DEVELOPMENT OF TOPOGRAPHIC DATABASE USING GLOBAL DIGITAL TERRAIN MODELS AND MEDIUM RESOLUTION SATELLITE IMAGERIES

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ABSTRACT

Computer technology has drastically revolutionizing mapping disciplines. The availability of powerful database engine supported by geographic information packages has attracted many mapping agencies to improve the capability and versatility of their topographic database. A quality digital Topographic Database (TDB) is indispensable for geographic information users and economic development projects. The input data quality and database structure are crucial in the development of a versatile topographic database. In this study, the prototype of topographic database for the Sultanate of Oman is designed and developed. ArcGIS Software package has been used in this study for the database development. Topographic Database was designed in three main phases, conceptual, logical and physical models. The integration between TDB contents show a compatibility with geo-referencing image and data quality after a ground truth adjustment. The suitability of vertical and horizontal components of Shuttle Radar Topographic Mission (SRTM) elevation data and Indian Remote Sensing (IRS) 5m imagery have been analysed in this study. The assessments are made for the development of topographic database at 1:50,000 map-scales. Analyses show that the SRTM and IRC medium resolution image can be used as an alternative source of large scale topographic map production. Assessments of TDB indicate that the spatial-attribute relationships are of good quality and can be a model for nationwide topographic database development for the Sultanate of Oman

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ABSTRAK

Teknologi perkomputeran telah secara drastic merevolusi displin pemetaan. Kewujudan enjin pangkalan data yang berkuasa yang didokong oleh pakej-pakej maklumat geografi telah menarik banyak agensi pemetaan untuk menambahbaik keupayaan dan keserasian pangkalan data topografik mereka. Pangkalan Data Topografik yang bermutu amat diperlukan oleh para pengguna maklumat geografi dan bagi projek pembangunan ekonomi. Sumber data yang bermutu serta rekabentuk pangkalan data adalah penting dalam membangunkan sesuatu pangkalan data yang dinamik. Dalam kajian ini, prototaip bagi pangkalan data Kesultanan Oman telah direkabentuk dan dibangunkan. Pakej perisian ArcGIS telah digunakan dalam pembangunan pangkalan data tersebut. Pangkalan Data Topografi (TDB) direka dalam tiga fasa utama iaitu konseptual, logikal dan fizikal. Perbezaan integrasi kandungan TDB menunjukkan keserasian imej rujukan dan kualiti data selepas pelarasan.Kestabilan komponen pugak dan mendatar bagi data ketinggian Shuttle Radar Topographic Mission (SRTM) dan imej satelit Indian Remote Sensing Satellite (IRS) juga turut dianalisa dalam kajian ini. Penilaian dibuat berdasarkan pembangunan pangkalan data pada skala 1:50,000. Analisa menunjukkan data SRTM dan imej resolusi sederhana IRC boleh digunakan sebagai data pilihan bagi penghasilan peta topografi berskala besar. Penilaian terhadap DTD menunjukkan terdapat perkaitan yang baik diantara data ruang dan attribute yang mana boleh dijadikan model untuk pembangunan pangkalan data topografi kebangsaan bagi Kesultanan Oman.

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LIST OF ABBREVIATION

ASCII	**American Standard Code Information Interchange**
DBMS	**Database Management System**
DGI	**Digital Geographic Information**
DGIWG	**Digital Geographic Information Working Group**
DTED	**Digital Terrain Elevation Data**
DTM	**Digital Terrain Model**
FACC	**Feature and Attribute Coding Catalogue**
FK	**Foreign Key**
GCP	**Ground Control Point**
GIS	**Geographic Information System**
GPS	**Geographic Positional System**
IRS	**Indian Remote Sensing Satellites**
NASA	**Aeronautics and Space Administration**
NGA	**National Geospatial-Intelligence Agency**
NSA	**National Survey Authority**
NTDB	**National Topographic Database**
ODBMS	**Object Database Management System**
ORDBMS	**Object-Relational Database Management System**
PK	**Primary Key**
RMSE	**Root Mean Square Error**
RDBMS	**Relational Database Management system**
SQL	**Structured Query Language**
SRTM	**Shuttle Radar Topography Mission**

TDB	**Topographic Database**
TIN	**Triangulated Irregular Network**
UTM	**Universal Transverse Mercator**
WGS	**World Geodetic System**

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Computer technology has revolutionised topography and cartography disciplines; geodetic data is collected and calculated almost exclusively by computer. The stereo photogrammetric compilation of aerial or satellites images depends largely on computer-assisted hardware and software.

