IKONOS Stereo Matching with Land Cover Map for DEM Generation

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ABSTRACT

Various matching methods have been introduced by investigators to improve digital elevation model (DEM) accuracy of satellite imagery. This study proposed an area-based matching method according to land cover property using correlation coefficient of pixel brightness value between the two images for DEM generation from IKONOS stereo imagery. For this, matching line (where "matching line" implies straight line that is approximated to complex non-linear epipolar geometry) is established by exterior orientation parameters to minimize search area. The matching is carried out based on this line. Land cover classes are divided off into water, urban land, forest and agricultural land. Matching size is selected using a correlation-coefficient image in the four areas. The selected sizes are 81×81 pixels window, 21×21 pixels window, 119×119 pixels window and 51×51 pixels window in the water area, urban land, forest land and agricultural land, respectively. And hence, DEM is generated from IKONOS stereo imagery using the selected matching sizes and land cover map on the four types.

KEY WORDS: DEM, Area-based Matching, Land Cover Property, Matching Line, Matching Size

1. INTRODUCTION

Matching methods for digital elevation model (DEM) generation from satellite images have been generally utilized area based matching using a fixed patch size (Baltasavias et al, 1993; Reinartz et al, 2006). However, in case of high-resolution satellite imagery (HRSI), parallax appears differently due to terrain slope and land cover property is clearly different. The DEM accuracy in mountainous area and homogenous pattern areas (forest, water and agricultural land) therefore will be lowered if matching is performed using a fixed patch size.

This study proposed an area-based matching method according to land cover property using correlation coefficient of pixel brightness value between the two images for DEM generation from IKONOS stereo imagery. For this, matching line (where "matching line" implies straight line that is approximated to complex non-linear epipolar geometry) is established by exterior orientation parameters. The matching is carried out based on this line. Land cover classes are divided off into water, urban land, forest and agricultural land. Matching size is selected using a correlation-coefficient image in the four areas.

2. MATCHING USING LAND COVER MAP

2.1 Matching line establishment

The matching line is established using exterior orientation parameters (EOPs), which are determined from the proposed method by Lee and Ahn (2006). Equations 1 and 2 can be derived from traditional collinearity-based models. Details in relation to Equations 1 and 2 are described in a thesis of Morgan (2006) as follows:

$$Z = \left[\frac{B_5}{B_4}\right] \cdot l + \left[\frac{B_6}{B_4}\right] \tag{1}$$

$$x_i = \frac{E_4 + E_3 \cdot l}{E_1 + E_2 \cdot l} \tag{2}$$

where Z is height of the arbitrary point; B_4, B_5, B_6, E_1, E_2, E_3, E_4 are derived by the collinearity-based models and the EOPs; x_i is column number of image coordinates of the conjugate point in a stereo pair.

The matching line is assumed as straight line because of the characteristics of the HRSI. Inputting Z values of the minimum and maximum height in object area, image coordinates (x_i, l) can be computed as a solution of the Equations 1 and 2. An area based matching can be performed within the range of straight line, which is connected with two points of (x_i, l) corresponding to minimum and maximum heights and represents the locus of potential conjugate points in a stereo pair.

2.2 Matching size determination

For stereo matching each of land cover properties, land cover classes are divided off into water, urban land, forest and agricultural land. Matching sizes are selected by the highest average values of correlation-coefficient images in the four areas. The images can be generated by the performing the matching from the patch size 11×11 pixels to 195×195 pixels with 2 pixels spacing.

2.3 Matching using land cover map

To perform the matching of the four areas using the selected sizes, land cover map of the four classes is acquired by the supervised classification method from multi-spectral bands that took at the same time as stereo panchromatic bands of the HRSI. Stereo matching of the HRSI then are carried out by the selected matching size as the class of the land cover map

3. EXPERIMENTAL RESULTS

IKONOS stereo images, acquired in January 10, 2001 over Yangsan city, Gyeongsangnam-do, Republic of Korea, were used to test the proposed method (Figure 1). They are Geo-level panchromatic images of the Yangsan test field and cover an area of approximately 7×7 km^2.

Thirty points were measured by GPS surveying to acquire ground control and check points. Among the collected points, ten points were used as GCPs for determination of EOPs and others are used as check points (CHKs) for accuracy assessment of the EOPs as shown in Figure 1. The details of the images used are given in Table 1.

EOPs are determined from the proposed method by Lee and Ahn (2006). In order to validate the positioning accuracy of the EOPs, calculated ground positions for 20 CHKs were compared to ground coordinates measured in-situ. The RMS errors were ±0.722m, ±0.921m, and ±1.153m in X, Y, and Z coordinates and the maximum error did not exceed ±3m in each coordinate. The matching line was established by the EOPs.

Figure 2 shows matching lines of the first image corresponding to the GCP 1 for the second image. Consequently, the matching could be carried out based on a straight line model. Matching sizes of the four classes were selected by the highest average values of correlation-coefficient images. The selected matching sizes are 81×81 pixels window, 21×21 pixels window, 119×119 pixels window and 51×51 pixels window in the water area, urban land, forest land and agricultural land, respectively.

