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GENERATION OF DIGITAL ORTHOPHOTOS FROM IKONOS GEO IMAGES

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ABSTRACT: Due to its high spatial resolution, IKONOS imagery has the highest potential in large-scale topographic mapping among other resources satellites currently available. The orthorectification for IKONOS images is thus an important task. Since the raw image data would, in general, not be provided by the satellite company, we propose a method to perform the rectification for IKONOS GEO images. The proposed scheme includes following steps:(1) correction of relief displacement for GCPs, (2) performing affine transformation between the ground coordinate system and the image coordinate system, (3)performing back projection for each pixe l in the orthoimage, (4) using DTM to calculate the relief displacement for the pixel in the previous step, and (5) image resampling. Experimental results indicate that the generated orthoimage may reach an accuracy of 2m.

1. INTRODUCTION

The generation of orthophotos from remotely sensed images, such as aerial photos, satellite images, and airborne scanning images, is an important task for various remote sensing applications. Employing this geometrical rectification, the image can be correctly geocoded. Due to its high spatial resolution, IKONOS imagery has the highest potential in large-scale topographic mapping among other resources satellite images currently available. The orthorectification for IKONOS images is thus an important task.

The digital rectification required to generate an orthoimage from an image may be accomplished in two ways. The first is the Anchorpoints method (Mayr and Heipke, 1988). In this method, a set of ground control points (GCPs) (i.e., the anchorpoints), are collected at locations which can be identified on both the image and on a corresponding map. Once enough GCP samples have been collected, the image coordinates are modeled as functions of the map coordinates using the least-squares method to fit low-order polynomials to the data(Jensen, 1986). For each pixel on the orthoimage, which has the same coordinate system as the map, the grey value is determined by locating the corresponding image position on the raw image followed by resampling. The method may be performed globally or locally. The advantage of this method is that it is computationally fast (Mayr and Heipke, 1988). However, high frequency image distortions due to terrain relief can be rigorously compensated for only when extremely dense GCPs are available.

Tao et al. (2000) proposed a Rational Function Model (RFM) to correct for IKONOS images. The RFM uses a ratio of two polynomial functions to compute two dimensional image coordinates from three dimensional ground coordinates. It is reported that the RFM may reach a high accuracy. While a large number of ground control points are needed.

The second approach is the rigorous solution and is called the Pixel-by-Pixel approach (Mayr and Heipke, 1988). This approach considers the three dimensional (3D) ground surface variations. Specifically, the associated DTM is utilized in the orthoimage generation. The correspondence between an image pixel and the conjugate ground element is characterized by the collinearity condition for central perspective images. In principle, there are two ways to do this. The first method, which is called the Direct or the Top-Down method, starts from the image space and projects each image pixel onto the object surface (Mayr and Heipke, 1988). This method is also known as Ray-Tracing method (O'Neill and Dowman, 1988). Conversely, it is possible to do the opposite, i.e., the Indirect or the Bottom-Up method (Chen amd Lee, 1993; Mayr and Heipke, 1988; Wiesel, 1985). Starting from the object space, each ground element is projected onto the image space. The grey value of a ground element on the orthoimage is then resampled using the projected location and its neighboring pixel values on the raw image.

The most rigorous approach for generating orthoimage from IKONOS is to model the orientation parameters using bundle adjustment followed by a Pixel-by-Pixel approach. However, the raw image data would in general, not be provided by the satellite company. Thus, the rigorous solution would be impractical. Thus, we propose a method to perform the rectification for images with lowest processing level, i.e., GEO.

A GEO image is the one with system correction and is georeferenced with UTM coordinate system. It is claimed that the horizontal accuracy is better than 20m without using any ground control points (IKONOS, 2001). This high precision is because that both of the orbital parameters and the attitude data, observed by GPS and Star Tracker respectively, are with high precision. In addition, the field of view (FOV) of the satellite is very small, i.e. $< 1°$. Thus, the residual displacements of tilt part after system correction may be assumed linear.

2. THE PROPOSED SCHEME

The proposed scheme includes following steps: (1) correction of relief displacement for GCPs, (2) performing affine transformation using GCPs, (3) back projection and compensation for relief displacement, and (4) image resampling.

