ACCURACY ASSESSMENT BETWEEN DEM GENERATED BY HYPSOGRAPHIC DATA AND RADARSAT STEREO IMAGES IN THE PRODUCTION OF HILLY FOREST ROAD ALIGNMENT MAP

Musa, M. K. A,
Malaysian Centre for Remote Sensing (MACRES)
No. 13 Jalan Tun Ismail, 50480 Kuala Lumpur.
Tel: 603-26973400 Fax:603-26973360
Email: kamal@macres.gov.my
MALAYSIA

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ABSTRACT

The paper is written to address an accuracy assessment between digital elevation models (DEM) by hypsographic data and Radarsat synthetic aperture radar (SAR) fine mode images (F2-F5) in the production of hilly forest road alignment map. The study sought to measure differences in DEMs created from both contour lines and stereo images. The main objective was to evaluate the potential of DEMs product for use as key information layer in Forest Road Alignment Model. The accuracy of evaluations were evaluate for two DEMs of an area in Dungun, Terengganu. The first was a DEM derived from 1: 50000 scale Topography Map that are in use for long time and considered to be more reliable and accurate. The second DEM of the same area was produced from a Radarsat stereo-pair using Erdas Imaging. DEM accuracy was assessed through comparisons of DEM-derived to field surveyed value for elevations. The result showed that DEM from Radarsat stereo images appeared to provide a better representation of topographic phenomena; elevation error for both hypsographic data and stereo images DEMs averaged less than 7 meters. Hypsographic data DEM had 6.2 m RMS error and Radarsat DEM 2.8 m RMS error. Based on the analysis, it is conclude that the Radarsat DEM is the more accurate representation the topographic landscape at study site, furthermore when looking at the Spectral Profile Viewer , it is important that topography surface of the Radarsat DEM be accurate when comparing with the DEM- field surveyed.

1.0 INTRODUCTION

Digital Elevation Models (DEMs) was introduced by Miller and Laflamme (1958) and since that its have been increasingly used by various discipline for a variety of purpose and at range of scale. A DEMs offers the most common methods for extracting vital topographic information and even enable the routing of flow a cross topography (Kirkby, 1990). Topography information is a controlling factor in certain application and must be represent as accurately as possible (Desmet, 1997).

In term of forest sustainable management, DEMs technology represents a major asset in the carried out programme. Parts of them are already considered as available in operational conditions and some of its still in research stage. In Malaysia, little is known about the DEMs and their contribution to forest road network alignment. Exactly forest road network alignment differs by landscape position. Ridge top, mid-slope and valley floor all produce different effect on the environment. Thus, planning for forest transportation will ensure that roads are located where potential impacts to natural resources such as water quality and aquatic habitat are minimized. We may state that, different phase of road development have different effect on the landscape. And we know that, DEMs very useful to develop more physically realistic structure for forest road network alignment and directly account for the impact of the environment. This help to explain the relevance of DEMs and forest road network alignment. Without topography information, developing a comprehensive picture of where the road system currently stands will be difficult and analyses may be limited at best.

There are many ways of representing surface elevation in a model. Some of the ways DEM's can be generated using manual measurement from topography map. However, we do not know to what extent this method will influence the DEM and the modeling results. Another way of represent surface elevation in a model is by using satellite images. In this paper, we aims to evaluate the quality of DEM extracted from hypsographic data and fine mode Radarsat stereo images over a hilly-forested area in Dungun, Terengganu, Malaysia.

This study has mainly evaluated the accuracy of DEMs with the focus on quantity and quality. Qualitatively, the differences are determined through visualization. Meanwhile, errors in DEMs are analyzed and evaluated with the topographic ground truth through absolute and relative deviation between datasets. There was a consensus in the result of the DEM extraction. The result showed that DEM from fine mode Radarsat stereo images data appeared to provide a better representation of topographic phenomena.

2.0 MEASURING ACCURACY

There are many potential sources of errors in DEMs. Ones must be aware of the fact that the resulting analysis will depend on the input data. Inaccurate and inappropriate data will still give the user a resulting analysis and this analysis will give a good result for the in accurate and inappropriate data. Therefore the user must make sure of the integrity of the input data. In DEMs the accuracy is usually quoted in its *Relative* accuracy and *Absolute* accuracy.

