INTEGRATION OF THEOS AND FORMOSAT-2 IMAGES TO GENERATE DIGITAL ELEVATION MODELS

Li-Hsueh Chang [a], Liang-Chien Chen [b], and Wen-Chi Chang [c]

[a] Associate Researcher, National Space Organization, National Applied Research Laboratories 8F,9 Prosperity 1st Road, Hsinchu Science Park, Hsinchu, Taiwan, Tel: 886-3-5784208;
Email: LHChang@nspo.narl.org.tw

[b] Professor, Center for Space and Remote Sensing Research, National Central University, No.300, Jhongda Rd., Jhongli City, Taoyuan County 32001, Taiwan, Tel: 886-3-4227151 ext 57622
Email: lcchen@csrsr.ncu.edu.tw

[c] Ph. D Student, Department of Civil Engineering, National Central University, No.300, Jhongda Rd., Jhongli City, Taoyuan County 32001, Taiwan, Tel: 886-3-4227151 ext 57623
Email: wenchi@csrsr.ncu.edu.tw

KEY WORDS: THEOS, Formosat-2, Image Matching, Digital Elevation Model

Abstract: With the improvement of spatial resolution for satellite images, using such images to generate high resolution digital elevation model (DEM) is expected. This paper aims to generate DEM by the integration of Thailand Earth Observation System (THEOS) and Formasat-2 satellite images. The major works in this study include the establishment of geometric sensor model, image matching, and DEM reconstruction. This paper employs the object-based matching to generate DEM using image pyramid. Finally, we exclude the outliers through the continuity check in object space. Experimental results show that the proposed method can reconstruct quality DEM.

1. INTRODUCTION

The digital elevation model (DEM) is important information for remote sensing applications. It's also a basic component in Geographic Information System (GIS) database. With the improvement of spatial resolution for satellite images, using satellite images to generate high resolution DEM is expected. The satellite images have the advantage of the wide-area acquisition. When the terrain changed caused by the natural disasters, it can quickly update the DEM over a large area. Many researches have generated DEM with the stereo pairs from the same satellite images, for example, SPOT pairs (Chen and Rau, 1993; Toutin, 2006), or IKONOS pairs (Rau and Chen, 2005; Zhang and Gruen, 2006). Rhee and Kim [2011] compared the DEM reconstructed form Worldview-1, IKONOS, and Kompast-2 stereo images. The accuracy cloud better than 3.5 meters with the Worldview-1 stero images.

Taiwan is an island, which is often covered by cloud in satellite imagery. However, the employed images with close acquisition times and less cloud cover area are favorable to generate DEM. Thus, integrating different satellite images could provide higher flexibility of data acquisition for DEM generation. Formasat-2 satellite had launched on May 21, 2004 (NSPO, 2005). It's a sun-synchronous satellite, which can acquire the images for Taiwan area every day. Thailand Earth Observation System (THEOS) (Kaewmanee et al., 2006) and Formasat-2 have similar sensor characteristics in terms of spatial resolution and metadata. Thus, this paper aims to derive DEM by the integration of THEOS and Formasat-2 satellite images.

2. METHODOLOGY

The major works in this study include the geometric modeling, object-based matching, and DEM reconstruction. Both Formasat-2 and THEOS provide the exterior orientation parameters, including orbital positions and attitudes (GISTDA, 2010). Thus, we use direct georeferencing for the establishment of geometric sensor model. Then, the object-based matching is employed to generate DEM with image pyramid. Finally, DEM reconstruction is performed to generate raster DEM. The workflow is shown in Figure1. The input data contain Formasat-2 and THEOS-1 images with the orientation parameters, and an initial DEM. The details of each step are given below.

