The Generation of True Orthophotos from IKONOS GEO Images

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ABSTRACT

The focus of this investigation is performing the geometric correction for the IKONOS satellite images. Since raw image data would, in general, not be provided by the satellite company, we have developed a method that performs the rectification of IKONOS GEO images. We also considered the occlusions caused by terrain and buildings, thus, the generated orthoimages will be called the “True Orthoimage”.

The first part of the proposed scheme includes the following steps: (1) the correction of relief displacement for GCPs, (2) the performing of two dimensional transformation between the ground coordinate system and the image coordinate system, (3) the performing of back projection for each pixel in the orthoimage, (4) the use of DTM to calculate the relief displacement for the pixel in the previous step, and (5) image resampling. Then, the relief corrections for buildings and occlusion process will also be handled toward generation of true orthoimage when building models are available. The experimental

results indicate that the generated orthoimages, including the ones by using DTM and the one considering building effects may reach an accuracy of better than 2 pixels when 6 GCPs were employed.

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 mapping applications. High-resolution satellite imagery, such as IKONOS, has a high potential for large-scale topographic mapping. Urban planning, for instance, the imagery has been widely used in extraction of necessary feature information (Kuo et al. 2001; Park and Kim 2001). Orthorectification for IKONOS images is thus an important task.

Theoretically, the most rigorous approach for generating an orthoimage from satellite images is to model the orientation parameters first, followed by a Pixel-by-Pixel approach. (Mayr and Heipke, 1988; O'Neill and Dowman, 1988; Wiesel, 1985) However, the raw image data from an IKONOS satellite would, in general, not be provided by the satellite company, so this rigorous solution would be impractical. Therefore, we propose a method that performs image rectification using the lowest possible processing level, i.e., GEO. GEO is also the most popularly used type of image in the IKONOS data family.

It is that claimed the GEO images have horizontal accuracy better than 20 m without the use of any ground control points (IKONOS, 2001). This high precision can be achieved because both the orbital parameters and the attitude data observed by the GPS, INS, and the Star Tracker, respectively, are highly precise. In addition, the field of view (FOV) of the satellite is very small, i.e. < 1°. Thus, any residual displacement of the tilt part after system correction may be assumed to be linear.

Considering the relief displacements and hidden effects caused by buildings, we consider building models as a part of input data. The generated orthoimages are called "true orthoimages".

2. THE PROPOSED SCHEME

Two major parts are included in the proposed scheme. The first one is similar to the pixel-to-pixel approach where digital terrain models are employed. The second part treats the building effects. The flowchart of the proposed scheme is shown in figure 1.

2.1. Orthorectification Using DTM

As stated in Chen et. al (2002), we include four major steps in this stage when DTMs are employed. Procedurally, they are (1) the correction of relief displacement for GCPs, (2) the performing of affine transformation using GCPs, (3) back projection and compensation for relief displacement, and (4) image resampling. The generated product is a traditional orthoimage. A true orthoimage may be derived by further processing.

