

AUTOMATED UPDATE OF EXISTING ORTHO-IMAGE DATABASE AND DEM USING HIGH RESOLUTION SATELLITE IMAGES

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ABSTRACT:

The DEM (Digital Elevation Model) and ortho-image have been used in various fields such as 3D (dimension) map, 3D urban model, simulation, and so on. Today, users require more detail data but many existing DEMs and ortho-images have low spatial resolution. Meanwhile, high resolution satellite images such as QuickBird, IKONOS, KOMPSAT-2 images have appeared recently, so we propose the technique for automated update of existing DEMs and ortho-images database using high resolution satellite images. This method uses stereo images matching technique by GCPs (Ground Control Points) for DEM generation from satellite images. We automatically extracted GCPs from high resolution satellite images by matching satellite image against existing ortho-image and using DTED (Digital Terrain Elevation Data) Level 2 data (30m spatial resolution). We used the robust estimation, RANSAC (Random Sample Consensus), to minimize error of extracted GCPs. The tie-points for automatic stereo matching is extracted from stereo pairs using existing DEMs. We tried to generate accurate DEMs, which is DTED Level 3 (10m spatial resolution). We also made ortho-images from high resolution satellite images by existing DEMs and GCPs generated automatically. We applied our method to IKONOS, SPOT 5, QuickBird for test. The test result showed that automatic generation of DEMs and ortho-images was performed successfully. We could update DEM from DTED Level 2 to DTED Level 3 and we could update existing ortho-images using high resolution satellite images.

1. INTRODUCTION

Many researches have performed studies for generation of a DEM and an ortho-image. The DEM and the ortho-image have been used in various fields such as 3D map, 3D urban model, simulation, and so on. Recently, the interest on 3D map and urban model is increasing as they can be applied to many fields. In particular urban areas are changing rapidly, so this change has to be reflected to new 3D maps and models. Today, many satellite data are widespread by image maps such Google Earth. Users require more detail 3D data but many existing DEMs have low spatial resolution. Meanwhile, high resolution satellite images have appeared recently. These satellite images include Quickbird, IKONOS, KOMPSAT-2, SPOT-5 images and so on. In this paper, we propose the technique for automatic update of existing DEMs and ortho-images database using high resolution satellite images. This method uses existing DEMs and ortho-images for automatic processing. For DEM generation in this paper, we use stereo images matching technique by GCPs and tie-points from stereo satellite images. We can obtain GCPs by GPS survey, but this method needs many times or resources. We propose an algorithm to extract GCPs automatically from high satellite images by matching technique and existing DEM and ortho-image. For automatic GCP extraction the ortho-image was made by DTED data. We used the robust estimation algorithm, called RANSAC, to remove points of mis-match from the result. Our algorithm also extracts tie-points automatically using existing DEM and sensor model technique. For test, we used DTED Level 2 as existing DEM. This DTED Level 2 has 30 m spatial resolution. The ortho-image which we

used has 1 m spatial resolution. We applied our technique to IKONOS, Quickbird, SPOT-5 stereo pair. We applied DLT (Direct Linear Transform) (Kim and Im, 2003) for IKONOS stereo pair and orbit-attitude model (SPOT Image, 2002) for SPOT-5 and Quickbird stereo pairs. The stereo images matching technique which we use for DEM extraction and GCPs extraction is based on epipolarity and scene geometry (Lee et al., 2003).

For validation of proposed algorithm, we compared new DEM (DTED level 3) with existing DEM (DTED level 2) by visual inspection and by check points.

2. ALGORITHM DESCRIPTION

This section explains our algorithm. Our algorithm is divided three parts: automatic GCPs extraction, automatic DTED Level three data generation, automatic ortho-image generation. Total procedure is as follow (Figure 1)

First, proposed algorithm automatically extracts GCPs using satellite image, existing DTED level 2 and existing ortho-images. Extracted GCPs are used for DTED level 3 data generation from stereo pair automatically. To update ortho-image, the algorithm uses GCPs extracted, existing DTED level 2 and high resolution satellite images.

