Faculty of Information and Communication Technology

MOVING OBJECTS DATABASE FOR GIS-BASED EMERGENCY RESPONSE SYSTEM

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ABSTRACT

Road traffic accidents (RTA) are among the ten causes of death in the world (WHO, 2006). Just like any other emergency events, immediate response in RTA is extremely needed to minimize greater damage and casualties. In other words, an effective and efficient emergency response management is able to minimize unnecessary risks. Emergency Response System (ERS) is a very important application in today society. It is a system that designed to provide assistance to emergency responder to deal with emergency situation.

The implementation of Geographic Information System (GIS) in ERS has become widely used nowadays. When responding to an incident, first responders can use GIS to identify the various resources required – police, ambulances, fire fighters in order to help respond to an emergency in a timely and efficient manner. Parallel to that, the overall objective in GIS for emergency response is to deliver accurate, appropriate timely information to all the parties involved in an emergency case at the proper stages of the emergency. From the previous statement, it is clearly stated that time is an inherent aspect in ERS. Moreover, it is apparent that ERS is an application that deals with not only with spatial but also with temporal aspects. Therefore, time must be treated as an integrated dimension rather than an attribute. However, in reality, most implementations of temporality in GIS database still treat the two as quite separate. For that reason, ERS requires the management of spatial and temporal data. As stated above, ERS deals not only with static but also dynamic object. Consequently, the implementation of Moving Objects Database (MOD) as a backend for ERS is necessary.

The purpose of this study is to develop a generic model of MOD for ERS especially in RTA. A generic model of Moving Objects Database for GIS-Based Emergency Response System called MODGERS has been developed. The basic requirements to develop such system are discussed in this research. The integration of temporal element into the coordinate system as 3D (2D + time) is also highlighted. Furthermore, technique in querying current, future, continuous and past location of moving objects data is also presented. In this research, we use vector-based tracking to estimate the current location of the moving object. On the other hand, the segment-based tracking is used to solve future and past query problems. A real time simulation has been conducted to validate the model and query operations. Vector-based tracking with additional factor of connected segment and segment direction is introduced to solve the current query. In future query, the used of segment-based tracking is explained while database view is used to solve the continuous query. Moreover, the trajectory segment is used for querying past location estimation of moving objects. The method of indexing moving objects data is also discussed to improve the querying process.

Moreover, in reality, ERS operates in distributed heterogeneous environment. In addition to the issue associated with the development of MODGERS, the issue related to interoperability has also been highlighted. The approach of interoperability using ontology and available standard such as XML/GML is discussed in this research. Additionally, the example of interoperability scenario in MODGERS is presented to provide the real view of the problem. In the end, the generic model and interoperability framework can be extended to be applied to other problems.

ABSTRAK

Kemalangan Jalan Raya (RTA) merupakan salah satu daripada sepuluh penyebab utama kematian di dunia (WHO, 2006). Seperti peristiwa kecemasan yang lain, tindakan segera dalam RTA amatlah diperlukan untuk meminimumkan kemusnahan dan kehilangan yang besar. Dalam erti kata yang lain, satu tindakan segera yang efektif dan efisien mampu mengurangkan risiko-risiko yang tidak diingini. Sistem Tindakbalas Kecemasan (ERS) ialah satu aplikasi yang sangat penting dalam masyarakat sekarang. Ia merupakan satu sistem yang direkacipta untuk membekalkan bantuan kepada pihak-pihak tertentu dalam menangani kes-kes kecemasan.

Untuk menyokong operasi, implementasi Sistem Maklumat Geografi (GIS) dalam ERS telah digunakan secara meluas pada masa kini. Apabila bertindakbalas terhadap sesuatu insiden, pihak terdahulu boleh menggunakan GIS untuk mengenalpasti pelbagai sumber yang diperlukan – polis, ambulans, bomba dalam usaha membantu untuk bertindak dengan cepat dan efisien terhadap kes-kes kecemasan. Objektif keseluruhan GIS untuk tindakbalas kecemasan ialah untuk menghantar informasi yang tepat dan cepat kepada semua pihak-pihak yang terlibat dalam hal-hal kecemasan berdasarkan tahap kecemasan yang wajar. Amat jelas bahawa ERS adalah satu aplikasi yang bukan sahaja berdepan dengan aspek ruang tetapi juga dengan aspek masa. Tambahan pula, dalam ERS masa merupakan aspek yang berunsurkan semulajadi. Oleh itu, ia mestilah dianggap sebagai satu dimensi yang telah diintegrasikan selain dianggap sebagai satu atribut semata-mata. Walau bagaimanapun, kebanyakan implementasi *temporal* di dalam pangkalan data GIS

masih memperlakukan kedua-duanya secara berasingan. Atas sebab tersebut, ia memerlukan pengurusan data ruang dan masa. Tambahan pula, seperti telah dijelaskan diatas, ERS tidak hanya berurusan dengan objek tetap, tetapi juga dengan objek bergerak. Maka, implementasi Pangkalan Data untuk Objek Bergerak (MOD) sebagai *backend* untuk ERS adalah diperlukan.

