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GENERATION AND ASSESSMENT OF ACCURACY OF DIGITAL ELEVATION MODEL BY USING PCIGEOMATICA (10.3)

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ABSTRACT

This study aims to assess the accuracy of Digital Elevation Model (DEM) which is generated by using Toutin's model. Thus, Toutin's model was run by using OrthoEngine^{SE} of PCI Geomatics 10.3.Thealong-track stereoimages of Advanced Spaceborne Thermal Emission and Reflection radiometer (ASTER) sensor with 15 m resolution were used to produce DEM on an area with low and near Mean Sea Level (MSL) elevation in Johor Malaysia. Despite the satisfactory pre-processing results the visual assessment of the DEM generated from Toutin's model showed that the DEM contained many outliers and incorrect values. The failure of Toutin's model may mostly be due to the inaccuracy and insufficiency of ASTER ephemeris data for low terrains as well as huge water body in the stereo images.

Key Words: Digital elevation model, PCI geomatica, Assessment, Accuracy

INTRODUCTION

A Digital Elevation Model (DEM) is a digital representation of ground surface topography or terrain. It is also widely known as Digital Terrain Model (DTM) (Hirano et al., 2003:Trisakti and Carolita, 2005). There are many methods for obtaining DEM data such as terrestrial surveying, stereo photogrammetry, GPSdata and topographic maps. Although, High cost, limited access to the study area, time-consuming procedures and inadequate updating of maps drove scientific researches to new techniques for generating DEM maps. The various applications of DEM and the drawbacks of traditional techniques drastically have increased the significance of using satellite stereo images. Advanced Spaceborne ThermalEmission and Reflection radiometer (ASTER) waslaunched in December 1999 as the only high spatialresolution instrument on Terra satellite as a cooperativeprogram between National Aeronautics and SpaceAdministration (NASA) and Earth

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Observing System(EOS) and Japan's Ministry of Economy (Welch et al.,1998: Yamaguchi et al., 1998). ASTER sensor wasdesigned to obtain high spatial resolution, global and localimages in 14 spectral bands. ASTER sensor provides theimages in 14 Visible and Near-Infrared (VNIR) (15 m),Short-Wave Infrared (SWIR) (30 m) and Thermal Infrared(TIR) (90 m) spectral bands with 60 km swath width. TheVNIR subsystem records the stereo images in band 3 (0.78-0.86 µm) from nominal Terra altitude of 705 km at 15 m resolution. In order to minimize the image distortion, two independent telescopes capture the images in Backward (3B) and Nadir-looking (3N) modes (Yamaguchi et al., 1998) with interval of 60 seconds. Also, Along-track stereo images yield a B/H ratio of 0.6 which is suitable for automatic DEM generation. Furthermore, the capability of two telescopes for rotating ±24ºC provides across-track stereo images data with B/H ratio close to one (Toutin, 2008).

Since the availability of ASTER data in March 2000 many scientists have investigated and validated the generated DEM, mostly due to special characteristics of ASTER stereo images, such as world-wide coverage, along-track configuration, high spatial resolution (15 m),easy to access and inexpensive images. These characteristics make ASTER stereo images as significant alternatives for generating DEMs in scientific and commercial applications. Two kinds of studies have been conducted: first the pre-launch or simulation studies and, second the investigations by employing real ASTER data.The first group of studies mostly conducted on mountain areas, showed accuracy between ±7 and ±50 m for absolute DEM (Arai, 1992: O'Neill and Dowman, 1993:Dowman and Neto, 1994: Giles and Franklin, 1996: Tokunaga et al., 1996: Welch et al., 1998), while the relative DEM yielded RMSEz of 10-30 m (Lang and Welch, 1999). The second group of studies used the off the-shelf software such as PCI Geomatica^{TM}OrthoEngine® of PCI Geomatics, Desktop Mapping System (DMS)TM (R-WEL), ERDAS Imagine® OrthoBASE Pro™ (ERDAS), ENVI DEM Extraction Module of ENVI 4.2- 4.8 and SilcAst of Sensor Information Laboratory Corp (Hirano et al., 2003:Toutin, 2008). According to Toutin (2008) the Geomatica^{TM}OrthoEngine^{SE}ofPCIGeomatics is the most used software, which employs the Toutin'smodel developed at the Canada Centre for Remote Sensing. The Toutin's model showed the vertical accuracy between ±15-25 m depending on the type of terrain of the study site as well as numbers and distribution of applied GCPs (Kaab, 2002:Toutin, 2002:Toutin and Cheng, 2002:Chrysoulakis et al., 2004:Cuartero et al., 2004, 2005a, b: Eckert et al., 2005). However, slightly better results were obtained from ENVI 4.1 (RPC model) and Desktop Mapping System (DMS) which showed the accuracy between ±7 and ±20 m (Hirano et al., 2003: Lee et al., 2008). In comparison to the above software, the absence of specific model for ASTER sensor led to poorer results by OrthoBase Pro module ofErdas Imagine®. The studies yielded the RMSEz of ±34.8 and ±27 m by Cuartero et al. (2004) and Trisakti and Carolita (2005) respectively. Finally, the SilcAst (available version 1.10) which is offered by Sensor Information Laboratory Corp from Japan showed the best results with RMSEz of ±6.1m for relative DEM (Cuartero et al., 2005b).

