The Generation of True Orthophotos from High Resolution Satellites Images

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Abstract: The purpose of this investigation is to generate true orthophotos from high resolution satellite images. The major works of this research include 4 parts: (1) determination of orientation parameters, (2) generating traditional orthophotos using terrain model, (3) relief correction for buildings, and (4) process for hidden areas. To determine the position of satellites, we correct the onboard orientation parameters to fine tune the orbit. In the generation of traditional orthophotos, we employ orientation parameters and digital terrain model (DTM) to rectify tilt displacements and relief displacements for terrain. We, then, compute relief displacements for buildings with digital building model (DBM). To avoid double mapping, we detect hidden areas. Due to the satellite's small field of view, an efficient method for the detection of hidden areas and building rectification will be proposed in this paper. Test areas cover the city of Kaohsiung in southern Taiwan. Test images are from the QuickBird satellite.

Keywords: High Resolution Satellites Images, DTM, DBM, Hidden areas, and True orthophotos

1.Introduction

A number of investigations on the generation of orthophotos from aerial photos (Wiesel, 1985; Hohle, 1996), and satellite images (O'Neill & Dowman, 1988; Chen & Teo, 2001; Chen, *et. al.*, 2001) have been reported. Rectification of distortion caused by sensor orientation, topographic relief displacement for terrain, earth curvature, and relief displacement for building is called true orthorectification. As each point is portrayed accurately at its true geographic position, building rooftops are positioned vertically above their footprint. The generation of true orthophotos is more complicated than that of traditional ones. A number of investigations on the generation of true orthophotos from aerial photos (Fahmi, *et. al.*, 1998; Rau & Chen, 2002) have been reported. Due to high spatial resolution satellites are considered, we cannot ignore buildings as parts of terrain.

To increase the efficiency of generating true orthophotos, we proposed to rectify relief displacement for terrain first and then for buildings. The proposed procedure is shown in Fig 1. The major works of the scheme include 4 parts: (1) manipulation of rational polynomial coefficients (RPCs), (2) generating traditional orthophotos using terrain model, (3) relief correction for buildings, and (4) process for hidden areas.

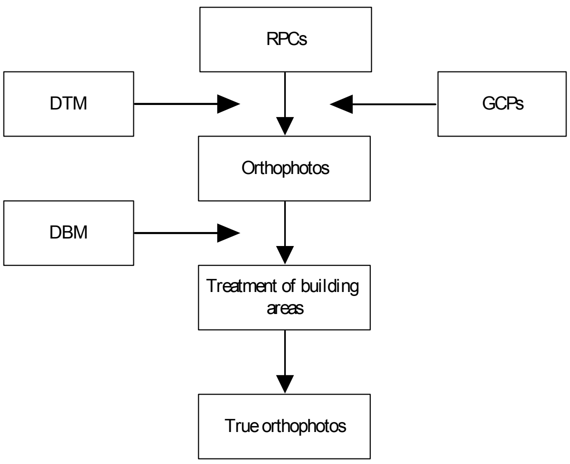

Fig. 1. The proposed scheme

2.Generation of Traditional Orthophotos

Rational function model has recently being applyed in high resolution satellite images such as Ikonos and Quickbird. The RFM is a mathematics between the 2D image space and 3D object space. It uses a ratio of two polynomials to perform the transformation. In this investigation, we used RFM to set up a transformation from the 2D image space and 3D object space.

The RPCs provided by the satellite company performed high accuracy, because the RPCs are generated from the high accuracy on-board data. Usually, the RFM is in third orders; hence, 80 RPCs are given. The systematic bias of the RPCs will be compensated by an affine transformation. A limited number of GCPs is needed in the systematic compensation.

3.Treatment of Building Areas

After generating traditional orthophotos, we perform 3 steps for the treatment of building areas: (1) registration of building areas from vector data to the image, (2) blacking out the hidden areas, and (3) correction of relief displacement for the building. In this way, building rooftops are positioned vertically above their footprint and the rest areas are hidden areas. Due to the small field of view of satellite, we found that the variation range of relief displacement in the same buildings is from $-1.0*10^{-4}$ meters to $1.5*10^{-4}$ meters. With this property, we treat the relief displacement for the same building as a constant to accelerate the process.