Due to several reasons such as map updates requirements, cartographic need for different proposes and new digital software, National Topographic Data Base (NTDB) becomes very important. In addition to that, the NTDB is highly useful to users of geographic information systems (GIS) and is a good data source for the creation of thematic maps. NTDB is required to support economic development, resource management and other related activities conducted by government and non-government users of geographic information.

NTDB is a digital topographic database for the entire Sultanate of Oman. Topographic Data Base (TDB) includes all features normally found on topographic maps at the scale of 1:50,000 and adder to the provincial standards specifications. The TDB is able to provide multiple uses while, at the same time reducing duplication of effort and ensuring that the products can easily be exchanged and integrated.

The topographic database will consist of a number of individual GIS layers (ArcView format) that can be viewed separately or can be combined to create a composite map. Many themes will exist at a scale of 1:50,000 including: transportation networks, hydrology features, vegetation, urban features, landforms and relief (contours). TDB will be used as an excellent base for many Geographic Information Systems (GIS) and desktop mapping applications.

TDB standards, specifications, metadata, data dictionary will be created, therefore in order to carry out geometric assessment of TDB, capture features of geo-reference satellite coverage will be identified.

The Shuttle Radar Topography Mission (SRTM) data set (90 meter accuracy) of a study area in Sultanate Oman acquired freely from the internet, after had been unable to obtain (30m) accuracy from the producer.

1.2 Literature Review

A topographic map depicting terrain relief showing ground elevation usually represented through either contour lines or spot elevations. The map represents the horizontal and vertical positions of the features. It is a graphic representation delineating natural and man-made features of an area or region in a way that shows their relative positions and elevations.

The independence of the layers which represent those features usually leads to difficulties in overlays, since those points and lines which should be identical vary from layer to layer by the amount of their uncertainty. The individual layers must therefore be built up from a common geometric base. One needs, in addition to an edgenode topology and a surface topology, a "vertical" topology (Pilouk and Kutouiyi, 1994).

Therefore database design is very important to reduce the diffusion and duplication during capturing or drawing. However database design undergoes different stages such as conceptual, logical and physical models. The conceptual model can be created through user's view by collection data reports, then define objects and relationships and select the geographic representation.

Logical model of geographic database types supported by the GIS to be used to create and maintain the database. This can be implemented in Oracle, Microsoft access, Arc GIS or any proprietary system. This is defined as a logical modelling task. Organize geographic database structure includes items such as defining topological associations, specifying rule and relationships, and assigning coordinate system through data model (Goodchild *et al*., 2001).

The final stage is definition of actual physical database schema which defined as physical model. This is usually created using Database Management Systems (DBMS) software's data definition language. The data model is the mechanism used to represent real-world objects digitally in the computer system. All DBMS include standard general-purpose data models suitable for representing several types of objects.

The geodatabase supports a model of topologically integrated feature classes, similar to the coverage model. It also extends the coverage model with support for complex networks, relationships among feature classes, and other object-oriented features. The ESRI® ArcGIS applications (ArcMap., ArcCatalog., and ArcToolbox.) work with geodatabases as well as with coverages (Andrew M., 1999).

Nations may differ in their concepts for digital production. In one case, a range of products may be produced by largely separate production processes. For each product, data is extracted from source material and that data is then formatted for the specific product in the input to a product database, from which the needs of users are constrained to use a limited range of standard products. The product data may be further transformed, by the user, to obtain data in the precise form needed (Geomatics Canada, 1997).

International exchange standards for Digital Geographic Information (DGI) are the principal concern of Digital Geographic Information Working Group (DGIWG). The development of a multi-national digital geographic information system is needed to facilitate the exchange. The system consists of standards and procedures needed to permit data to be exchanged among nations.