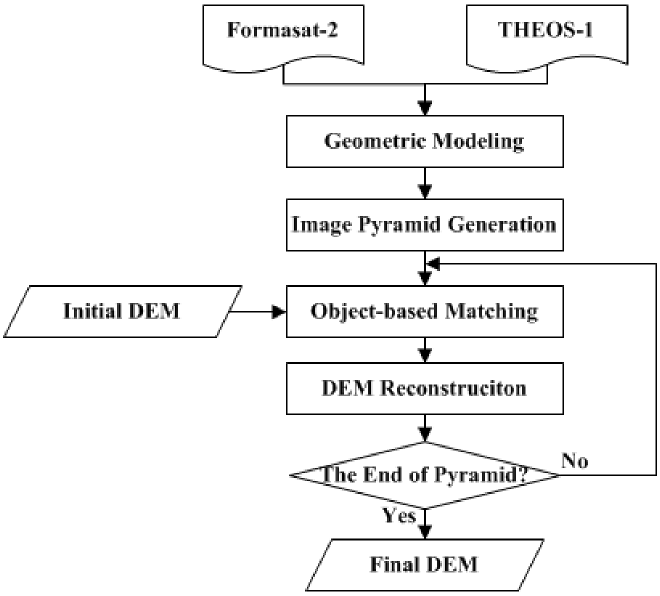


Figure 1: Workflow of the propose scheme

Geometric Modeling

Direct georeferencing (DG) employs the orientation parameters to establish an observation vector for each image point followed by a fitting procedure using ground control points (GCPs) (Chen et al., 2012). The first step for DG is orbit fitting to compensate exterior orientation for systematic errors. The exterior orientation's initial value was derived by ephemeris data. We compensate the systematic errors of the exterior orientation via GCPs.

The line-of-sight vector of image coordinates can be calculated by ray tracing after orbital fitting processing. The tracing procedure is used to locate the object position for each image point, provided that the orientation and the DEM are available. In addition, in order to improve the geometric consistency between the image strips, least squares collocation is employed for compensating the local systematic errors of object coordinates finally. We assume that the X, Y, Z-axis are independent. Thus, we use three one-dimensional least squares collocation functions to adjust the object coordinates.

Object-based Matching

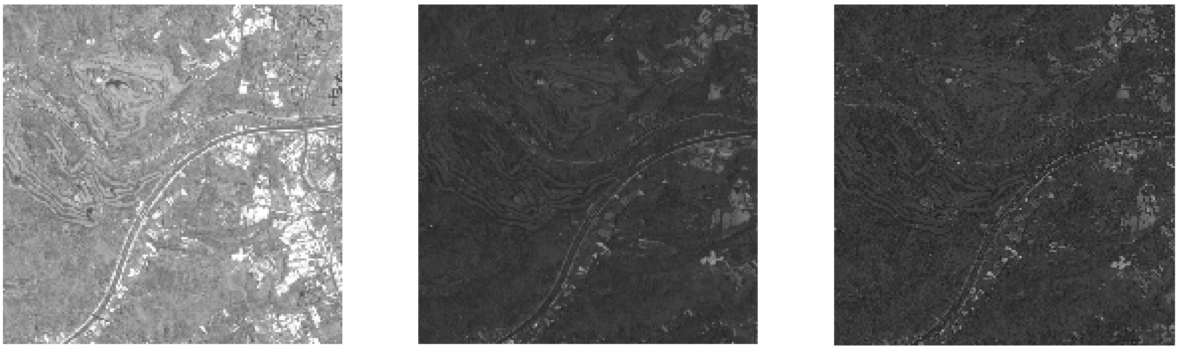
This paper selects the object-based matching method (Otto and Chau, 1989) for image matching. Starting from an object planimetric coordinate, the method connects the correspondences in different images to determine the optimal elevation coordinate. In the first step, the candidate object coordinates sets are generated with the initial DEM , a reasonable elevation range and the elevation resolution for each object planimetric coordinate. For each candidate coordinate, we generated the set window in object space. Then the window is back projected to the master images and other images to obtain the target window and search windows, respectively. The weighted mean of correlation coefficients are calculated for a target window in the master image and the search windows. The final correspondences for the candidate point are determined by the maximum average correlation coefficient. In addition, the object-based matching is performed with image pyramid to improve the quality of image matching.

DEM Reconstruction

The initial DEM is with lower resolution. After object-based matching step, we can get new 3D point clouds to generate new DEM with higher resolution than the initial one by interpolation of 3D discrete points with the Kriging method. And then the new DEM will be treated as the initial DEM in the next iteration until all the images pyramid are calculated completely. Before the interpolation, it needs to exclude the outliers of the point clouds. For each 3D point, we calculate the four slopes with the nearest 3D point in north, south, east, west direction. And the 3D point is deemed as outliers if there are more than three directions' slopes larger than the threshold.