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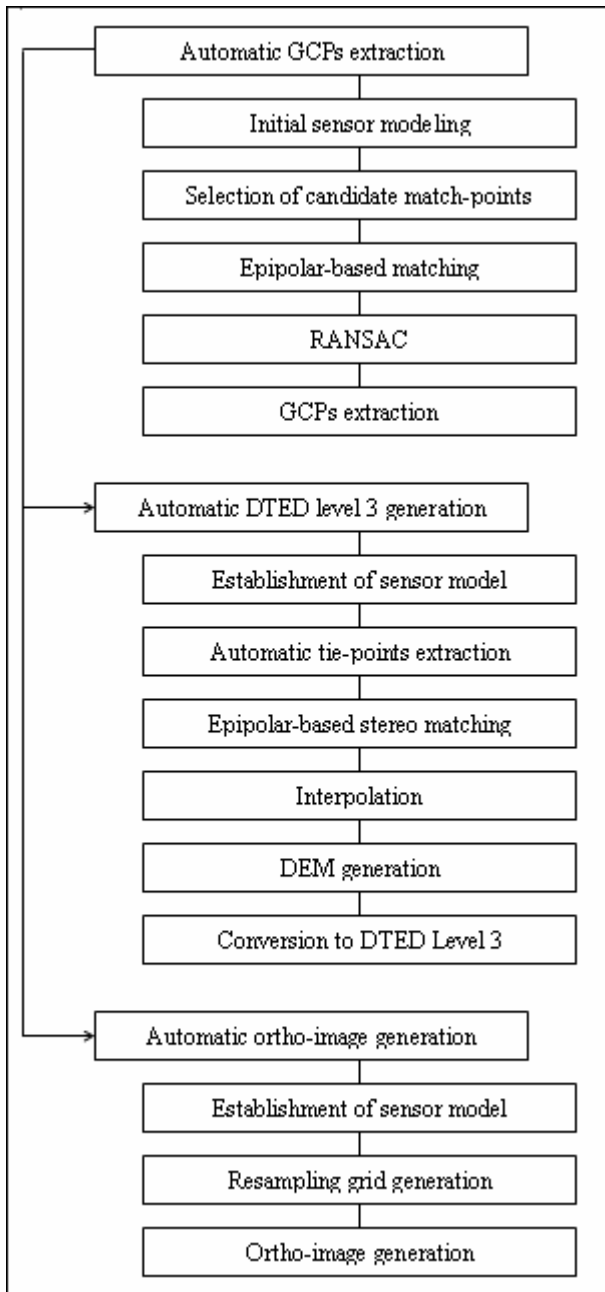


Figure 1. Total procedure of proposed algorithm

2.1 Automatic GCPs extraction

The proposed algorithm uses matching technique between satellite images and existing ortho-images for GCPs extraction. This algorithm makes many patch images to use as candidate match-point. In this step, we applied initial sensor model to satellite image for determination of search area. For initial sensor model, we use satellite metadata, which includes satellite orbit, attitude, and so on. We determined size of search area by the magnitude of established initial sensor model errors. In next step, the algorithm generates image pyramid for each image patch and then algorithm performs matching. We used Epipolar-based matching technique and zero mean normalized cross-correlation for matching step. After matching image patches against ortho-images, we can obtain planimetric coordinates (X and Y) values. The algorithm also uses existing DEM (DTED level 2) to obtain height values on surface

because we cannot know height from just ortho-images. Through this step, we can get GCP, i.e., image coordinates and corresponding surface coordinates(X, Y, Z). Next, we applied RANSAC to result of matching. RANSAC (Fischler and Bolles, 1981) is used to remove outlier (big error) from matching results. This robust estimation selects minimum control points for establishment of sensor model and then this RANSAC estimates model parameters. Error of total control points except for selected points is checked by the model established. The algorithm checks the number of supporting points, which have model errors smaller than predetermined threshold. This step is repeated and the algorithm chooses the model with largest supporting points. Finally the algorithm accepts the selected and supporting points for the chosen model as inliers and others as outliers. Through these steps, we can extract GCPs with small errors automatically.