This study aims to generate the DEM from ASTER stereo images on low and near MSL area in Malaysia. Thus, DEMwas produced by using Toutin's model (OrthoEngine^{SE}of

PCIGeomatics10.3). Finally, the accuracy of the extracted DEM was assessed based on the independent Ground Control Points (GCPs).

Study Area and Dataset

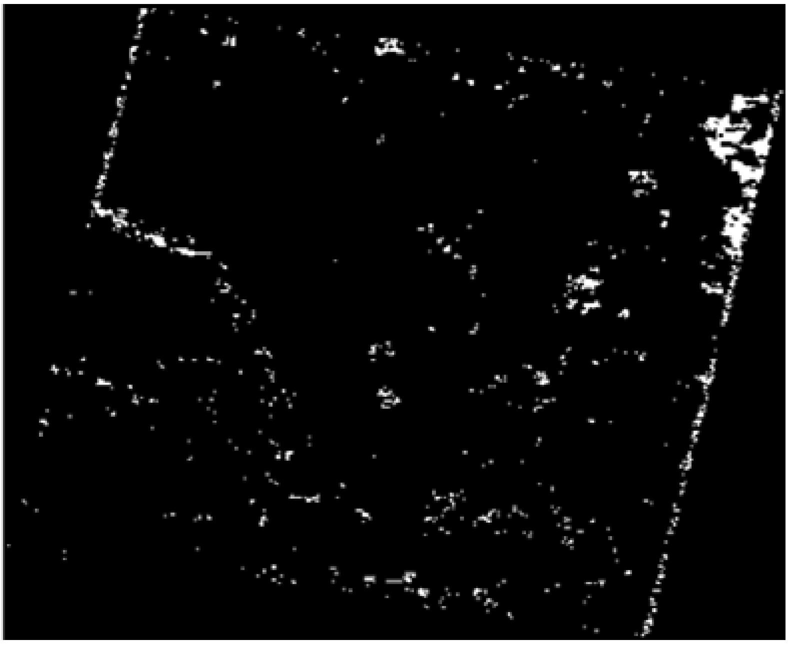
The area of study located in Johor state in southern Malaysia (103º16"45.30"E to 103º42"48.46" E to 1º10"12.62"N and 1º47"42.40"N) covers Johor Bahru, Skudai and other small urban and rural districts such as Kulai, Benut, Pekan Nanas, mostly located near the Straits of Malacca. The area comprises flat topography, mainly less than 100 m in urban and clear-cut areas as well as dense tropical forests. The moderate and hilly terrain restricted to the west of Johor Bahru ranges approximately between 100 to 600 m and more. The land cover of the study site mainly consists of dense oil palm and tropical forests. Johor Bahruis the major city in the south while the other residential and urban areas are sparse in the study area.