3. EXPERIMENTS

The test site is located at Taouuan of Taiwan. The experimental data include a Formasat-2 image, two THEOS-1 images, and an initial DEM with 40 m resolution. Figure 2 shows the test images in the test area. The related information of test image is shown in Table 1.



(A) Formasat-2 (B) THEOS-1_1 (C) THEOS-1_2

Figure 2: Test Images

Table 1: Information Related to Test Data

Descriptions	Formosat-2	THEOS-1_1	THEOS-1_2
Level	1A	1A	1A
Date	2012/05/02	2012/05/08	2012/05/08
GSD (m)	2	2	2
Image Size	12000 x 12000	12000 x 12000	12000 x 12000
Viewing Angle Along Track (degree)	-24.61	-0.66	-0.65

Figure 3 shows the results of final DEM with 5 m resolution. And the reference DEM, as shown as Figure4, is reconstructed by aerial images with 5 m resolution. We calculate the difference between the results and the reference DEM. The accuracy estimation results are shown in Figure 5. The values in Figure 5 (A) are obtained by subtracting the reference DEM from the generated DEM. And the error histogram is shown as Figure 5 (B).

The terrain variation of the results is similar to the reference data visually. However, the reference DEM does not contain the trees and artificial buildings, such as roads and houses. The generated surface obtained from image matching is actually a digital surface model (DSM), which contains the height of trees and artificial buildings. The difference between those two DEMs could be an indicator of the above ground objects. According to the error histogram, the mean is about 7 meters. The mean indicates the difference between the DEM and the DSM. The root mean square error (RMSE) is 9.5 m. After shifting the difference between the DEM and the DSM, the RMSE is improved to 6.8 m. Considering the convergent angle (about 25 degree), the RMSE of elevation is reasonable. It means that the proposed method could provide an effective way to generate quality DEM.