2.1 Relative Accuracy

Relative accuracy is a measure of the point-to-point accuracy within the DEM. For many applications, relative accuracy is more important than absolute accuracy. A DEM with good relative accuracy is one that models the shape and dimensions of the terrain accurately, but it may not be accurately registered to actual geographic coordinates. The relative accuracy of a DEM is expressed as the standard deviation (shown as "σ") of the vertical error after removing the systematic horizontal and vertical offsets, where:

$$\sigma = \sqrt{\left[\frac{1}{n} \left(Z_i - Z_i^* \right)^2 \right]}$$

n = is the number of check points

Z_i = derived elevation at check point i

Z_i^* = terrain elevation at position i

2.2 Absolute Accuracy

Absolute accuracy is a measure of the error between a DEM and the geographic coordinates of the actual terrain. For some applications, such as cartography, absolute accuracy is important. To produce a DEM with good absolute accuracy, reliable ground control can be used to remove biases. Absolute accuracy is expressed as the *vertical RMSE*, or root mean square error of the vertical error measured at geographic coordinates:

$$RMSE = \sqrt{\left[\frac{1}{n-1} \sum_{i=1}^{n} \left(z_i^* - z_i \right)^2 \right]}$$

n = is the number of check points

z_i = derived elevation at check point i

z_i^* = terrain elevation at position i

A systematic offset between the DEM and the real world geographic coordinates contributes to absolute errors. This offset is comprised of both horizontal and vertical components.

RMSE is the more widely used statistic but assumes a zero mean error, and therefore no systematic bias in the DEM., Li (1988) advocates the use of the standard error ($s_{\check{z}}$) and mean error ($\check{z}$)

3.0 STUDY AREA

Dungun District, which forms part of Terengganu, Malaysia was chosen as the study area for this study. The area is located in the Northeastern of Peninsular Malaysia centered at 04 ^{0} 40’ N and 102 ^{0} 56’ E. The area is hilly, with minimum and maximum elevation of 510 meter to 782 meter above mean sea level (MSL). The area is owned by Kumpulan Pengurusan Kayu Kayan Terengganu (KPKKT) under concession holder.

The topography is generally undulating with long, narrow ridges and steep slopes. Based on a survey of the site, it was found that a total of 53.6% of the site had a slope of 11^o or higher and only 46.4% had slopes of less than 10^o. On the whole, the area, contained a Dystric Cambisol soil type, however on the steep slopes, soil type is Haplic Acrisol with exposed boulders and corestones (WWF, 1999). The site chosen for the research is within Block A of Compartment 30. It covers a total area of 149 ha of the total of 380 ha for the whole of Compartment 30.

4.0 DATA AND METHODS

4.1 Experiment Dataset

Stereo pair images from Radarsat were used for experiment. The images were acquired on 01 November 2002 and 08 November 2002. These two images that have 7 days interval between them were used to generate DEM over the study area. Table 1 summarized the general characteristics of the images. Meanwhile Images of the two SAR scenes, which include compartment 30, Pasir Raja Forest Reserve, are shown in figure 1. The images are in ground range presentation, orbit oriented, coded in 16 bits without any radiometric processing.

Table 1: General Characteristics of the Radarsat Images.

Image Characteristics	Image 1	Image 2
Scene Date	01 November 2002	08 November 2002
Scene Time	11:30:22 GMT	11:26:15 GMT
Beam Mode	Fine 2	Fine 5
Orbit	Ascending	Ascending
Product Type	Path Image	Path Image
Product Size	10195 lines x 7844 pixels	10215 lines x 8906 pixels
Pixel Spacing	6.25m	6.25m

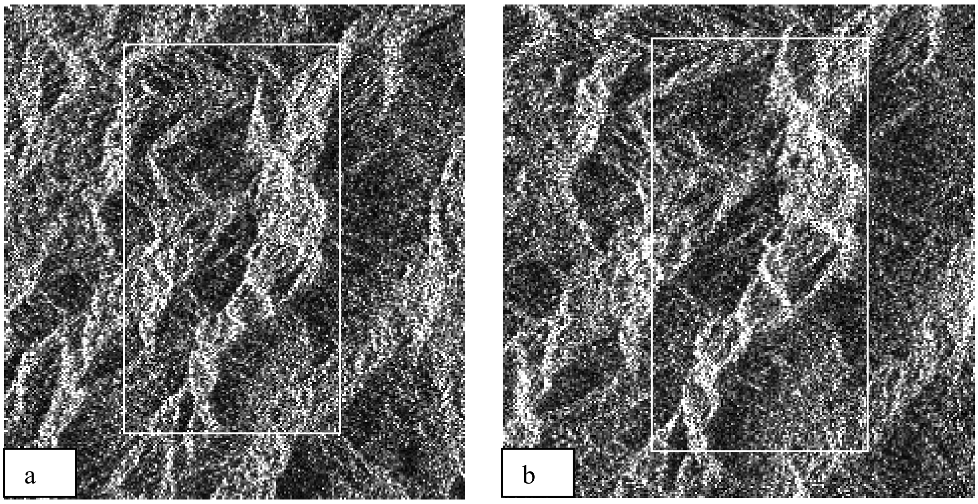


Figure 1:Extracted sub-images from the Radarsat images depicting the study area and its surroundings.(a) Fine 2 image and (b) Fine 5 image.

