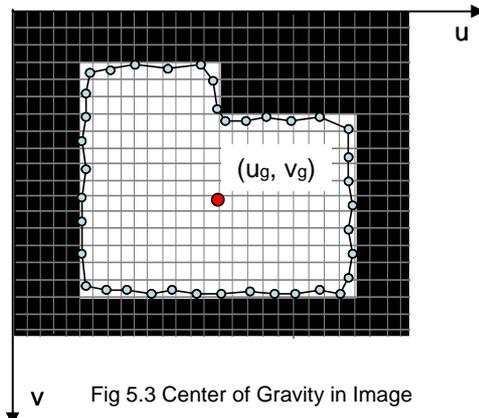


Fig 5.3 Center of Gravity in Image

### 5.3. Acquired GCP by Field Surveying

In this study 15 polygons for geometric correction were acquired. Fig 5.4 shows spatial distribution of polygons on IKONOS image. Fig 5.5 shows example of polygon data. All polygons were selected small unduration area. Difference of elevation in each polygon showed maximum 3.1m. The area of the smallest polygon was 9,023m<sup>2</sup>. At least 10,000 m<sup>2</sup> should be prepared (Miyata, 2004).



Fig 5.4 Spatial distribution of GCP polygon



Fig 5.5 Acquisition of GCP polygon

### 5.4. Result of Geometric Correction

The numbers of acquired GCPs were 15 points: 8 points were used for Geometric Correction and 7 points were used for validation. Table 5.2 showed RMSE in 3D affine transform. RMSE around GCPs showed less than 0.27 pixels. RMSE around validation points showed less than 0.56 pixels. Figure 5.6 shows error vectors of GCPs. Fig 5.7 shows error vectors of validation points.

Table 5.2 Error of Geometric Correction by 3D affine transform

RMSE ( pixel )	u	v
GCP	0.273	0.196
Validation point	0.559	0.390

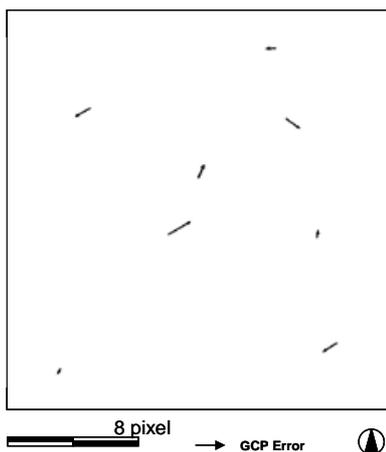


Fig 5.6 Error Vectors of GCP

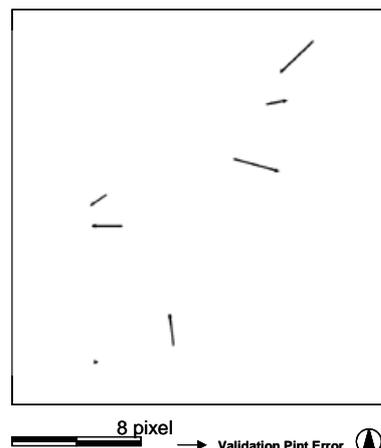


Fig 5.7 Error Vectors of validation point

## 6. GCP using Image Matching between Aerial Photograph and the IKONOS image

### 6.1. Geometric correction of the IKONOS image using image matching

Fig 6.1 describes the flow of geometric correction of the IKONOS image using image matching. Firstly, ortho image was established using aerial photograph and DSM. And, template image was generated from the ortho image. Finally, image matching was carried out by using the template image and IKONOS image to acquire GCPs.

Fig6.2 shows a sample of aerial photograph for image matching. This aerial photograph was taken on Oct 10, 1998. Acquisition data was 2 years and six month different from IKONOS image. This aerial photograph was scanned in 300dpi.

To carry out accurate geometric correction, more than 100 scenes should be prepared to cover whole IKONOS image. And, it was difficult to generate true ortho image because highly accurate DSM and GCPs dataset must be used. This is same situation as geometric correction for high-resolution satellite image.

