UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF A SPATIOTEMPORAL DATA MODEL FOR MANAGEMENT AND VISUALIZATION OF SURFACE MOVEMENT DATA

MOHD SHAFRY BIN MOHD RAHIM

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By

MOHD SHAFRY BIN MOHD RAHIM

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

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DEDICATION

This work is dedicated to my family members who are always giving me encouragement and support

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

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Chairman: **Associate Professor Abdul Rashid Mohamed Shariff, PhD**

Faculty: **Institute of Advance Technology**

Spatiotemporal data is a part of geographical data required in Geographical Information System (GIS). Generally, the existing GIS are not suited to manage changes occurring in the data with time. The capability of managing geographic data with time depends on the underlying data model in which the data model has to take into account the spatiotemporal aspects of the geographic data. Thus, a Spatiotemporal Data Model is required to manage changes in GIS data. Spatiotemporal Data Model represents the abstraction of data management in GIS. Surface movement on three dimensional objects is one of the spatiotemporal data which represents changes of the surface taking place in geographic phenomena. However, current Spatiotemporal Data Model and current GIS software are not adequate for managing the surface movement of three dimensional objects while representing the data. Most of the existing data models brought us to the conclusion that a new Spatiotemporal Data Model is needed to improve the management of three dimensional data with temporal element. Therefore, a new Spatiotemporal Data Model, Surface Movement Spatiotemporal (SMST) Data Model is proposed, which supports the management and visualization of surface movement data in three

dimensional objects such as terrain model. The data model were developed under consideration of real world events together with current data collection, for example, a terrain model in the geographic phenomena which deals with changes from time to time based on natural phenomena and human activity. The data were collected by capturing images from time to time. Formalization of the surface movement reconstruction is a fundamental knowledge to develop the SMST Data Model. Currently, in many fields, surface reconstruction does not consider the temporal element. Therefore, the surface movement of three dimensional objects is formalized by enhancing the surface reconstruction method; that is by integrating it with temporal element. In order to test and evaluate the SMST Data Model, a database management system with a loading and a retrieval algorithm suitable to this model were developed. The retrieved data from the database system is saved in the proposed data format for surface movement visualization. In developing the visualization tool, visualization algorithm was used by employing the morphing technique which uses parametric equation. The proposed model was tested using digital terrain model digitized from a series of aerial photos. The model can store and manage surface movement data while reducing the redundancy of data in the database system. Percentage of reduced data redundancy is based on the number of points involved in the movement process. The model stores only the movement points in the surface. Besides, the proposed model can retrieve data for simulating surface movement on the three dimensional object. Therefore, the major contributions of this research are the formalization of surface movement data and the proposed SMST Data Model which can manage surface movement data on three dimensional objects with respect to time.

Abstrak tesis yang dikemukakan kepada senat Universiti Putra Malaysia sebagai memenuhi sebahagian keperluan untuk ijazah Doktor Falsafah

PEMBANGUNAN MODEL DATA SPATIOTEMPORAL UNTUK PENGURUSAN DAN VISUALISASI DATA PERUBAHAN PERMUKAAN

by

MOHD SHAFRY BIN MOHD RAHIM

Januari 2009

Pengerusi: **Professor Madya Abdul Rashid Mohamed Shariff, PhD**

Fakulti: **Institut Teknologi Maju**

Data “Spatiotemporal” adalah sebahagian daripada data geografi yang diperlukan oleh Sistem Maklumat Geografi. Sistem Maklumat Geografi sedia ada tidak sesuai untuk digunakan bagi tujuan mengurus data geografi yang mempunyai faktor masa. Keupayaan untuk mengurus data geografi yang mempunyai faktor masa adalah bergantung kepada model data. Model data itu perlu mengambilkira faktor masa. Oleh itu, Model Data “Spatiotemporal” diperlukan bagi mengurus perubahan dalam data geografi. Perubahan permukaan dalam tiga dimensi adalah sebahagian daripada data “spatiotemporal” yang menerangkan perubahan yang berlaku. Model Data “Spatiotemporal” dan perisian Sistem Maklumat Geografi tidak dapat memenuhi keperluan untuk mengurus dan visualisasi data perubahan permukaan dalam tiga dimensi. Satu Model Data “Spatiotemporal” yang baru perlu bagi mengurus perubahan permukaan dalam tiga dimensi. Oleh itu, Model Data “Spatiotemporal” Perubahan Permukaan telah dicadangkan yang mana ia mempunyai keupayaan untuk menampung keperluan pengurusan dan visualisasi data perubahan dalam tiga dimensi seperti perubahan bentuk muka bumi. Model data ini telah dihasilkan