Major features categories, different from counter to counters up on their needs and products. However, the feature types are identified through their characteristics. The definition of a kind of geographical entity will place it in a particular view and, perhaps, subview. For instance the Digital Geographic Information Exchange Standard (DIGEST) has ten major features while Canada NTDB have fourteen and Malaysia has twelve feature categories.

The aim of the feature and attribute coding specification is to provide a standard scheme for documenting features and attributes necessary to distinguish those features commonly found in a Digital Geographic Information System and for the orderly exchange of such data. Within Feature and Attribute Coding Catalogue (FACC), each feature is identified by a unique five-character code. The first character corresponds to the feature category and can have an alphabetic value from A to Z (DGIWG Part 4, 2000) as seen in UK , Canada and Malaysia features attributed codes.

Digital Terrain Models (DTMs) are digital files consisting of points of elevations, sampled systematically at equally spaced intervals. It is captured normally thought photogrammetric workstation from aerial photograph. However the elevation information can be extracted from satellites observation, for example SRTM.

The Shuttle Radar Topography Mission (SRTM) is an international project spearheaded by the National Geospatial-Intelligence Agency (NGA) and the National Aeronautics and Space Administration (NASA) to obtained elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of Earth. SRTM consisted of a specially modified radar system that flew onboard the Space Shuttle Endeavour during an 11- day mission in February of 2000 (Hounam and Werner, 1999).

The elevation information is derived from the signals reflected on the Earth's surface. Depending on the wavelength the radar signals penetrates the ground coverage and in some cases even the ground. The short wavelength of the X-band however, normally causes normally a reflection on the surface producing a height surface model similar to the optical stereo case. The Digital Terrain Elevation Data (DTED) is a cell defined by latitudes and longitudes of a geographic reference system. The terrain elevation information is expressed in meters. The locations of elevation posts are defined by the intersections of rows and columns within a matrix.

Each elevation is a true value referenced to mean sea level datum recorded to the nearest meter. The horizontal position is referred to the longitude-latitude locations in terms of the current World Geodetic System (WGS), determined for each file by reference to the origin at the southwest corner. The elevations are evenly spaced in latitude and longitude at the interval designated in the user header label in a South to North profile sequence.

1.3 Problem Statements

National Survey Authority (NSA) is the national mapping agency of the Sultanate of Oman related to Ministry of Defence. It is responsible for creating and maintaining NTDB. NSA compiles the specifications for both 1:50,000 and 1:100,000 map scales. The specification have been implemented by foreigner consulting staff who have definitive set decampment entitled Featured Attribute Coding Catalogue (FACC) to be adapted as the base of digital captured. This database is under evaluation after its implementation in a new digital software. This study will focus on creating GIS TDB for 1:50,000 map scale. In addition TDB will be the basic model of NTDB which has not yet been implemented in the sultanate.

At present DTM is collected manually through stereo photogrammetric compilation of aerial photos which is time consuming and tedious. With New technology, it is found that manual data captured which has been replaced with SRTM to produce digital terrain models with 90 m accuracy (Appendix A). Consequently it is worth if this product suitable to our 1:50,000 map production. SRTM is free and cover all the Sultanate's lands. SRTM is evaluated in order to gather information about it's suitability with different terrain phenomenon. The train model of the sultanates is ranging from 3000m in the mountainous area and 0 m level in the flat area close to the shore line. The outcome from this study can be used as a basic model of National Digital Topographic Database of the Sultanate's of Oman.

1.4 Objectives of the Study

This proposed research aims to achieve the following main objectives:

(i) To analyse and evaluate the existing global DTM models (STRM 90) for 1:50,000 mapping purpose.

(ii) To create 1:50,000 map scale TDB using combined global DTM models and medium resolution satellite imageries.

1.5 Scopes of Research

In order to achieve the research objective the scope of research will cover the following aspects:

(i) Acquisition of Global DTM Models SRTM (90m accuracy).

1. Reference ground control point and check points.
2. Captured DTM.
3. Accuracy Assessment.

(ii) Acquisition of Medium Resolution Satellite Imageries 5 m Resolution.

1. Extraction of remote sensing data for (20×20km) of selected study area.
2. Ground control observation.
3. Geo-referencing of the satellite image scene.
4. 2D feature capturing for topographic mapping.