2.1 Correction of Relief Displacement

After tilt correction, a GEO image is almost equivalent to a vertical image. Thus, computation for relief displacement may be done by using Azimuth and Elevation of satellite included in the metadata. Referring to fig. 1, target A has an height of H. The relief displacement for point A is L when the satellite has an elevation angle EL. The calculation of L may be done by eq. 1. Given an Azimuth, AZ, the two components of the displacement E and N may be determined by eq. 2.

$$L = H / \tan EL \qquad \text{(eq. 1)}$$

$$\Delta E = L \cdot \sin AZ \;\; ; \;\; \Delta N = L \cdot \cos AZ \qquad \text{(eq. 2)}$$

2.2 Performing Affine Transformation

It has been discussed in the preview section that the tilt displacement of GEO images may be assumed linear. Thus, an affine transformation may be applied to compensate for the displacement using GCPs. Thus, the ground coordinates for GCPs after corrections for relief displacement are suitable for the affine transformation. Notice that the correction for relief displacement is still influenced by the residual tilting errors. However, it is a sort of second order error and might be ignored.

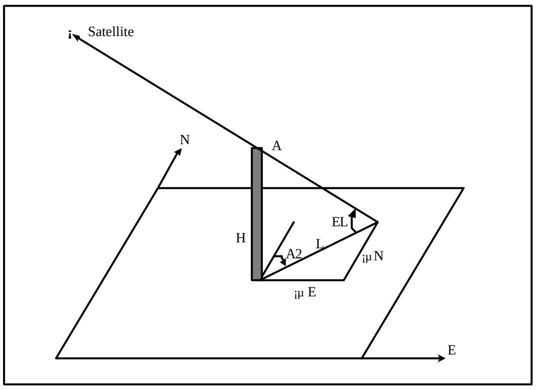

Fig. 1 Illustration of Relief Displacement

2.3 Back Projection and Compensation for Relief Displacement

Referring to fig. 2, the generation of an orthoimage is to fill in appropriate grey value for each of the output image. Point P for instance, it corresponding height, H, may be determined in a DTM. According to the Elevation and Azimuth of the satellite, the two components of E’ and N’ may be determined by eq. 1 and eq. 2. Using the coefficients of affine transformation derived in the previous section, we may determine the corresponding location i.e.,P’ for P. Including E and N, we may determine the location of P”. Which is the right location to select for the grey value to fill in point P.

2.4 Image Resampling

Referring also to fig. 2, we need to resample the grey value for point P”. The next step is to fill the resampled value into pixel P of the output image. The process is done pixel by pixel until the area of interest is complete.

3. EXPERIMENTAL RESULTS

The experiment includes tests of the proposed method for Orthophoto generation from an IKONOS GEO panchromatic image. The image was sampled on Oct. 09, 2001 with a 59.70793°elevation angle and 142.6061° azimuth. The image covers city of Tai-Chung in central Taiwan with an area of 11km * 11km as showen in fig. 3. Total number of 49 ground points, including GCPs and check points, were measured from 1:1000 scale topographic maps. The planimetric accuracy of the maps is better than 0.5m. The DTM used in the orthorectification was acquired from the Topographic Data Base of Taiwan. The pixel spacing of DTM is resampled from 40m to 1m. Fig. 4 illustrates the terrain variation. The elevation ranges from 30m to 160m.