The image dataset used was a level 1A ASTER stereo images that were recorded on, July, 14, 2009 with the scene center of 1.47681ºN and 103.498ºE. The stereo pair consists of 4100 pixels by 4200 lines, covering an area approximately 60 km by 60 km which was delivered in Hierarchical Data Format (HDF). Also, the automatic geometric correction and radiometric calibration are available by utilizing applicable appended coefficients (Toutin, 2002).

Dem Generation

The OrthoEngine^{SE} of PCIGeomatics10.3 uses the Toutin’s model to generate DEMfor ASTER stereo images. The satellite orbital model, alsocalled Toutin’s Model, is a rigorous model developed byDr. Toutin of the Canada Center for Remote Sensing tocompensate for distortions: such as sensor geometry,satellite orbit and attitude variations, earth shape, earthrotation and relief (Toutin and Cheng, 2002). The rigorous models employ the photogrammetric collinearityequations to relate the position of the point on the imageto the position of the correspondent point on the ground.The orbital model shows the accuracy ofapproximately one-third of a pixel for VIR images whenthe quality GCPs are used. Although, the Toutin’s modelis not implemented when there are no orbital parameters,a subset of the original image is used and the image has been geometrically processed. In order to generate DEM, the earth model and datumwere set to UTM (zone 48N) and WGS84 respectively. The OrthoEngine^{SE}applied of geometric processing for 3N and 3B images individually. Although 4 GCPs are theoretically adequate to compute the stereo model, a larger number (53) were used to achieve an overestimation to improve the least square adjustment to reduce the errors of map and plotting errors. In addition,26 tie points were extracted to enhance the fitting of images to ground coordinate system and fitting of overlapping images to each other. Unfortunately, the output DEM contained many blunders and outliers which were impossible to perform the post-processing and removing the uncorrected values (Figure. 1).

Figuren-1. Output DEM by using Toutin's model (PCIGeomatics)



RESULTS AND DISCUSSION

Pre-processing accuracy of Toutin's model: The preprocessing for generating ASTER-extracted DEM byutilizing Toutin's model includes geometrical correction, qusai-epipolar image generation and image matching (Toutin and Cheng, 2002). The results of geometrical correction which has been done individually for each stereo image gave the RMS of 0.87 pixels (53 GCPs) and 0.88 pixels (53 GCPs) for 3N and 3B images respectively. Finally, in order to perform bundle adjustment and generate quasi-epipolar images 26 well-distributed tie points were selected in each stereo image. Consequently, the residuals between 0.150 and 1.402 pixels were achieved.

DEM accuracy of Toutin's model: Despite the satisfactory pre-processing results the visual assessment of the DEM generated from Toutin's model showed that the DEM contained many outliers and incorrect values.Table 1 lists the main statistics extracted from Toutin's model of DEM. In the Table 2 almost 98% of DEM includes data value equal to -100 (failed values) which represents the value for the points that were not either computed or extracted from the stereo images by using Toutin's model.

Table-1. Main statistics of DEM from Toutin's model, almost 96% of the DEM is covered with failed values (-100)

Number of pixels	23912549.000
Number of pixels with data value of -100 (failed value)	23454133.000
Mean Value	-94.596
Maximum Value	636.000
Percentage of failed value	98%
Minimum value	-100.0000
Median value	-100.0000
Standard deviation	45.6683
Number of pixel with maximum value	4.0000
Percentage of maximum value	<1%

CONCLUSION

The Advanced Space borne Thermal Emission and Reflection radiometer (ASTER) is the only multispectral high resolution sensor on the Terra platform which captures along-track stereo images with the Base-to-High (B/H) ratio of 0.6. The stereo images are recorded in near infrared wavelength region (band 3) in Nadir (3N) and aft-looking (3B) mode. In this study, the DEM was produced by using Toutin's Model (PCI Geomatics10.3). In order to, generate the DEM by using Toutin's model, also, 53GCPS were used for 3N (nadir looking) and 3B (backward looking) images. The DEM of Toutin's model contained many outliers and blunders which showed the inefficiency of Toutin's model for areas with low and near MSL elevation. The failure of Toutin's model is mostly due to the low sensitivity of ASTER stereo images for lowand near MSL elevation. Also, it indicates that the ephemeris data of ASTER is not sufficient and accurate enough to generate DEM for low elevation areas.

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