2.2 Automatic DTED level 3 generation

This step is the procedure for DTED level 3 data generation. In the previous step, we obtained GCPs and therefore we establish sensor model for stereo matching. As sensor models, we use DLT for IKONOS image and the orbit-attitude model for SPOT-5 and Quickbird images. For stereo matching, tie-points are needed. This algorithm automatically determines tie-points using existing DEM (DTED level 2). Stereo matching begins from tie-points. These points indicate initial guesses for conjugate points on stereo pair. For each grid in the existing DEM, its corresponding image coordinates are calculated using the established sensor model. Next, this algorithm performs Epipolar-based stereo matching. Through this step, we obtain matching result, which includes 3D surface coordinates. For DEM generation from this matching result, interpolation is needed. This algorithm uses nearest neighbour interpolation method. Then the algorithm converts DEM to DTED format (NIMA, 1997; NIMA, 2000). DTED has been developed by the National Imagery and Mapping Agency (NIMA) for support of military applications. In this format, data is defined in coordinates of latitude, longitude and elevation (m). There are many DTED level 2 data (30 m spatial resolution) available world wide. This algorithm can make DTED level data more detail than DTED level 2. In this paper, we made DTED level 3 data from satellite stereo pair.

2.3 Automatic ortho-image generation

For ortho-image update, this algorithm automatically generates ortho-image from satellite image. For ortho-image generation, the algorithm uses GCPs, which are extracted from automatic GCPs extraction step, and the existing DEM. In this paper, we use DTED level 2 data as the existing DEM. Using GCPs extracted automatically, this algorithm establishes sensor model. For making ortho-images, inverse mapping is applied to all pixels of ortho-images to remove distortions due to height relief and to align the pixel with map coordinates.

3. TEST AND RESULT

3.1 Test data

In this paper, our algorithm was applied to IKONOS, Quickbird and SPOT-5 stereo pairs. We used DTED level 2 as the existing DEM and existing ortho-image made by DTED. Basic spec of DTED format is follow as (Table 1) and Figure 2 shows DTED level 2 data which we used for test.

As Table 1, DTED level 2 has 30 m spatial resolution and level 3 has 10 m spatial resolution. Horizontal Datum of all DTED data is WGS84.

Spatial resolution of satellite image is as follow: 1m (IKONOS), 2.5m (SPOT-5), 0.61m (Quickbird). Area of used satellite images is Daejeon.



Figure 2. DTED level 2 data used

Area of DTED level 2 data (Figure 2) is Daejeon, Korea.

DTED level	2	3
DTED size	1° x 1°	5' x 5'
Interval	1 x 1 seconds	0.4 x 0.4 seconds
Resolution	30 m	10 m
Absolute horizontal accuracy	90% Circular error WGS datum <= 23m	90% Circular error WGS datum < 10m
Absolute vertical accuracy	90% Linear error mean sea level <= 18 m	90% Linear error mean sea level <= 10 m
Horizontal Datum	WGS84	WGS84

Table 1. DTED spec[NIMA, 1997; NIMA, 2000]

In this paper, we used existing ortho-image for automatic GCPs extraction. Spatial resolution of this ortho-image is 1 m and datum is WGS84 and accuracy of the ortho-image is less than 25 m in 90% circular map accuracy standard WGS84.

3.2 Result of automatic GCPs extraction

We applied our algorithm to IKONOS, Quickbird, SPOT-5 images for GCPs extraction automatically. User has to select threshold value for error check in RANSAC. We determined that threshold is 20 pixels through testing. We also used DLT as a model for RANSAC. For validation of GCPs extracted by our algorithm, we used 10 check points, which is obtained by GPS

survey. The result of model performance by GCPs extracted automatically and check points is as follow (Table 2)

Satellite image		Number of GCPs	RMSE (pix.) by check points
IKONOS	Left image	19	5.1
	Right image	25	4.0
Quickbird	Left image	8	35.8
	Right image	7	60.3
SPOT-5	Left image	20	10.6
	Right image	11	18.9

Table 2. Performance of model by GCPs extracted

In table 2, the number of GCPs is the number extracted by RANSAC. In IKONOS case, RMSE is about 4~5 pixels, but RMSE of Quickbird and SPOT-5 is high. The cause of high errors for Quickbird and SPOT-5 is under investigation. Nevertheless the IKONOS case indicates the possibility of automatic extraction of GCPs.