The hypsographic data were obtained from topographic map. The data was originally digitized from 1:50000 scale topographic map. The 20-meter contour lines are used to generate a triangulation irregular network, which is then transformed into 5-meter grid file.

In order to measure uncertainty in a digital elevation model is to compare an elevation in the data set to an actual elevation. For this study actual ground are available through ground survey. In December 2002, a detail field survey was set up in order to measure the topography, river and the gully or rill pattern formed during the raining season. The work took eight months to finish. All measurement was taken by using an automatic theodolite. Where necessary, an irregularly spaced point was sampled. From these point a grid based DEM was interpolated. Because of the original requirement of this study, a fine resolution of 5 meter was required; the density of the sample points enables such fine grid spacing.

4.2 DEM Generation

The following method is to produce different DEMs and measuring their differences. One DEM will be created from contour coverage data. The other DEM is created from Radarsat stereo imagery. All DEM are in RSO projection and elevation area in a mean sea level (MSL) format. Using commercially available software, the digitized contour line was used to generate DEM through contour interpolation model.

DEM data from Radarsat StereoSAR is created using IMAGINE StereoSAR DEM. The main digital processing steps are (i) the stereo model input, (ii) Acquisition of GCPs in Modeler, (iii) Image Matching (Tie Point (TPs) collection) and (iv) Compute Output DEM (Quality control). Generally the method is based on the correlation of amplitude images of a pair of SAR images. Its application mainly requires the determining of the matching of the points between the two images in order to measure the parallax. The overall stereoSAR system is illustrated in Figure 2.

In order to determine the accuracy of the DEMs, model will evaluate quantitatively and qualitatively. Qualitatively, the differences are determined through visualization. Errors in DEMs can be calculated quantitatively by determine RMSE, absolute and relative deviation between datasets, using equation above.

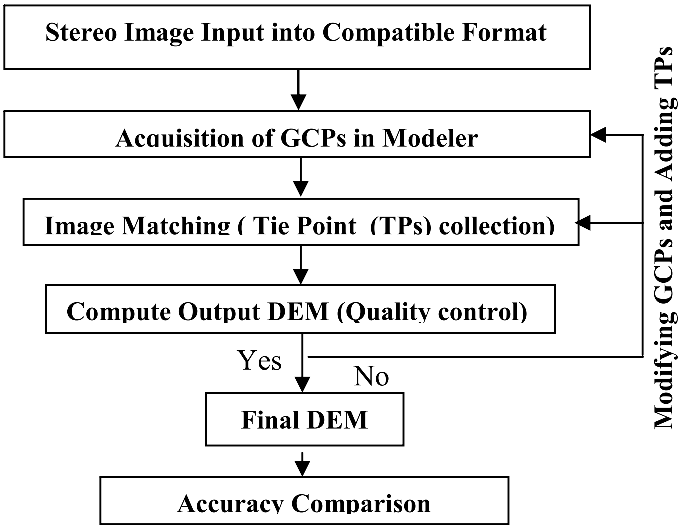


Figure 2 : Stereo processing flow diagram

5.0 RESULT AND DISCUSSION

5.1 Accuracy of elevation estimates

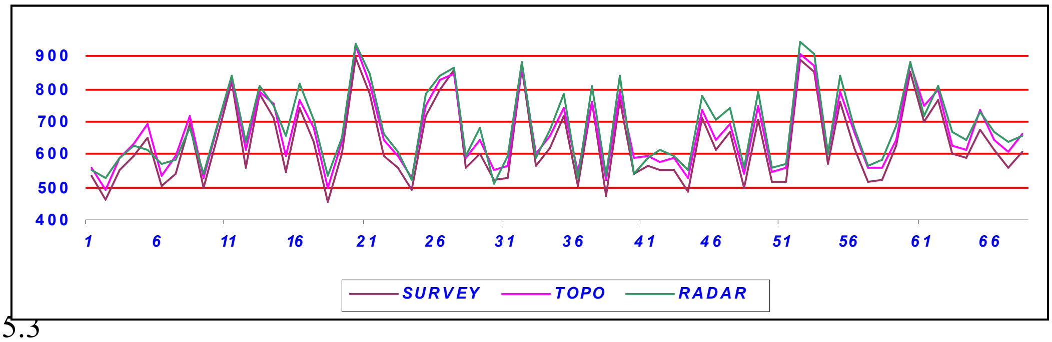
Table 2 present the accuracy statistic for DEMs extracted from hypsographic data and radarsat Stereo Images with the ground truth. The table shows that the DEM extracted from Radarsat stereo images had the lowest RMSE compare to the DEM, interpolate from contour line. The DEM extracted from Radarsat also had the lowest mean error and standard error statistic. The DEM extracted from Hypsographic Data generally over-estimate elevation by 6 meters, while the DEM extracted from Radarsat stereo images over-estimate elevation by 3 meters. The Standard error statistic and relative accuracy (standard deviation) suggest that DEM extracted from Radarsat stereo images perform slightly better than the DEM extracted from Hypsographic Data.

