UNIVERSITI PUTRA MALAYSIA

HEIGHT ACCURACY OF RADARGRAMMETRIC GENERATED DIGITAL ELEVATION MODEL

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By

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The stereoscopic concept used in photogrammetry was successfully extended to the optical sensor of SPOT (System Probatoire d'Observation de la Terre) to generate the digital elevation model (DEM) and to extract the planimetric features. Following this success, scientists are impressively encouraged to explore the feasibility of using stereoscopy on synthetic aperture radar (SAR) images, applying the radargrammetric technique. In the regions where cloud cover or darkness prevails, active microwave remote sensing data such as SAR can be fully utilized to procure information about land surface and forest canopy.

The objective of this study is to analyze the accuracy of the elevations extracted from the DEM generated using the radargrammetric technique as compared with the elevations generated from the photogrammetric technique. The capability of the radargrammetric technique and its potential in extracting the altimetric information were subsequently assessed.

The stereo RADARSAT images of Klang Valley with coverage of 100 km by 100 km were acquired. A total of 199 Ground Control Points (GCPs) were selected on relatively low terrains as backscattering radar data is very sensitive to the slope and high terrains. The primary input data was the coordinates of GCPs which were extracted from the topographical maps. When the errors produced in the GCP collection report were acceptable, the next process was creating epipolar images and generating DEM. It was then followed by generating the geocoded DEM.

The height accuracy analysis was carried out by comparing the elevation values extracted from the geocoded DEM with the original elevation values of GCPs. Comparisons with known points on the ground were also made for the purpose of checking. About 2% of the GCPs produced gross errors which were greater than 50 m or 4 pixels. Other errors were GCP conversion to check points (CPs) and falling into background or failure values. GCPs located closer to the water bodies which had zero intensity value experienced greater errors. Almost 94% of GCPs were eventually used for the height accuracy analysis. The DEM height accuracy was found to be between one to three pixels. The results obtained are very encouraging, showing that the radargrammetric technique has great potential to be considered for the future applications. However, further studies are still needed especially to identify exactly the probable causes for the occurrence of gross errors and ways to reduce or overcome these errors in order to increase the reliability level of the DEM generated using the radargrammetric technique.

Abstrak tesis yang dikemukakan kepada kepada Senat Universiti Putra Malaysia
sebagai mematuhi keperluan untuk mendapatkan Ijazah Master Sains

KETEPATAN KETINGGIAN MODEL KETINGGIAN BERDIGIT YANG DIJANA SECARA RADARGRAMMETRI

Oleh

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Konsep stereoskopi yang sebelum ini digunapakai di dalam kaedah fotogrammetri telah berjaya diperluaskan penggunaannya kepada sensor optik SPOT untuk menjana model ketinggian berdigit (MKB) dan paramuka planimetri. Kejayaan ini telah memberikan dorongan kuat kepada saintis untuk menerokai kemungkinan penggunaan konsep stereo yang dipanggil radargrammetri ke atas imej "Synthetic aperture radar" (SAR). Di dalam kawasan yang sering diliputi awan ataupun kegelapan, data gelombang mikro aktif seperti SAR boleh memberi faedah sepenuhnya untuk mendapatkan maklumat permukaan bumi dan silara hutan.

Objektif kajian ini adalah untuk menganalisis ketepatan ketinggian yang dihasilkan dari MKB menggunakan teknik radargrammetri berbanding dengan nilai ketinggian yang dihasilkan menggunakan teknik fotogrammetri. Keupayaan teknik radargrammetri dan potensinya menghasilkan maklumat altimetri kemudiannya telah dibuat penilaian.

Imej stereo RADARSAT kawasan Lembah Kelang yang meliputi kawasan seluas 100 km kali 100 km telah diperolehi. Sejumlah 199 titik kawal bumi (TKB) telah dipilih di atas permukaan rendah kerana pantulan balik radar adalah sangat peka bagi kawasan bercerun dan tanah tinggi. Data kemasukan utama ialah nilai kordinat dan ketinggian TKB yang diperolehi dari peta topografi. Apabila ralat yang dihasilkan di dalam laporan pengumpulan TKB telah boleh diterimapakai, maka proses membuat imej epipolar dan penjanaan MKB dimulakan. Proses seterusnya ialah penjanaan MKB "geocoded".