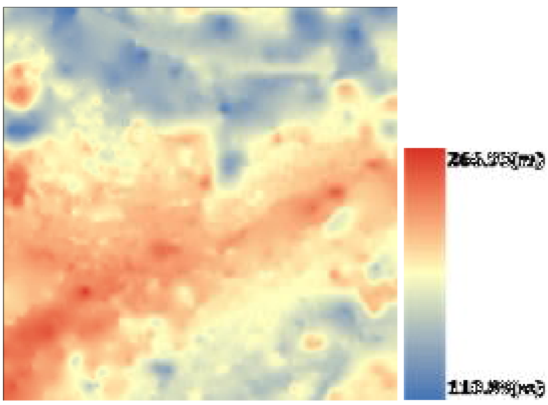


Figure 3: The Generated DEM

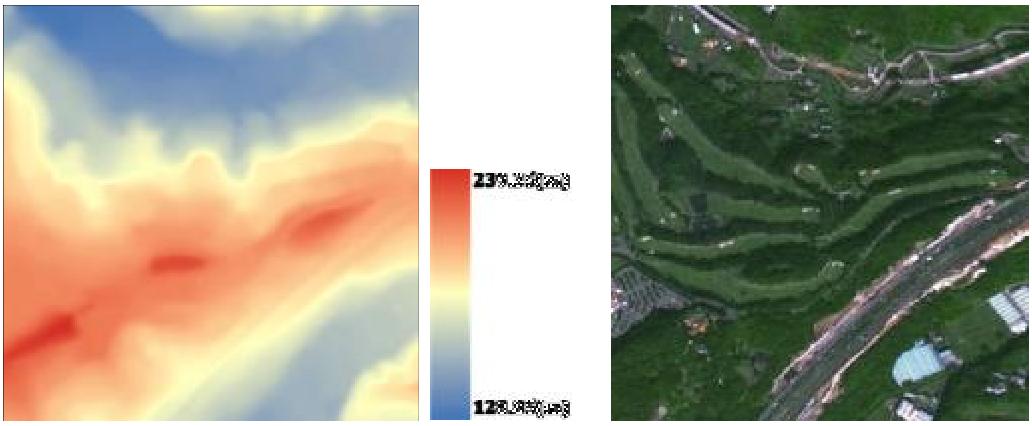
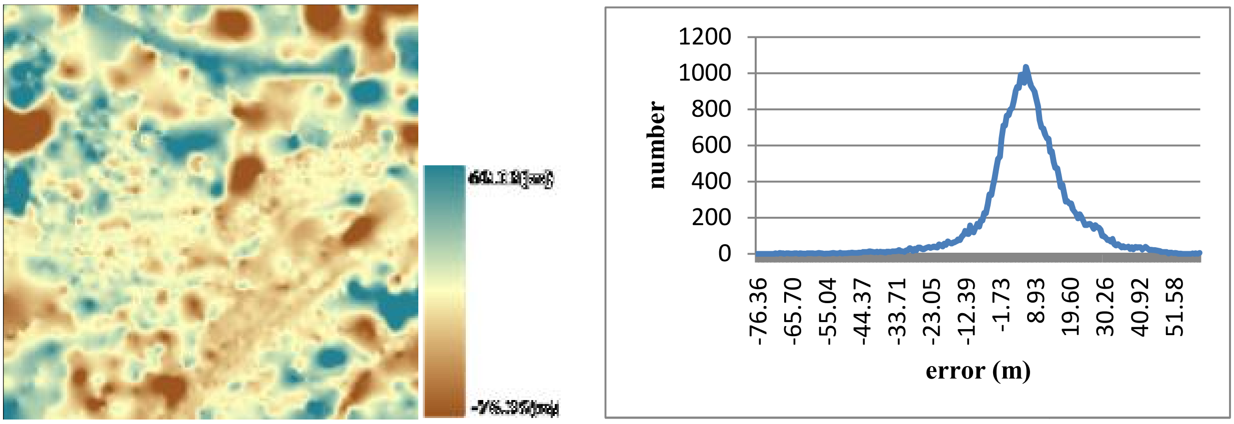


Figure 4: The Reference DEM and the image for test area



(A) The error map (B) The error histogram

Figure 5: Accuracy Estimation

4. CONCLUSIONS

This investigation reconstructed DEM by the integration of THEOS and Formasat-2 satellite images. The experimental results indicate that the proposed method could provide an effective way to generate quality DEM. And the accuracy check will be more reasonable if the reference data is the DSM instead of the DEM. It is obvious that unreliable matching still exists. Thus, the improvement of the matching reliability is subject to further investigation.

ACKONWLEDGMENTS

This investigation is partially supported by the National Space Organization, National Applied Research Laboratories, Taiwan.

REFERENCES:

Chen, L. C. and Rau, J. Y., 1993. A Unified Solution for Digital Terrain Model and Orthoimage Generations from SPOT Stereopairs, IEEE Transactions on Geoscience and Remote Sensing, 14(6), pp. 1243-1252.

Chen, L.C., Chang, W.C., and Teo, T.A., 2012. Geometric Integration of Heterogeneous Models for Multi-Satellite Image Positioning, IEEE Transactions on Geoscience and Remote Sensing, 50(7), pp.2802-2809.

GISTDA, 2010. THEOS DIMAP/GeoTIFF Format and Description, Version 1.1.

Kaewmanee, M., Choomnoommanee, T., and Fraisse, R., 2006. Thailand Earth Observation System: Mission and Products. Proceedings of ISPRS Commission I Symposium, July 4-6, Paris, France.

NSPO, 2005. FORMOSAT-2 Remote Sensing Mission, URL: http://www.nspo.org.tw/e60/menu0403.html

Otto, G.P., Chau, T.K.W., 1989. A region-growing algorithm for matching of terrain images. Image and Vision Computing 7(2), pp.83–94.

Rau, J.Y. and Chen, L.C., 2005. DSM Generation from IKONOS Stereo Imagery, Journal of Photogrammetry and Remote Sensing, 10(3), pp.265-274.

Rhee, S. and Kim, T., 2011. DEM GENERATION AND ACCURACY ANALYSIS FROM HIGH RESOLUTION SATELLITE IMAGES THROUGH A 3D CORRELATION MATCHING ALGORITHM, International Symposium on Remote Sensing 2011, Nov. 2-4, Yeosu, Korea.

Toutin, T., 2006. Generation of DSMs from SPOT-5 in-track HRS and across-track HRG stereo data using spatiotriangulation and autocalibration, ISPRS Journal of Photogrammetry and Remote Sensing, 60 (3), pp. 170–181.