Table 1. Parameters of the IKONOS data sets used in this study

Image	First Image	Second Image
Collection Azimuth	18.5512°	187.2200°
Collection Elevation	73.345000°	74.40065°
Acquisition Date/Time	2001-01-10/02:06	2001-01-10/02:07
Image Size	7001 pixels × 7001 pixels	
Product Level	Geo	
Altitude/Pixel Size	681 kilometer/1 meter	
Datum/Map Projection	WGS84/UTM	

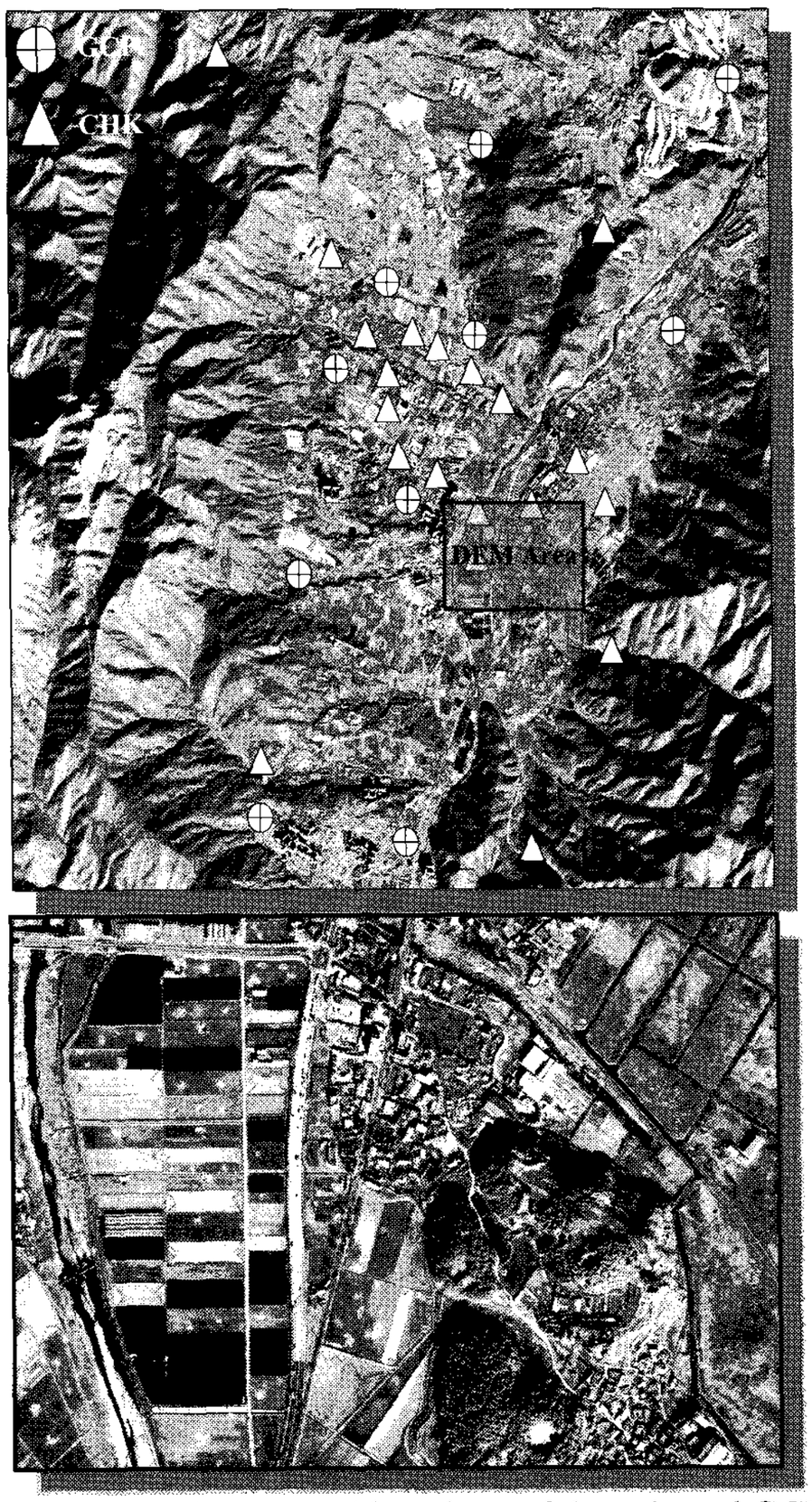

Figure 1. Study area and locations of the selected GCPs and CHKs in IKONOS image (top), and the target study site for DEM generation (bottom).

Figure 2. Linear matching line of the second image for GCP 1 of the first image.

The DEM was generated by the EOPs and the conjugated points, which are determined by stereo matching using the selected size with the class of the land cover map. Average of the height difference between the DEM by the proposed method and that of ERDAS IMAGINE software is 1.5 m.