berdasarkan kepada fenomena perubahan permukaan bentuk muka bumi yang berlaku dan proses pengumpulan data yang sering dilakukan. Secara umumnya, gambar udara diambil dari masa ke semasa bagi mengumpul data untuk melihat perubahan. Formalisasi pembentukan perubahan permukaan menjadi asas ilmu untuk menghasilkan Model Data "Spatiotemporal" Perubahan Permukaan. Dalam kebanyakan bidang, pembentukan permukaan secara tiga dimensi tidak mengambilkira faktor masa. Oleh yang demikian, definasi perubahan permukaan untuk objek tiga dimensi perlu ditakrifkan. Untuk melaksanakan pengujian terhadap model data yang dicadangkan, satu sistem pengurusan pangkalan data dengan algoritma kemasukan data dan pengambilan data dibangunkan. Data yang diambil daripada pangkalan data disimpan dalam satu format fail untuk visualisasi perubahan permukaan. Visualisasi perubahan permukaan tersebut dihasilkan dengan menggunakan persamaan parametrik. Model yang dicadangkan diuji dengan menggunakan siri foto udara. Hasil daripada pengujian, model tersebut boleh menyimpan dan mengurus perubahan permukaan disamping dapat mengurangkan kadar pertindihan data dalam pangkalan data. Peratusan pengurangan pertindihan data adalah bergantung kepada jumlah titik yang terlibat dalam proses perubahan. Hanya data yang dikenalpasti berubah sahaja disimpan dalam pangkalan data. Disamping itu, ia dapat mengeluarkan data bagi simulasi perubahan permukaan secara tiga dimensi. Dalam kajian ini, sumbangan ilmiah adalah formalisasi perubahan permukaan dan Model Data "Spatiotemporal" Perubahan Permukaan. Ia boleh mempunyai keupayaan untuk menguruskan data tiga dimensi bersama dengan parameter masa.

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I certify that an Examination Committee has met on **3 December 2008** to conduct the final examination of Mohd Shafry bin Mohd Rahim on his Doctor of Philosophy thesis entitled **"Spatiotemporal Data Model for Surface Movement Data Management and Visualization"** 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 Doctor of Philosophy.

Members of the Examination committee were as follows:

Jamarei Othman, PhD
Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Mohd. Amin Mohd. Soom, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner 1)

Helmi Zulhaidi Mohd. Shafri, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner 1)

Tengku Mohd. Tengku Sembok, PhD
Professor
Faculty of Information Science and Technology
Universiti Kebangsaan Malaysia
(External Examiner)

SHAMSUDDIN SULAIMAN, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date : 30 January 2009

This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirements for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Abdul Rashid Mohamed Shariff, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Shattri Mansor, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Ahmad Rodzi Mahmud, PhD
Associate Professor
Faculty of Engineering
University Putra Malaysia
(Member)

_____
HASANAH MOHD GHAZALI, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date : 9 April 2009

DECLARATION

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

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MOHD SHAFRY BIN MOHD RAHIM

Date: 30 January 2009

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Geography is a science of universe which describes phenomena, activity and time of an event occurring in the world (Narciso, 1999). It can be classified into three major areas: physical geography, human geography, and regional geography (Yattaw, 1997). Physical geography deals with natural phenomena for example Geomorphology, Climatology, Biogeography, Hydrology, Soil Geography and Environmental Management. Human geography takes care of the human activities, for example developing a city, managing resources, preserving and promoting significant cultural and historical values, and stabilizing the economy. Regional Geography compounds the issues related to the management of area for example Department of Surveying and Mapping Malaysia (JUPEM) activities of survey and mapping.

However, it cannot be denied that all aspects of geography involve the factor of ‘time’. This is the single most important element in determining the moments for the occurrence of a specific phenomenon. For describing a phenomenon it has been observed that there are three important questions i.e. ‘What’, ‘Where’ and ‘When’. The 'What’ question is generally extended for the introduction of the phenomena, the ‘Where’ question often deals with the geographical location of the phenomena in question and the ‘When’ question reveals the time factor of that specific phenomena. It may be noted that,

this factor brings to the surface period and duration of certain activities. Besides, it also unfolds a variety of important historical information. Figure 1.1 shows a Triadic Model describing the relationship among these three fundamental questions. It shows temperature of 32^0C occurring at location $5^0$25'00'North and $101^0$08'00'East, at Gerik, Perak, Malaysia on 19th January 2008.