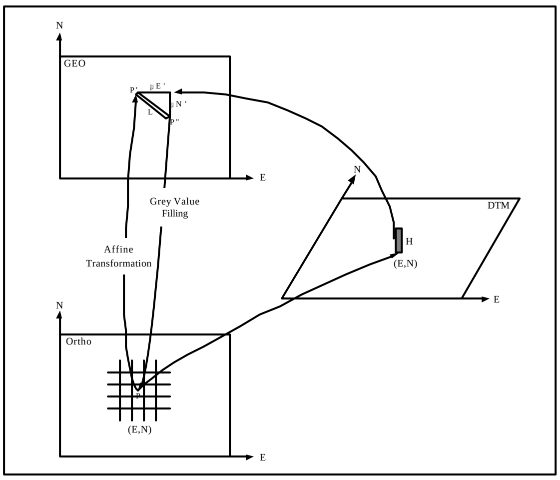

Fig. 2 Illustration of Orthorectification Procedure

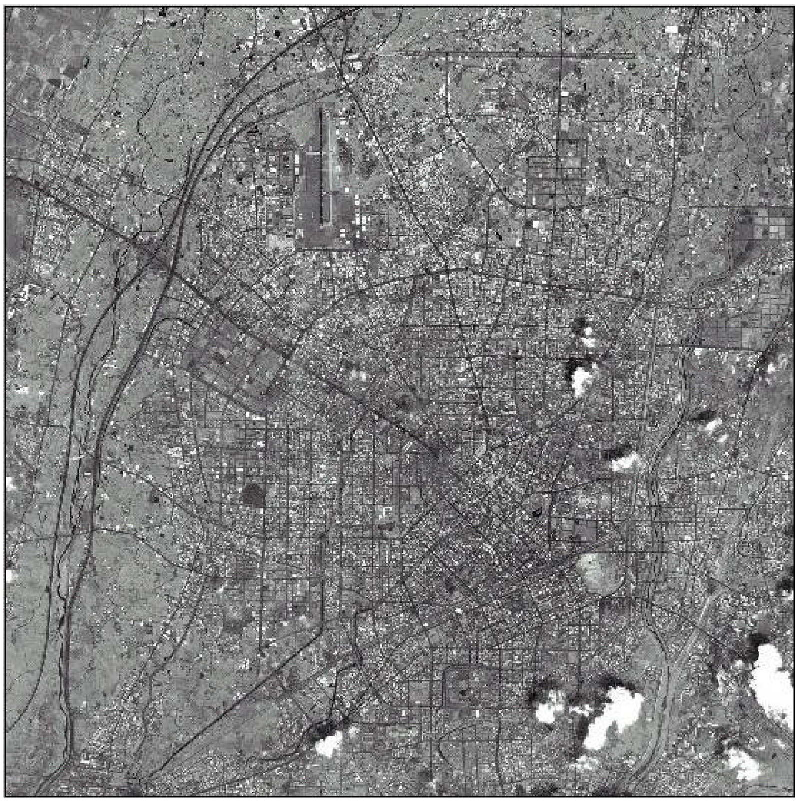

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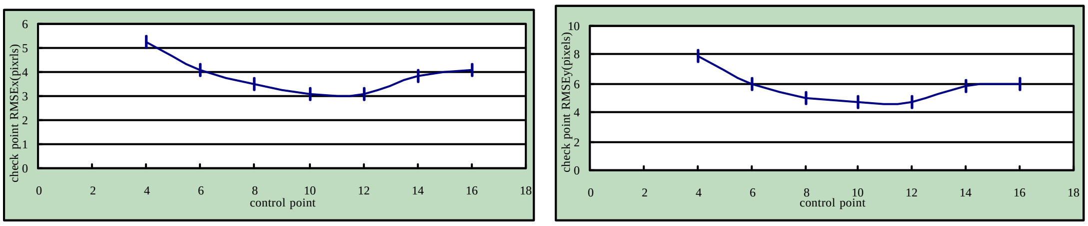
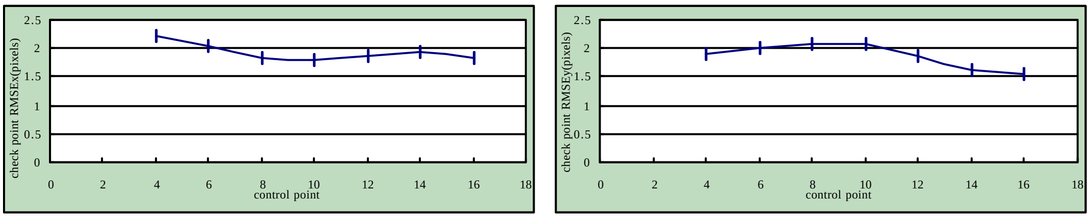
Fig. 3 The Test Image

Fig. 4 The DTM Used in Orthorectificate

fig. 5(a) depicts the RMSEs of check point when different numbers of GCPs are used. It is observed that a limit amount of GCPs may reach an result with high accuracy. As a comparison, fig. 5(b) depicts the RMSEs of check points with respect to different number of GCPs when relief displacements are not compensated.



(a)



(b)

Fig5 RMSE for Check Points:(a)After Correction for Relief Displacement

(b)Without Correction for Relief Displacement

The generated orthoimage using eight GCPs is shown in fig. 6. Where boxes represent the locations of check points. The error vectors are illustrated in fig. 7. The RMSEs of check points are 1.8m and 1.9m for E and N respectively. It is observed that the RMSEs are similar to that of the check points as shown in fig. 5.