4. EXPERIMENTS

1) Test Data

Test areas cover the city of Kaohsiung in southern Taiwan. The test image is the QuickBird basic raw image sampled on March 13, 2002, which is shown in Fig. 2. The ground control points (GCPs) and check points (CHKPs) were measured from 1:1000 scale topographic maps. The position accuracy is better than 50 centimeters. The DTM used in the orthorectification was acquired from the Topographic Data Base of Taiwan. The pixel spacing of DTM is resample from 40m to 0.5m. Fig. 3 illustrates the terrain variation. The elevation ranges from 0m to 340m. Digital building models as shown in Fig. 4. The area of interest in the true orthoimage generation is a small part in the raw image. It is shown as the rectangle in Fig. 2.

2) Experimental Results

With the indirect method, we generate traditional orthophotos as shown in Fig. 5. The RMSE of 121 CHKPs is about 1.92 pixels and 2.77 pixels in E and N directions, respectively. The error vectors plot of those 121 CHKPs are as shown in Fig. 7. To avoid double mapping, we have to detect hidden areas. We removed buildings and compute the relief displacement of each building with DBM to correct the rooftop to the right position. The rest areas are hidden areas. Finally, we generate true orthophotos as shown in Fig 6. The RMSE of true orthophotos is about 0.98 meters and 2.79 meters in E and N directions, respectively. The error vector plot of true orthophoto is shown in Fig. 8.

Fig. 2. Test image

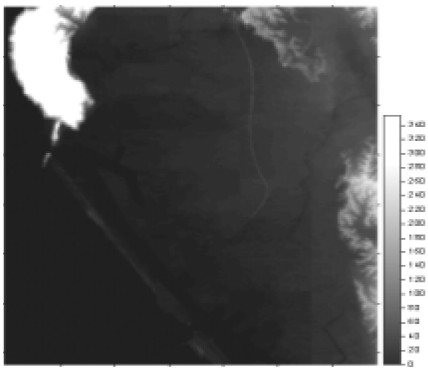

Fig. 3. DTM in the test area

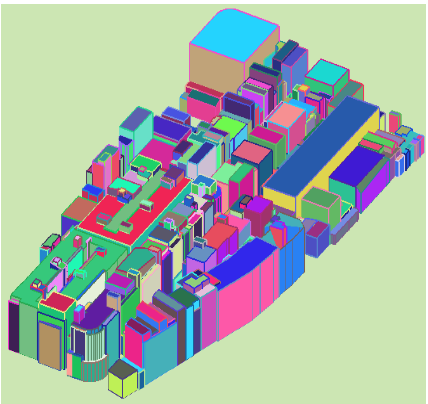

Fig. 4. Digital building models in the test area of true orthophoto generation

Fig. 5. Generated traditional orthophotos

Fig. 6. Generated true orthophotos

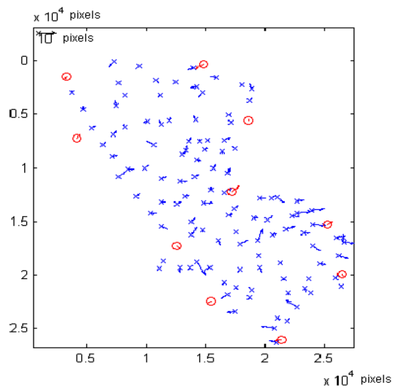

Fig. 7. Error vectors plot of the generated orhophoto

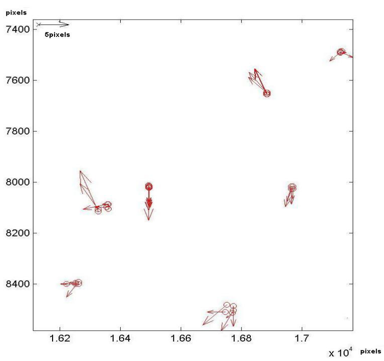

Fig. 8. Error vectors plot of the generated true orhophoto

5. Conclusions

In this investigation, we proposed a procedure of true orthorectification for a QuickBird image. To perform the procedure with higher efficiency, we execute the orthorectification first and then correct the relief displacement of buildings. We use RFM to achieve the orthorectification. Experiment results indicate RFM is an easy way to achieve orthorectification. The accuracy can reach 1.92 pixels and 2.77 pixels in E and N directions, respectively. We removed building with digital building models in orthophotos and then rectify the relief displacement for building. Finally, we detected the hidden areas and achieved the true orthorecitification. The RMSE of true orthophotos is about 0.98 meters and 2.79 meters in E and N directions, respectively.

6.Reference

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