3.3 Result of automatic DTED level 3 generation

We generated DEM from IKONOS, Quickbird and SPOT-5 stereo pair. Figure 3, 4, 5 shows a part of DTED level 3 generated from each satellite stereo pair.



Figure 3. IKONOS DTED level 3

In IKONOS case, GCPs extracted automatically was used for automatic DEM generation. However GCPs by GPS survey was used for Quickbird and SPOT-5 stereo pair because accuracy of GCPs extracted automatically was very low.

Through figure 6, we can check that DTED level 3 shows more detail surface and man-made objects than the existing DTED level 2 does. Table 3 shows RMSE of DTED level 3 data generated by proposed algorithm. We used the existing DTED level 2 data as reference DEM. So this RMSE was calculated by comparing height between the existing DTED level 2 data and DTED level 3 data by our algorithm, but grids of DTED level 2 data and DTED level 3 data correctly aren't correspond, so we



Figure 4. Quickbird DTED level 3

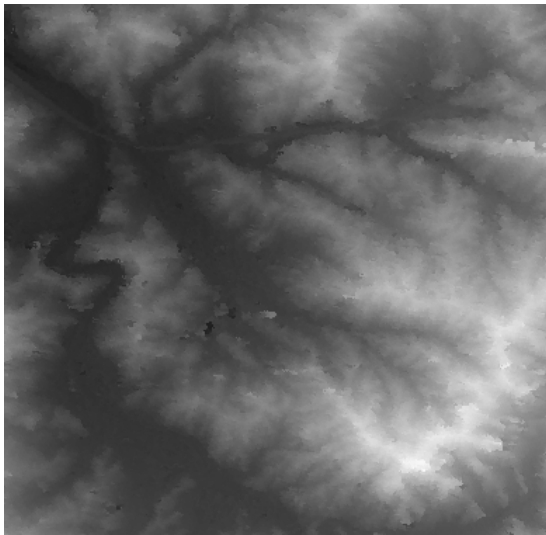


Figure 5. SPOT-5 DTED level 3

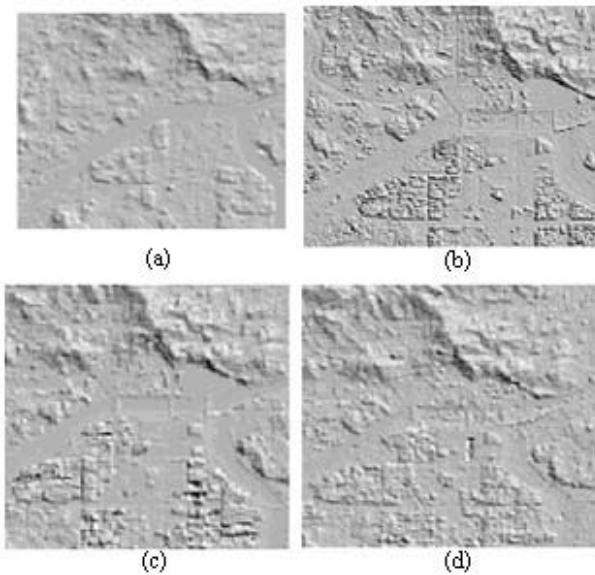


Figure 6. DTED level 2(a) and DTED level 3 (b: IKONOS, c: Quickbird, d: SPOT-5)

used bilinear interpolation for comparison. We can check that RMSE of DTED level 3 data generated by our algorithm is 13~15 m. RMSE of DTED level 3 data by GCPs extracted automatically from IKONOS is 9 m. This shows that accuracy DTED level 3 can be generated using GCPs extracted by our algorithm automatically.

Sensor	IKONOS	Quickbird	SPOT-5
RMSE (m)	9	13	15

Table 3. Accuracy of DTED level 3 generated

3.4 Result of automatic ortho-image generation

We generated ortho-images from IKONOS, Quickbird and SPOT-5 image using existing DTED level 2. Figure 7 shows a part of SPOT-5 image and ortho-image from SPOT-5 image by our algorithm. New ortho-images which we generate from IKONOS and Quickbird image have 1 m resolution and SPOT-5 ortho-image has 5 m resolution. For ortho-image generation, sensor model was established by GCPs. Table 4 shows sensor model errors. In table 4, sensor model of IKONOS used GCPs extracted automatically. Sensor model errors established were 1~2 pixel (RMSE).