(iii) Review of Digital Topographic Mapping Requirements for 1:50,000.

1. Creation of topographic map standards.
2. Topographic specifications for 1:50,000 scale.
3. Topographic database specifications .

(iv) Establishment of DTDB Creation Procedure.

1. Catalogue features code.
2. Features attributes.
3. Logical model (create Schema).
4. Physical model (developing database)

(v) Topographic Database Analysis

1. Attribute and spatial accuracy.
2. Entity-attribute agreement.

1.6 Significant Of Study

The significances of this study include:

i. Preparation of a guide line for establishment of National Topographic Database for Sultanate of Oman.
ii. Production of Topography Database at 1:50,000 map scale.
iii. Verification of the capabilities of using 90 SRTM satellite image for 1:50,000 maps.

1.7 Research Methodology

The research methodology basically implemented into four phases to achieve the objectives of the research as in Figure (1.1). Those phases had discussed in detail in both chapter 3 and 6 .

(i) Assessment of SRTM 90 DTED

The accuracy of SRTM DTM is assessed by comparing the values with known elevation values (ground control and check points). The accuracy assessment of SRTM data also include the computation of minimum and maximum differences of elevation value between SRTM and check point. Statistical analysis (Root- mean – square - error (RMSE) and Standard deviation) of the elevation difference is tabulated.

(ii) Geo-referencing Satellite Image.

The satellite imagery for the study area geo-referenced using ground controls (GPS) and be assessed using check points.

(iii) TDB design and development

There are three main Phases in TDB design and development as follows:

1. **Requirements Phase:** is a data model is developed where Data model is a logical representation of the database structure.
2. **Design Phase**: the data model is transformed into tables and relationships.
3. **Implementation Phase**: Tables, relationships, and constraints for TDB are created however, the database is filled and systems tested are stored in addition to that procedures and triggers will be written.

(iv) Assessment of TDB will involve :

1. Spatial accuracy.
2. Attribute accuracy.
3. Agreement between spatial and attribute.
4. Ground truth survey.
5. Generalization effect.
6. Digitizing error.
7. SQL operation.

(vi) Map Production and Evaluation.

A digital data will be set at the 1:50,000 scale covering about 40 km^2window or approximately 20 km (30 arc-minutes) by 20 km (30 arc-minutes) for Muscat area. The

Data Format which used to create TDB is in ArcView Shape file format or other formats request.

Two types of accuracy are assessed NTDB: planimetric (X, Y) and altimetric (Z). They vary depending on the data source (global satellite imager and DTM). In addition to that, the implementation of NTDB will be evaluated during digitizing process.

1.8 Thesis Outlines

The study thesis is subdivided into eight chapters as follows:

(i) **Chapter 1** is the introductory chapter. It explains the background of the study research objectives, problems statements, research methodology, scope of the research and literature review.

(ii) **Chapter 2** discusses the theoretical background for the main important points encountered in the study.

(iii) **Chapter 3** focuses on given evaluation of data sources which are involved in this study. In this chapter quality assessment for 90 m RSTM DTM methods for 1:50,000 map was covered. The accuracy of DTM is determined by comparing known elevation values (check points) on the terrain surface with RSTM DTM.

(iv) **Chapter 4** explains geo-reference steps of 5m satellite image which is used to digitize TDB features.

(v) **Chapter 5** describes standards and specifications of TDB including the criterion of topographic maps 1:50,000 based on a few international models and countries.

(vi) **Chapter 6** presents topographic database design stages using Arc GIS Software. Catalogue features code, features attributes schema; physical model and logical model are discussed in detail.

(vii) **Chapter 7 concentrates** in research results analysis. The analysis includes SRTM assessments, ground truth image geo-reference check and Topographic Database Analysis. TDB analysis includes attributes and spatial accuracy and entity-attribute agreement appraisal.

(viii) **Chapter 8** concludes a summary and recommendations starting with a brief discussion about the work together with recommendations for further improvement.