Analisis ketepatan ketinggian dijalankan secara perbandingan ketinggian yang didapati dari MKB "geocoded" dengan nilai asal ketinggian TKB. Perbandingan dengan titik-titik lain diatas tanah yang diketahui ketinggiannya juga dibuat sebagai langkah semakan. Lebih kurang 2% TKB telah menghasilkan ralat besar yang melebih 50 m atau 4 piksel. Lain-lain ralat ialah penukaran TKB kepada titik semak (TS) dan terjatuh ke dalam nilai laterbelakang atau nilai gagal. TKB yang terletak berhampiran dengan kawasan berair yang mempunyai nilai intensiti sifar juga mengalami kesan ralat. Hampir 94% TKB akhirnya telah dapat digunakan untuk membuat analisis ketepatan ketinggian. Nilai ketepatan ketinggian MKB yang diperolehi ialah diantara satu hingga tiga piksel. Keputusan ini sangat menggalakkan dan menunjukkan bahawa kaedah radargrammetri mempunyai potensi untuk dipertimbangkan di dalam aplikasi masa hadapan. Walaubagaimana pun, kajian lanjut masih diperlukan terutamanya untuk mengenalpasti dengan tepat punca berlakunya ralat besar dan langkah yang mesti diambil untuk mengatasi atau mengurangkannya bagi menambahkan tahap kebolehpercayaan terhadap MKB yang dijana menggunakan kaedah radargrammetri.

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I certify that an Examination Committee met on 22nd November 2002 to conduct the final examination of Abdul Hadi Abdul Samad on his Master of Science thesis entitled "Accuracy Of Radargrammetric Generated Digital Elevation Model" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any degree at UPM or other institutions.

ABDUL HADI ABDUL SAMAD

Date: 26/02/03

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LIST OF ABBREVIATIONS

1D	One dimensional
2D	Two dimensional
3D	Three dimensional
ACRS	Asian Conference on Remote Sensing
AirSAR	NASA's Airborne Synthetic Aperture Radar
ASL	Above Sea Level
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer is an imaging instrument that is flying on Terra, a satellite launched in December 1999 as part of NASA's Earth Observation System (EOS).
AVHRR	Advanced Very High Resolution Radiometer
C	C-band
CCRS	Canada Center for Remote Sensing
CP	Check Point
DEM	Digital Elevation Model
DVP	The digital stereo workstation developed by CCRS
EMR	Electromagnetic Radiation
EOC	Earth Observation Center
ERS-1	European Remote Sensing Satellite 1
ERS-2	European Remote Sensing Satellite 2
ESA	European Space Agency
F2	The RADARSAT image with fine mode 2
F5	The RADARSAT image with fine mode 5
GCP	Ground Control Point
H	Horizontally polarized
HH	Horizontal polarized transmission, horizontal polarized reception
HV	Horizontal polarized transmission, vertical polarized receptio
IFSAR	Interferometry SAR
IKONOS	IKONOS, launched on September 24 1999 is the first commercial high-resolution satellite.
INPE	Instituto Nacional De Pesquisas Espaciais
IRS	Indian Remote Sensing
LANDSAT	An earth orbiting satellite operated by the United States. The LANDSAT series of satellites first began in 1972 with the launch of ERTS-1, subsequent launches have occurred in 1975 (Landsat 2), 1978 (Landsat 3), 1982 (Landsat 4) and 1984 (Landsat 5). Landsat 6 was due to be launched in 1994, but failed.
LANDSAT-TM	An electromechanical sensor onboard the LANDSAT series of satellites (Landsats 4 and 5). A Thematic Mapper image will have data recorded in 7 spectral bands of the electromagnetic spectrum.
JERS	Japanese Earth Remote Sensing
JPL	Jet Propulsion Laboratory
JUPEM	Jabatan Ukur dan Pemetaan Malaysia
MACRES	Malaysian Center for Remote Sensing

MODIS	Moderate Resolution Imaging Spectroradiometer.
NASA	National Aeronautics and Space Agency
NMO	National Mapping Organizations
R&D	Research and Development
RADAR	RAdio Detection And Ranging
RADARSAT	Radar satellite launched by Canadian Space Agency in 1995
RMS	Root Mean Square
RMSE	Root Mean Square Error
RSI	RADARSAT International
RSO	Rectified Skew Orthomorphic Projection System
SAR	Synthetic Aperture Radar
SEASAT	The first earth-orbiting satellite designed for remote sensing of the earth's oceans and had onboard the first spaceborne SAR.
SFS	Shape From Shading
SGA	Synoptics Geo-Application Limited
SIR	Shuttle Imaging Radar
SLAR	Side Looking Airborne Radar
SPOT	System Probatoire d'Observation de la Terre
TP	Tie Point
TPS	Thin Plate Splines
V	Vertically polarized
VIR	Visible and Infra Red
VH	Vertical polarized transmission, horizontal polarized reception
VV	Vertical polarized transmission, vertical polarized reception

CHAPTER 1

INTRODUCTION

1.1 General

DEM data are sampled arrays of surface elevations in raster form which provide elevation values in rows and columns corresponding to a regular grid of points on the earth's surface. They are stored as a series of profiles in which the spacing of the elevations along and between each profile is in regular whole number intervals. The DEM has always been considered very useful for deriving elevations which are necessary in managing various geospatial applications such as drainage and watershed, surface slope calculation, ortho-image generation and other applications related to infra structural planning and development.