This height difference of DEMs by the two methods is ranged within allowable average deviation. Figure 3 shows the two DEMs. The proposed method is consequently suitable for generating DEM using the HRSI.

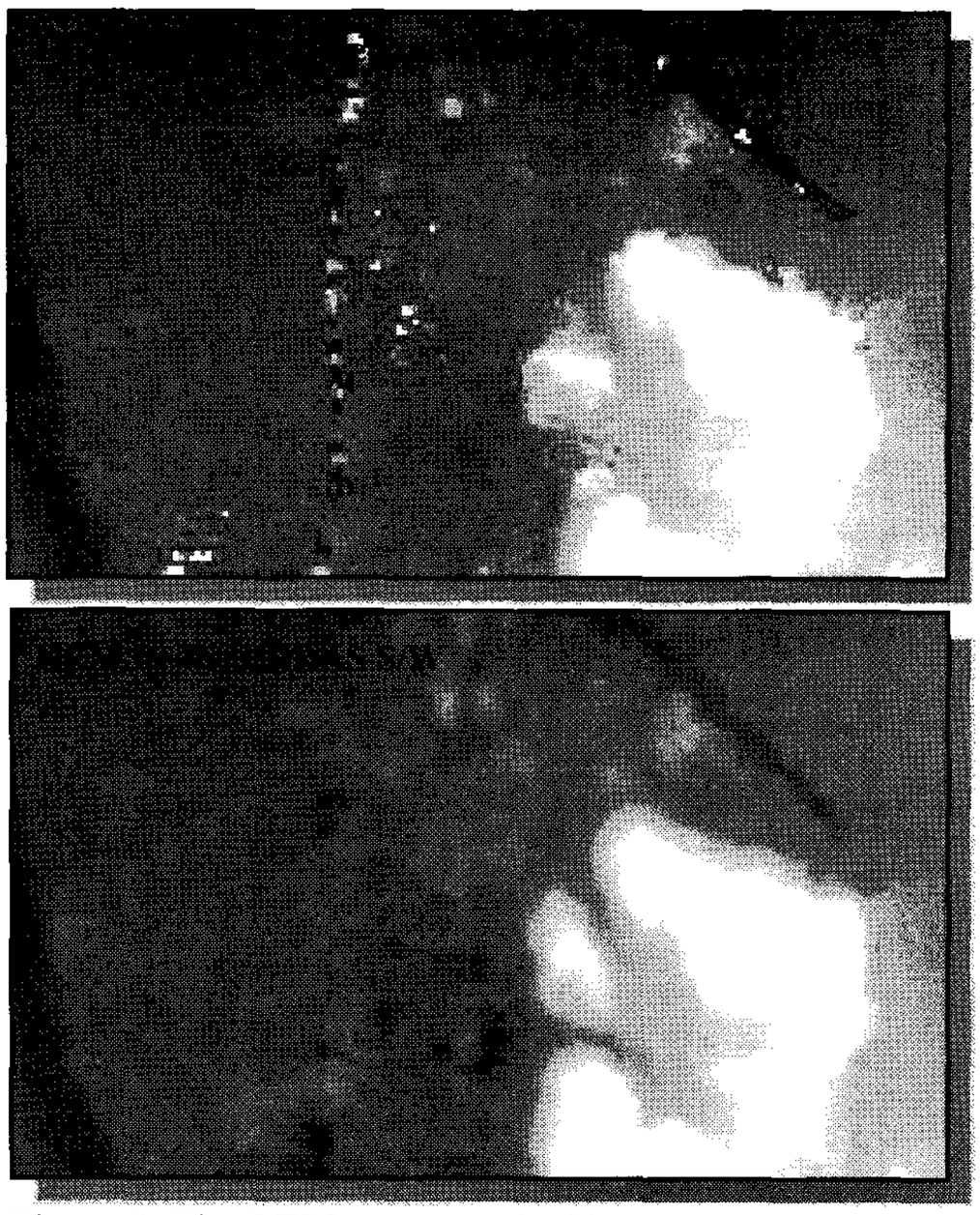

Figure 3. The DEMs generated with a 5 m spacing by the proposed method (top) and ERDAS IMAGINE software (bottom)

4. CONCLUSIONS

In this study, the authors have proposed an area-based matching method using the land cover map from IKONOS stereo imagery.

For this, matching line was firstly established by EOPs. Matching size was determined using a correlation-coefficient image in the four areas after land cover classes are divided off into water, urban land, forest and agricultural land. The determined matching size are 81×81 pixels window, 21×21 pixels window, 119×119 pixels window and 51×51 pixels window in the water area, urban land, forest land and agricultural land, respectively.

The DEM was generated by stereo matching using the selected size with the class of the land cover map. Average of the height difference between the DEM by the proposed method and that of ERDAS IMAGINE software is 1.5 m. The proposed method is consequently suitable for generating DEM using the HRSI.

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