1.9 Summary

GIS based topographic database facilitates the map production process. This technology provides fast and reliable topographic database. TDB has an advantage such as easy distribution, minimum duplication data, provides the data format exchange capability, and different models of output. STRM dataset is an alternative way to acquaint about elevation information for a large area. It is a reliable source for DTM generation especially for map production, depending on the map scale required.

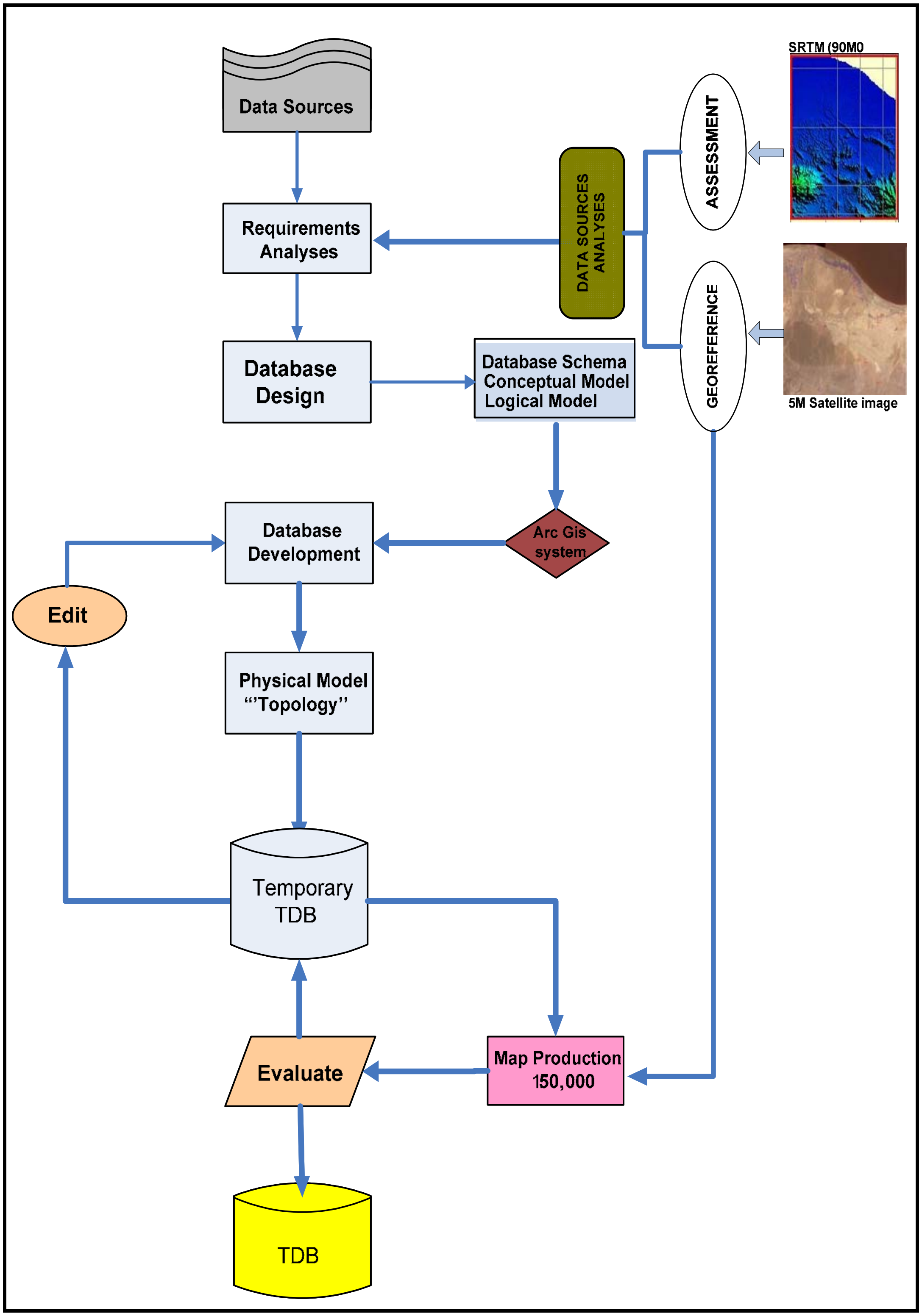

Figure 1.1: Research methodology steps