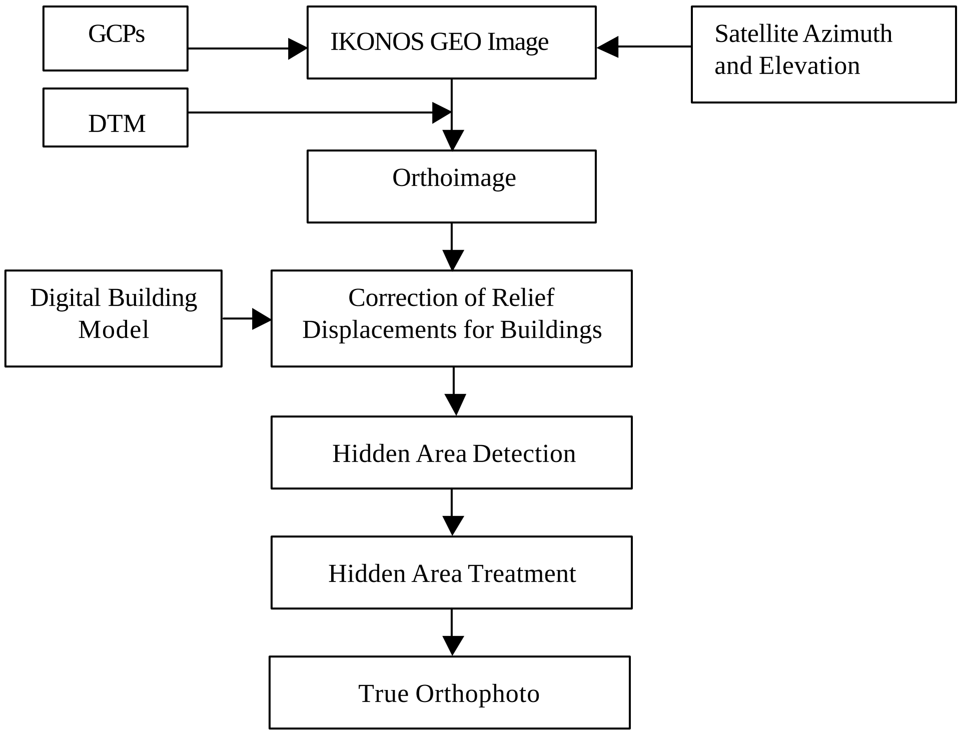

Figure 1. The Flowchart of the Proposed Scheme

2.2. Treatment For Building Effect

The treatment for building effect includes the following two steps: (1) the detection of hidden areas and (2) relief displacement correction of buildings.

2.2.1. Detection of hidden areas

Since the processed image has already orthorectified using the digital terrain model. The remaining relief displacement comes from the buildings. The detection of hidden area must consider both the roof and the vertical walls. So, a Digital Building Model (DBM) is necessary for true orthorectification. From the DBM, we can detect the location of buildings and discriminate them as roofs and walls. By means of the z-buffer technique [Rau, et al, 2002], we can detect the location of hidden areas for the buildings. The z-buffer stores the distance between the satellite and the object point. Figure 4 illustrates the detection of hidden areas for the vertical walls. In which, a number of pseduo groundel is introduced to calculate the distance. The number of pseduo groundel is depended on the satellite viewing elevation and the height of buildings. Object with longer distance is denoted as hidden areas. For example, in figure 2, object Y is occluded by the roof corner X. The detected hidden areas are filled with blank due to no information can be used for compensation when single image is utilized.

2.2.2. Relief displacement correction of buildings

Relief displacement correction for buildings is same as the orthorectification procedure. The height of building comes from the DBM instead of a DTM.

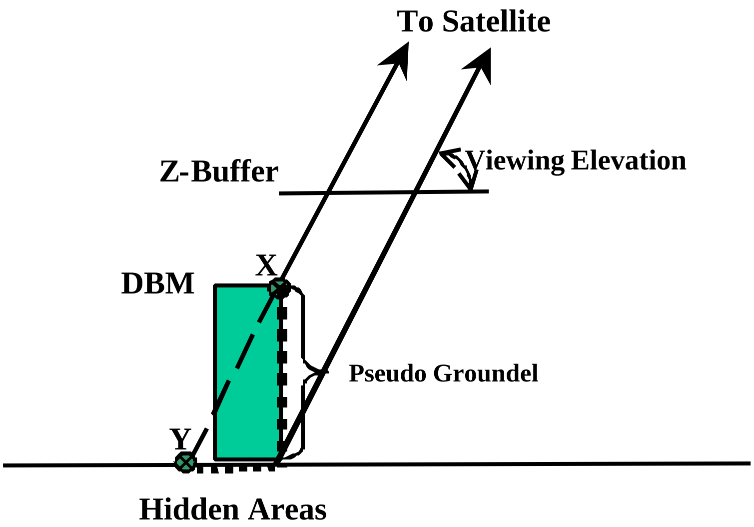

Figure 2. Illustration of Detection for Hidden Areas

3. EXPERIMENTAL RESULTS

The test case targeted Tai-chung city in central Taiwan. Ground control points and check points were measured from 1:1,000 scale topographic map sheets. The planimetric accuracy of the maps was better than 0.3 m in the one-sigma level. The DTMs were acquired from the Topographic Data Base of Taiwan. The pixel spacing of the DTM was resampled from 40 m to 1 m. The test image shown in figure 3 was sampled on Oct. 09, 2000 with a 59.70793°elevation angle and a 142.6061°azimuth angle. Thus, the original pixel resolution was 1.1 m. A total of 49 ground points, including 6 GCPs and 43 check points, were measured. Figure 4 illustrates the terrain variations. The elevation ranges from 30 m to 160 m.