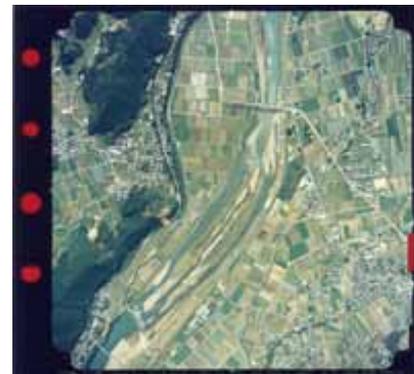
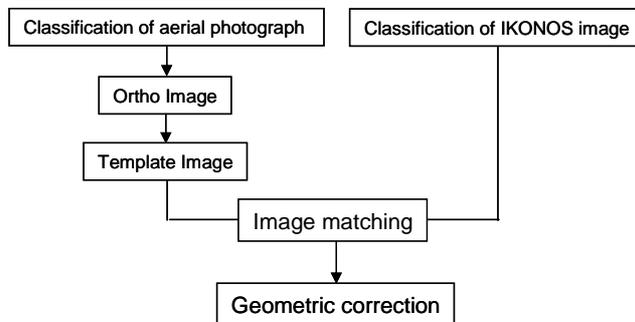


Fig6.1 Flow of Geometric Correction using Image Matching

Fig6.2 Aerial Photograph

## 6.2. Ortho Image

It was important to establish ortho image for image matching. Fig6.3 shows data used to generate an ortho image. In this study, GCP (x,y) were acquired from a map in 1:2500 scale. Elevation data were acquired from DSM with 1.0m resolution. DSM was generated from point based airborne laser data. The spatial resolution of laser data was about 1.0m. Ortho image was generated by using Direct Linear Transform (DLT) (Fig 6.4). The ortho image was resampled with 0.2m resolution. The ortho image was cropped around GCP polygon which was acquired by kinematic method of GPS for verification.

It was necessary to verify the geometric accuracy of the ortho image for image matching. Verification data was used center of gravity in GCP polygon. Firstly, a center of gravity in polygon image was calculated by GIS software. The center of gravity was compared with corresponded GCP acquired by field surveying. Table 6.1 shows verification result. Error in “v” axis shows large because the map in 1:2500scale did not have enough accuracy. Therefore, geometric correction could not be evaluated in this situation. In this study, possibility of image matching will be discussed.

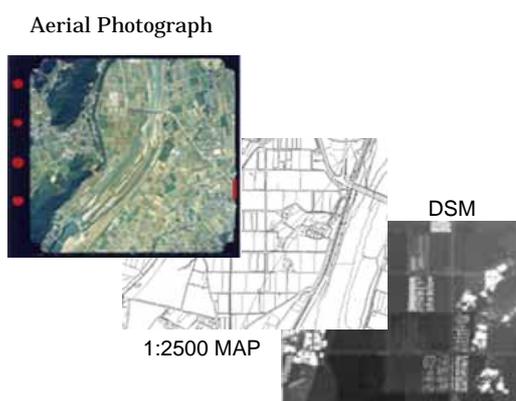


Fig 6.3 Data used data for generating Ortho image



Fig6.4 Generated Ortho image

Table 6.1 Verification of ortho image	
Error of Ortho image (Unit : m)	
Xg	Yg
0.17879	1.57691

### 6.3. Method of Image Matching

Template image for image matching was extracted from the ortho image. Spatial resolution of the ortho image was 0.2m. And the center of template image was corresponded to the center of gravity which was calculated from GCP polygon by kinematic GPS surveying. IKONOS image was also resampled in 0.2m resolution.

Correlation coefficient between template image and IKONOS image was calculated shifting “u” and “v” direction by following equation (6.1).

$$C_{ij} = \sum_{u=1}^m \sum_{v=1}^n \frac{(f(u,v) - f_{ave})(t(u,v) - t_{ave})}{\sqrt{f_s t_s}} \quad (6.1)$$

where

- $i$  = Column
- $j$  = Row
- $f(u,v)$  = target image ( $f$ ) of coulmn ( $u$ ) and row ( $v$ )
- $t(u,v)$  = template image ( $t$ ) of column ( $u$ ) and row ( $v$ )
- $C_{ij}$  = Correlation Coefficient
- $f_{ave}$  = Average of reflectance intensity from input image
- $t_{ave}$  = Average of reflectance intensity from template image

And, coordinate of the highest correlation were taken as GCP. So, coordinate of the highest correlation were compared with a center of gravity by ICP polygon image.

Fig 6.5 shows template image and corresponded IKONOS image. Land cover was much different between aerial photograph and IKONOS image. Therefore, the classified image was generated by normalized Euclidian distance form training data of road because road has no seasonal change. Fig 6.6 shows classified template image and IKONOS image.