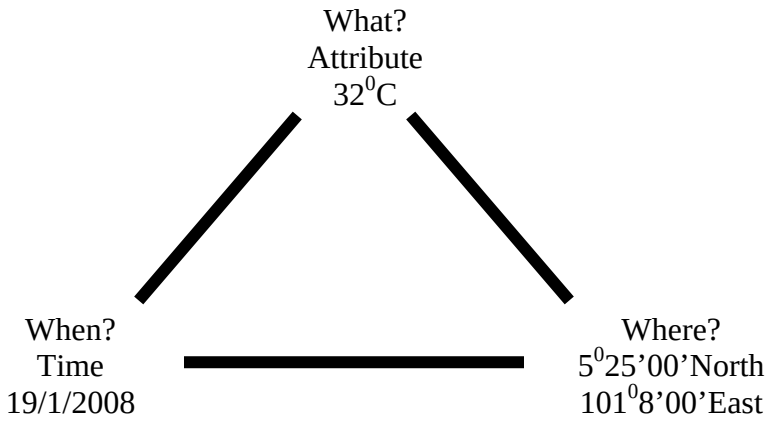

Figure 1.1. Triadic models of Space, Time and Attribute

Geographic movement refers to change of geographic information. These changes take place in various forms. Some changes affect locational data, some affect attribute data and some changes affect all of the data. It may be noted that change is a continuous process. Therefore, it cannot be ruled out that some times, new features and information may be observed due to this 'change' phenomenon. These changes are always described in the light of a single, most important factor, i.e. 'time'. Due to the enormous importance

of geographic movement, it has been classified into twelve categories (Nassima *et al.*, 2002).

Most of the GIS use data without thoroughly looking into movement or time in the application and software. However, Arcview software (Hogeweg, 2000; Gil and David, 2004; Jonathan *et al.*, 2003) carries an additional tool for handling 'time' factor. Additionally, Spatial Temporal Geographical Information System (STEMGis) (Morris *et. al.*, 2000) is a software that possesses the capability of managing geographic movement data. However, this software still has some serious shortcomings as it fails in dealing with the complete set of classification of the geographic movement data.

This research investigates commercial GIS software such as GeoMedia, STEMGis, Mike 11 and ArcView. All these software have different architecture and different data model to manage GIS data. In order to support geographic movement application, supplementary software and other development tool are still needed (Liyun *et. al.*, 2006; Raffaetà *et. al.*, 2008). Despite all these developments, a comprehensive examination of these application software comfortably confirms that generally, the current application does not fully support geographic movement analysis (Jin *et. al.*, 2007b). Besides, there is a growing tendency of working in high dimensional data and at present, there is no system that can manage three dimensional data under an integrated environment.

This research focuses on the data management aspect whereby a suitable data model for storing and retrieving geographic movement information for the principal objectives of analysis, manipulation, presentation and visualization. To solve this issue, a suitable Spatiotemporal Data Model is developed.

1.2 Problem Background

It is a well established fact that data management plays an important role in the application or software development. Data management deals with the data storing and data retrieval process. The reliable performance of this component will have an effect on other components such as analysis and manipulation; representation and visualization in system or software. Therefore, to achieve good data management, a good data model is a prerequisite.

This research deals with the development of spatiotemporal data model for geographic movement application. There are twelve important classes of geographic movement (Yattaw, 1997). These classes are divided into three basic categories of changes type like cyclical, intermittent, and continuous movement. There are several important issues regarding spatiotemporal data modeling (Sellis, 1999; Yattaw, 1997; Narciso, 1999; Langran, 1992; Glenn and Hanan, 2000; Hatayama, 2002; Li *et al.*, 2002; John *et al.*, 2004). These issues must be settled to meet the requirement of dynamic phenomena in the world. Through an extensive survey, it has been concluded that there

are six properties of spatiotemporal data which needs to be considered while modeling spatiotemporal information in GIS (Sellis, 1999; Yattaw, 1997; Narciso, 1999; Li *et al.*, 2002; John *et al.,* 2004). These properties include: space, time, space-time, scale, non-spatial data and historical.

Majority of the existing software support spatiotemporal data for point, line and area, as such, a lot of focus is on 2D data. Relational database model were used in these software and tools. The visualization is done in an animated map (D'Onofrio and Pourabbas, 2003; Hogeweg, 2000; Moris *et al.,* 2000). In spite of all these developments, these systems lack decision making ability mainly because of the unsystematic integration of the data (Geoffrey *et al.,* 2004; John *et al.,* 2004). This confirms that semantic relationship and ontology among the data cannot be obtained clearly and comfortably.

A major shortcoming of ArcView, GeoMedia, Mike 11 and the STEMGis is a lack of tools for managing geographic movement data. Though the available software is powerful, for example ArcView and GeoMedia have a great functionality for visualization of the data, Mike 11 has powerful analysis in hydrological and time series data, STEMGis has capability to handle temporal data, yet these application softwares need significant enhancement in dealing with diverse GIS. This is so, as geographic movement involves spatiotemporal data which requires the integration of space and time with their own attribute for establishing a detailed analysis and this is lacking in the above mentioned softwares.