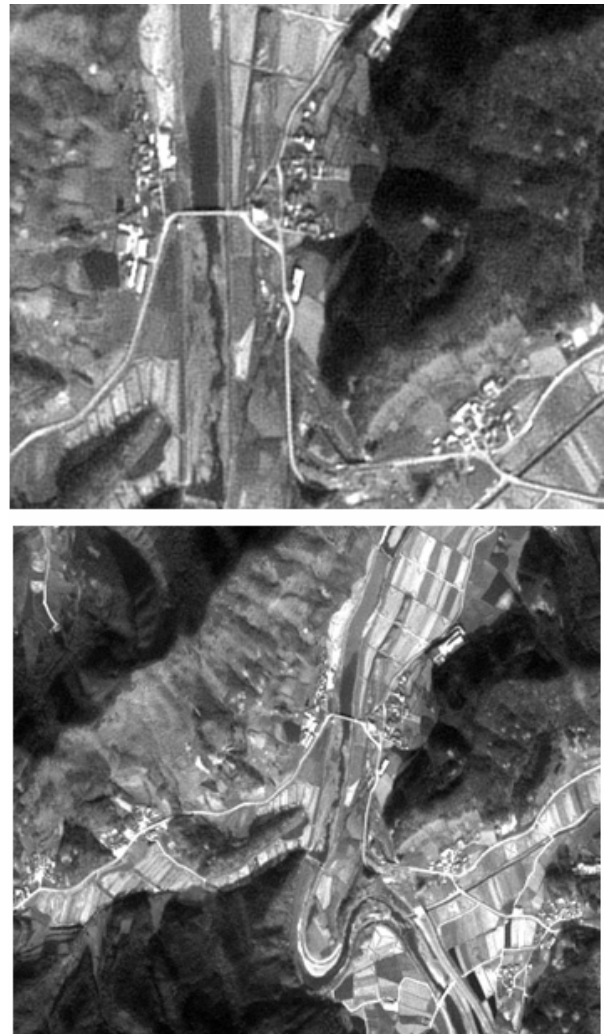


Figure 7. A part of satellite image(up) and ortho-image(down)

Satellite Type	RMSE (pixel)
IKONOS	1.5
Quickbird	1.9
SPOT-5	0.9

Table 4. Sensor errors in each image for ortho-image

Table 5 shows RMSE about distance between reference ortho-image and new ortho-image generated by our algorithm from each image type. We used the existing ortho-image as reference ortho-image. Table 5 shows that Quickbird ortho-image is comparatively accurate. RMSE of ortho-image from IKONOS image is bigger than RMSE of ortho-image from Quickbird because model performance for IKONOS image is low (Table 2).

Satellite Type	IKONOS	Quickbird
RMSE (m)	14.53	3.49

Table 5. New ortho-image accuracy from each images

However, considering the model performance of IKONOS image using GCPs extracted automatically, RMSE of IKONOS ortho-image shows that IKONOS ortho-image has enough accuracy.

4. CONCLUSION

In this paper, we proposed algorithm for update of DEM and ortho-image using existing DEM and existing ortho-image automatically. Proposed algorithm was applied to IKONOS, Quickbird, SPOT-5 stereo pair. Automatic GCPs extraction could be applied to IKONOS image. In IKONOS image case, RMSE was 4~5m in model by GCPs automatically extracted by existing DTED level 2 and matching between IKONOS image and existing ortho-image. Through automatic DTED generation, we could generate DTED level 3 data from satellite stereo pair using existing DTED level 2. We checked that DTED level 3 data shows more detail surface and building shape than existing DTED level 2. Finally we generated new ortho-image which has 1 m resolution using existing DTED level 2. These test results show that proposed algorithm can generate new DTED

level 3 and ortho-image from high resolution satellite data using existing DEM and ortho-image. However a part of automatic GCPs extraction has to improve for accuracy GCPs extraction for Quickbird and SPOT-5.

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