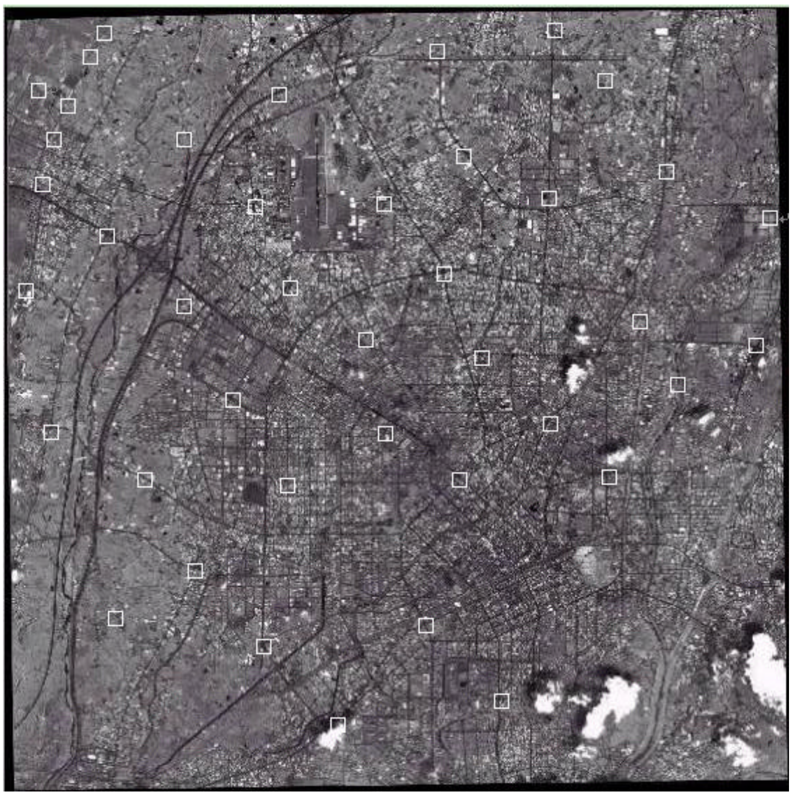


Fig. 6 Generated Orthophoto and Check Points

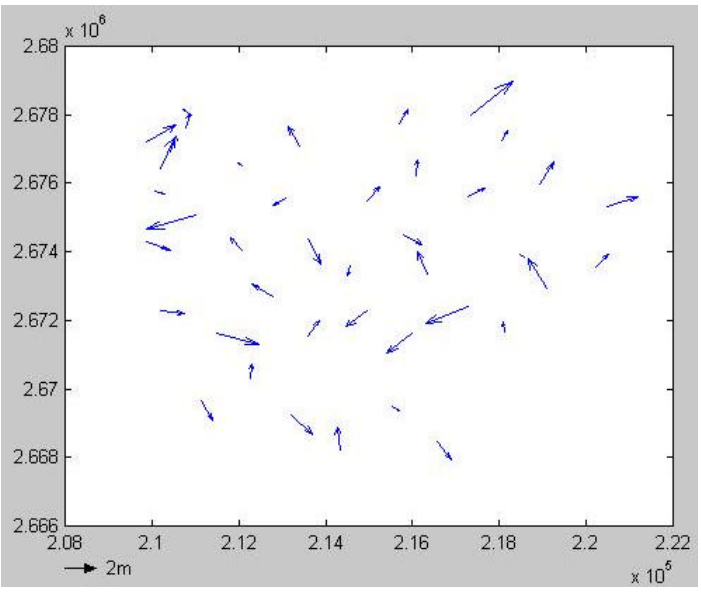


Fig. 7 Error Vectors for the Generated Orthophoto

4. CONCLUDING REMARKS

A method for generating orthophotos from IKONOS GEO images is given. A accuracy of 2m may be reached by the proposed method. This demonstrates a combination of (1) correction for relief displacement and (2) fine tune for tilt displacement by affine transformation might be appropriate. The proposed method is pretty straight forward. Thus, it would be easy to implement for future developments.

REFERENCE

Chen, L.-C., and Lee, L.-H., 1993. Rigorous Generation of Digital Orthophotos from SPOT Images, Photogrammetric Engineering & Remote Sensing, vol. 59, No. 5, pp.655-661.

IKONOS, 2001. http://www.spaceimaging.com/aboutus/satellites/IKONOS/ikonos.html

Jensen, R. J., 1986. Introductory Digital Image Processing, Prentice-Hall, Englewood Cliffs, New Jersey, 379 P.

Mayr, W., and Heipke, C., 1988. A Contribution to Digital Orthophoto Generation, International Archives of Photogrammetry and Remote Sensing, Kyoto, Japan, 27(B11):IV430-IV439.

O'Neill, M. A., and Dowman, I. J., 1988. The Generation of Epipolar Synthetic Stereo Mates for SPOT Images Using a DEM, International Archives of Photogrammetry and Remote Sensing, Kyoto, Japan, 27(B3):587-598.

Tao, C. V., and Hu, Y., 2000. Image Rectification Using a Generic Sensor Model – Rational Function Model. Int. Archives of Photogrammetry and Remote Sensing, vol. XXXIII, Part B3. Amsterdam. Pp.874-881.

Wiesel, J. W., 1985. Digital Image Processing for Orthophoto Generation, Photogrammetria, 40(2):69-76.