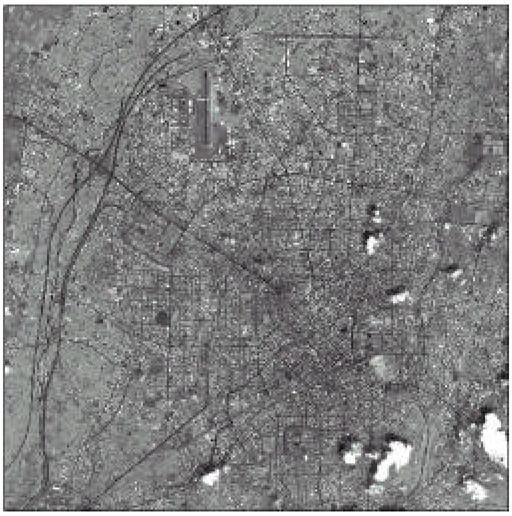

Figure 3. The Test Image

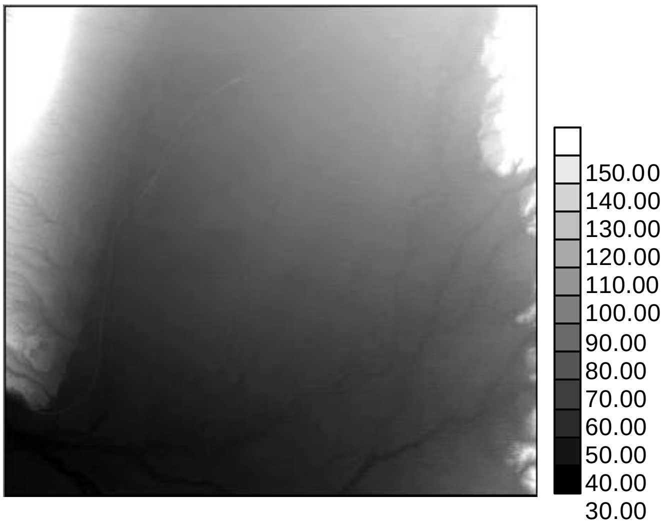

Figure 4. The DTM Used for

3.1. Tests Of Orthorectification

The orthoimage generated using six GCPs is shown in Figure 5. The 43 boxes represent the locations of the check points. The error vectors are illustrated in Figure 6. The RMSEs of the check points are 1.6 m and 2.1 m for E and N, respectively.

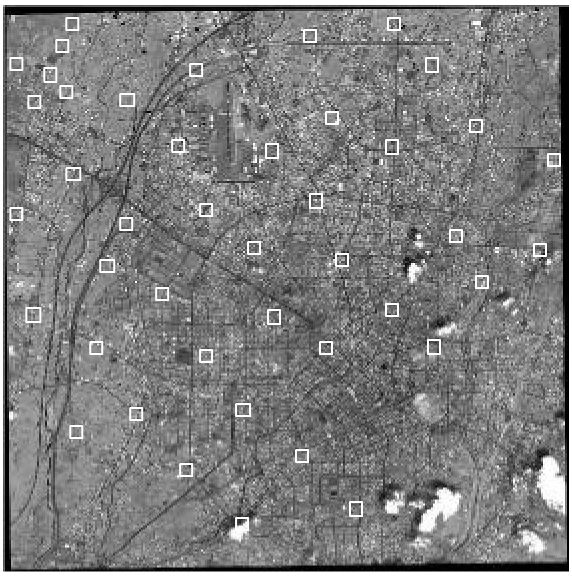

Figure 5. Generated Orthophoto and Check Points

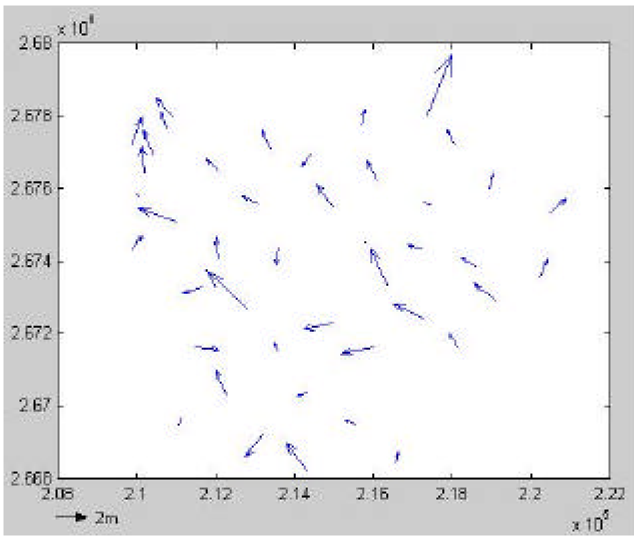

Figure 6. Error Vectors for the Generated Orthophoto

3.2. Tests Of True Orthorectification

Figure 7 represents the test area for generation of true orthoimage. Figure 8 illustrates the building model in the test. The building height ranges from 5m to 52m.