Table 2: Comparison of accuracy statistic for DEMs

	Hypsographic Data.	Radarsat Stereo Images.
RMSE	6.23	2.77
Standard Deviation	6.17	2.13
Standard Error	6.13	2.63
Mean Error	0.76	0.21

5.2 Surface Quality

The following graph, figure 3, shows the number of point (X-axis) and Y-axis shows the elevations derived from radarsat image, hypsographic data and field survey DEM elevations at same points. It may be observed that both of the lines maintain the same pattern with the elevations on moderate slopes exhibiting very close match, whereas on hilltops the difference increases slightly higher than actual. The failure areas are restricted either in high escarpment areas or in the mountainous terrain. The reason for such failures in Radarsat, appears to be principally due to layover and shadow effects of such terrains.



5.3

Figure 3: The number of point (X-axis) and Y-axis shows the elevations derived from radarsat image, hypsographic data and field survey DEM elevations at same points.

The last results are related to the DEMs accuracy as a function of the derivative topography surface. Figure 4 shows the Spectral Profile Viewer of the DEMs. The Spectral Profile Viewer allows us to visualize the reflectance spectrum of a single pixel. An overall natural shape of hills and valleys is visible. The DEM extracted from Radarsat stereo images results in round hills and gentle slope. Plains are flat and peaks are round but this characteristic less defined in DEM extracted from Hypsographic Data. In the DEM extracted from Hypsographic Data, the image visible is pointy, sharp hills and steep slopes.

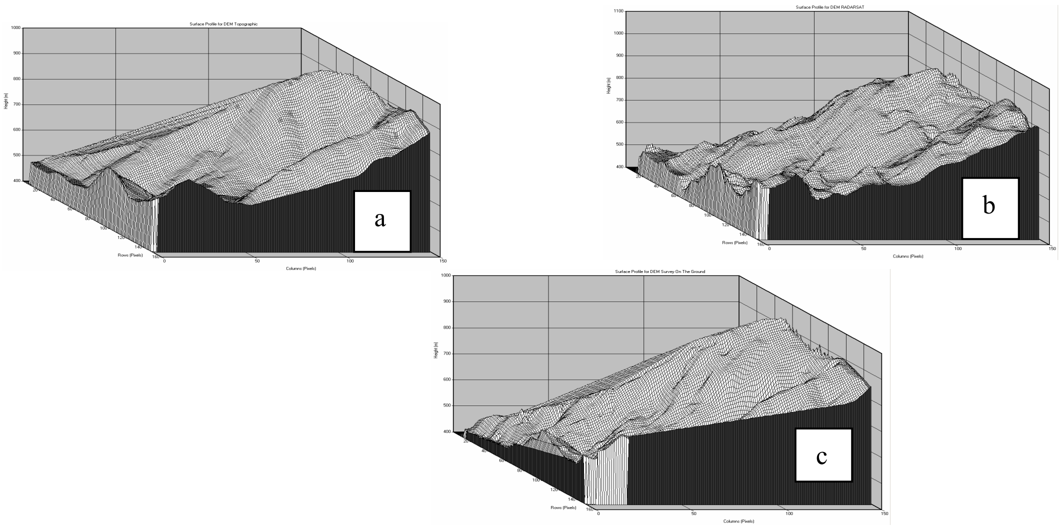


Figure 4: Surface Profile for DEM (a) Survey On The Ground, (b) Surface Profile for DEM Stereo SAR and (c) Surface Profile for Hypsography Data

6.0 CONCLUSION

The results described above show conclusively that it is possible to derive topographic data from stereo SAR data and give more accurate topographic information compared to the Hypsographic Data at the study site. Radarsat DEM does not exaggerate ground surface like Hypsographic Data. Peak and hill are not stretched and pointed, plain are flat and the overall curves of the ground more visible and follow the DEM-field surveyed pattern. This comes to conclusion that good quality DEMs can be created from Radarsat fine mode satellite image stereo pair.

Based on the results obtained in this study, it appears that Radarsat fine mode stereo images will prove suitable for a range of environmental mapping tasks involving the use of DEMs. Especially for forest road network alignments in the hilly forested area, at the study site.

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