It is also important to recognize and appreciate the DEM that allocates accurate control measures during implementation of such applications. For example, drains must be laid down at such gradient angle so as to enable the water's free flowing which could be accomplished by applying the DEM data along the proposed project site. Similarly, by using the DEM an earthwork development can be carried out at a much faster pace within an optimum cost. An equitable amount of earth volume cutting down at higher terrain could be filled up at the lower level of the project area. In the first case, the higher order accuracy of DEM is required whereas in the latter, the lower order accuracy is acceptable.

In the olden days, the conventional land survey techniques using the survey instruments such as the theodolite, level and tacheometer were applied to generate elevation values of terrains that were later converted into contours for easy interpretation and presentation. However, these techniques have proven to be very slow, tedious and indeed uneconomical especially for larger and rugged terrains.

Subsequently, the photogrammetric technique which utilized the stereo aerial photographs as its prime source of input data was introduced. Since then, this technique has been applied by most of the national mapping organizations (NMO) throughout the world to produce the various types of maps. The photogrammetric technique has been opted basically due to its capability to satisfy the accuracy compliance required in the mapping specifications.

A stereo model needs to be generated from a pair of the stereo aerial photographs before the geographical information can be extracted. It has distinguished characteristics that facilitate the extraction of both the planimetric and altimetric information. Nevertheless, this technique is quite tedious, time consuming and costly, particularly for developing large project areas that require periodical revision of outdated information.

Recent advances in the computer technology involving its speed, data handling and storage capability, and growing demand for the digital databases and computer based mapping production capabilities have encouraged the use of remotely sensed information as a data source for mapping applications. With the emergence of high spatial resolution data, such as a 1 m spatial resolution IKONOS image, the application of the visible infra red (VIR) remote sensing data has increased progressively. Scientists have continuously carried out numerous research studies to extend the use of the aerial photographs in the stereoscopic viewing concept to other remote sensing data, such as SPOT and SAR to generate the medium scale map of 1:100,000 or larger.

The radar data is comparatively often considered a superior data source since it is capable of collecting data in nearly every atmospheric condition by day and night. Due to the high spatial resolution of civilian satellite SAR sensors since the 1980s with the Shuttle Imaging Radar (SIR), a large number of researchers around the world have investigated the elevation modeling and the production of DEMs (Toutin and Gray, 2000). In addition, the recent research in the computer vision to model human vision has led to the advent of new alternatives applied to the satellite imagery. SAR data in different formats can be processed by different methods, taking advantage of different sensors and image characteristics using different types of technology and processing. It has thus allowed the mapping process to become more automated, though not completely due to the occasional matching failures.

To date, the radar remote sensing technology offers many new and unique observational possibilities, such as the use of the advanced multi frequency polarimetric and interferometric (IFSAR) systems as well as radargrammetry. Each system which has its own unique capabilities in extracting data can be used complementarily to each other to maximize its benefits.

1.2 Problem Statement

Since the last five years, request for the mapping digital data produced by the Department of Survey and Mapping Malaysia (JUPEM) has soared up remarkably. The users need the latest information which requires JUPEM to update its data periodically. This request is necessary in order to avoid the ground disorientation which is caused by the obsolete data, especially in the urban and fast-developed areas. Nevertheless, due to unanticipated factors, JUPEM has not been able to meet its clients' demand. One of the principal factors which has been identified by JUPEM is its inability to obtain the aerial photographs routinely at any desired time and location.

The problem arises because aerial photography is exposed to the various environmental phenomena, especially the presence of persistently heavy cloud cover which is absolutely beyond the human control. Consequently, mapping production or updating in any affected area is delayed indefinitely, causing difficulties to users who badly needed the geographical information to carry out their development projects. Due to this problem, the expectation on extensive research and development (R&D) studies which will produce an alternative data source has always been high. Recently, the radar development uncovered that its unique characteristics can penetrate the cloud cover, thus bringing it much closer to become an alternative data for aerial photographs. The author's decision to explore the radar application technology is thus encouraged and motivated by the high expectation of the usage of radar.