Fig 6.5 Template Image and Corresponded IKONOS Image

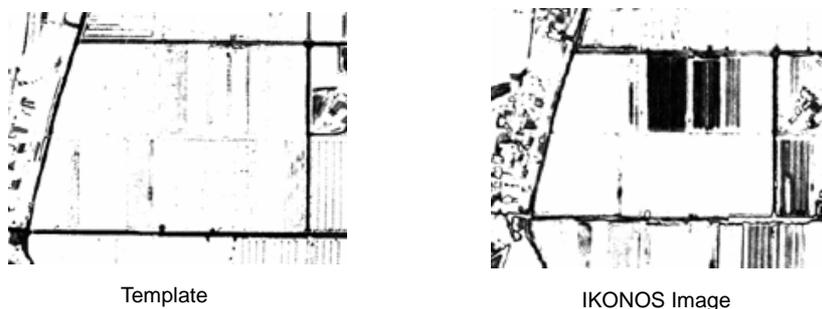


Fig 6.6 Classified Template Image and IKONOS Image

### 6.4. Matching Result

Table 6.2 shows the result of image matching using original color image and classified image. From Fig 6.7 to 6.8 shows correlation image in 3D view. The highest correlation coordinate ( $u, v$ ) were compared with calculated a center of gravity in ICP polygon image to calculate matching error. The original color image showed the big error. Image matching with classification image made reliable result rather than original color image.

Table 6.2 Result of Image Matching

	Correlation Coefficient	Highest correlation point		Error	
		u	v	u	v
Original Color image	0.07	5216.6	5427.0	14.06	0.189
Classification Image	0.08	5230.8	5427.0	0.139	0.189

Unit : pixel

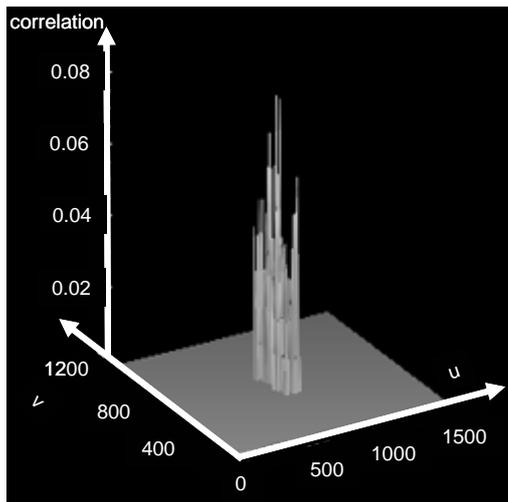


Fig 6.8 Correlation Image in 3D

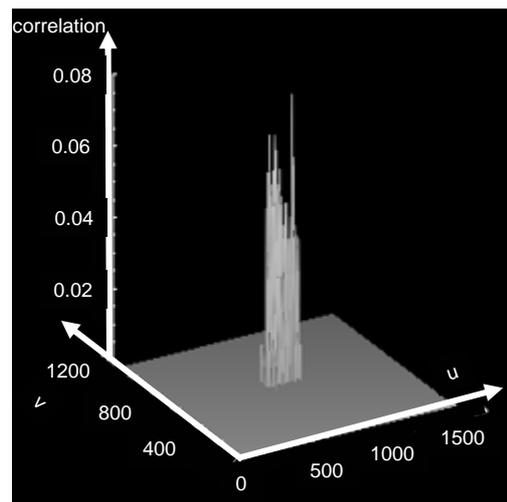


Fig 6.8 Correlation Image in 3D

## 7. Conclusions

In this study, two types of GCP for high-resolution satellite image were evaluated: one is gravity point calculation in polygon by field surveying using GPS and another is image matching with aerial photograph.

In case of GCP using gravity point calculation in polygon, RMSE showed less than 0.56 pixels. The gravity point calculation in polygon can be adapted for accurate geometric correction.

In case of image matching with aerial photograph, the original color image showed 0.07 correlation and 14.06 pixels error, for image matching. However, classification image can be adapted for image matching, which showed 0.08 correlation and 0.189 pixel error.

There are big problems in image matching because it is difficult to prepare accurate true ortho image. Higher resolution image is required for geometric correction of high-resolution image. However, the method was possible, but is not realistic in current condition.

## 8. References

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