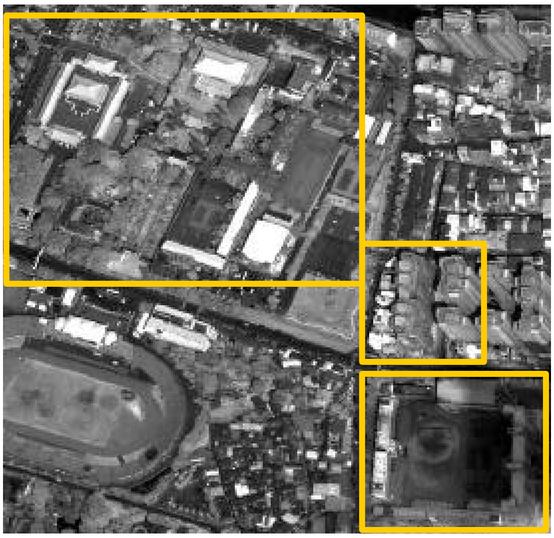

Figure 7. Test Area for True Orthorectification

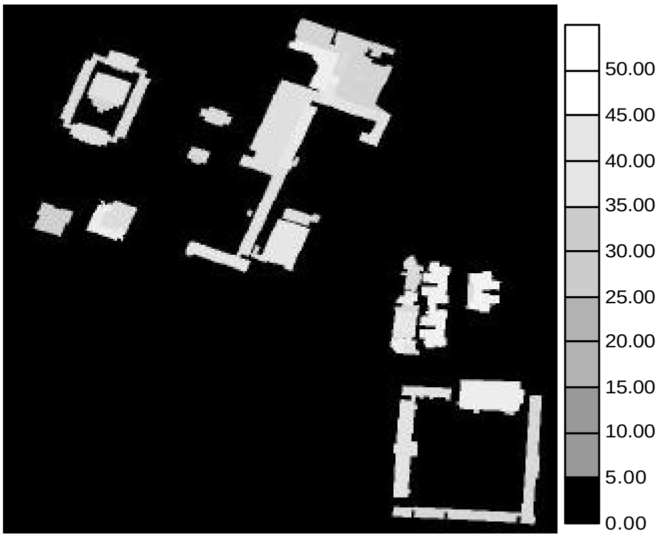

Figure 8. Building Model in the Test

Fig 9 is the generated true orthophoto. The RMSEs of the check points, as marked with boxes, are (0.55m, 0.92m) in E and N components respectively. The superimposition of the true orthophoto with building layer is shown in figure 10.

Figure 9. Generated True Orthoimage and Check Points

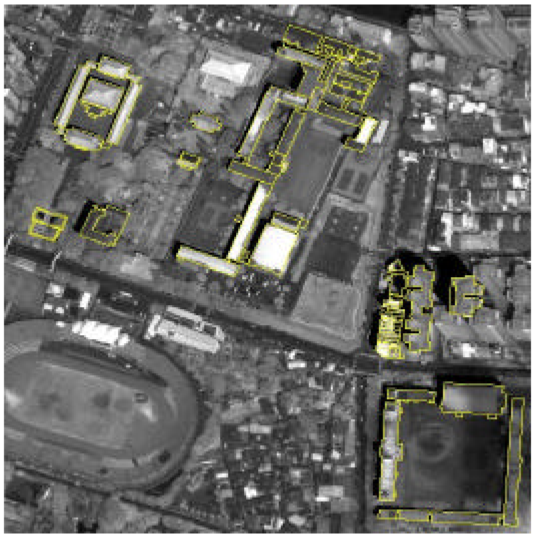

Figure 10. The Superimposition of the True Orthophoto and the Building Layer

4. CONCLUSIONS

A method for generating true orthophotos from IKONOS GEO images is given. An accuracy of 2m or better may be reached by using the proposed scheme. This demonstrates a combination of: (1) the correction for relief displacement, (2) the fine turning for tilt displacement by affine transformation, and (3) the treatments for building effects might be appropriate. The proposed method is straightforward. Thus, it would be easy to implement for general applications.

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