Tujuan penyelidikan ini dijalankan ialah untuk membangunkan satu model MOD yang tipikal untuk ERS terutama dalam RTA. Model Pangkalan Data untuk Objek Bergerak yang tipikal untuk ERS berdasarkan GIS telah dibangunkan dan dikenali sebagai MODGERS. Keperluan asas untuk membangunkan sistem telah dibahas dalam kajian ini. Integrasi elemen masa ke dalam sistem koordinat 3D (2D + masa) juga telah ditekankan. Selain daripada itu, kaedah untuk pertanyaan lokasi semasa, masa hadapan, berterusan dan masa lalu MOD juga dipersembahkan. Simulasi masa yang sebenar telah dijalankan untuk simulasi model dan operasi pertanyaan. Pengesanan berdasarkan vektor dengan penambahan faktor segmen terhubung dan segmen hala tuju telah diperkenalkan untuk menyelesaikan pertanyaan semasa. Dalam pertanyaan masa hadapan, penggunaan pengesan berdasarkan segmen telah diterangkan sementara pandangan pangkalan data digunakan untuk menyelesaikan masalah pertanyaan berterusan. Tambahan pula, segmen trajektori telah digunakan untuk pertanyaan jangkaan lokasi lepas untuk objek bergerak. Kaedah mengindeks objek data bergerak juga dibahas untuk meningkatkan muat pertanyaan.

Realitinya, ERS sebenarnya beroperasi dalam persekitaran pelbagai teragih. Lanjutan kepada isu perkembangan MODGERS, isu berkaitan *interoperablility* juga telah ditekankan. Pendekatan Interoperabilitas menggunakan ontologi dan sedia standard seperti

XML/GML telah dibahas dalam kajian ini. Lain itu, contoh senario Interoperabilitas dalam MODGERS disajikan untuk memberikan pandangan kepada masalah yang sebenarnya. Model tipikal dan rangka *interoperabilty* adalah sesuatu yang umum untuk siasatan lanjut iaitu dengan memperluaskan aplikasi tersebut kepada masalah-masalah lain.

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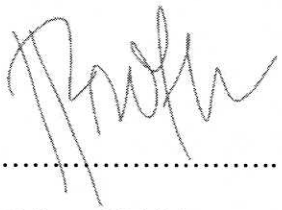
DECLARATION

I declare that this thesis entitle "MOVING OBJECTS DATABASE FOR GIS-BASED EMERGENCY RESPONSE SYSTEM" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.



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LIST OF ABBREVIATIONS AND GLOSSARY

2D	-	Two-Dimension
3D	-	Three-Dimension
4D	-	Four-Dimension
API	-	Application Programming Interface
ALI	-	Automatic Location Identification
ANI	-	Automatic Number Identification
CAD	-	Computer-Aided Dispatch
DBMS	-	Database Management System
DoD	-	Department of Defense
EDXL	-	Emergency Data Exchange Language
ERC	-	Emergency Response Centre
ERS	-	Emergency Response System
GIS	-	Geographic Information System
GiST	-	Generalized Search Tree
GML	-	Geography Markup Language
GPS	-	Global Positioning System
HLA	-	High Level Architecture
IBM	-	International Business Machine
IEEE	-	Institute of Electrical and Electronics Engineers
ISO	-	International Organization for Standardization
JKR	-	Jabatan Kerja Raya

LCIM	-	Levels of Conceptual Interoperability Model
LISI	-	Levels of Information Systems' Interoperability
MBB	-	Minimum Bounding Box
MBR	-	Minimum Bounding Rectangle
MOD	-	Moving Objects Database
MODGERS	-	Moving Objects Database for GIS-Based Emergency Response System
MOST	-	Moving Objects Spatio-Temporal
MOSTI	-	Ministry of Science Technology and Innovation
NATO	-	North Atlantic Treaty Organization
NC3TA	-	NATO Consultation, Command and Control Technical Architecture
NMI	-	NC3TA Reference Model for Interoperability
OASIS	-	Organization for the Advancement of Structured Information Standards
OGC	-	Open Geospatial Consortium
OGIS	-	Open Geo-data Interoperability Specification
OWL	-	Web Ontology Language
PDA	-	Personal Digital Assistant
RMODTN	-	Route-based model for Moving Objects on Dynamic Transportation Networks
RDF	-	Resource Description Framework
RTA	-	Road Traffic Accident
SEB-Tree	-	Start/end Timestamp B-tree
SETI	-	Scalable and Efficient Trajectory Index
SDTS	-	Spatial Data Transform Standard

SQL	-	Structured Query Language
SQL/CLI	-	SQL Call Level Interface
TAERS	-	Traffic Accidents Emergency Rescue System
TB-Tree	-	Trajectory-bundled tree
TC211	-	Technical Committee 211
uDig	-	User-friendly Desktop Internet GIS
UML	-	Unified Modeling Language
UTeM	-	Universiti Teknikal Malaysia Melaka
WAAS	-	Wide Area Augmentation System
WHO	-	World Health Organization
XML	-	Extensible Markup Language
XSLT	-	Extensible Stylesheet Language Transformation

Accuracy represents degree of conformity with a standard or accepted value. It relates to the quality of a result.

Algorithm is an effective method for solving a problem using a finite sequence of instructions. Algorithms are used for calculation, data processing, and many other fields.

Automatic Number Identification (ANI) is a feature of telephony intelligent network services that permits subscribers to display or capture the billing telephone number of a calling party.

Automatic Location Identification (ALI) is a system that is used to map the calling phone number to an address in a database.

Computer-Aided Dispatch (CAD) is a method of dispatching taxicabs, couriers, field service technicians, or emergency services assisted by computer. It can either be used to send messages to the dispatchee via a mobile data terminal (MDT) and/or used to store and retrieve data (i.e. radio logs, field interviews, client information, schedules, etc.

Coordinate System is a system to measure horizontal and vertical distance on a planimetric map. In a GIS, it is the system whose units and characteristics are defined by a map projection. A common coordinate system is used to spatially register geographic data for the same area.

Data model in software engineering is an abstract model that describes how data is represented and accessed. Data models formally define data elements and relationships among data elements for a domain of interest.

Database Management System (DBMS) is a set of computer programs that controls the creation, maintenance, and the use of the database of an organization and its end users.

Emergency Response System (ERS) is a system that designed to provide assistance to emergency responder to deal with emergency situation. More over, it also seeks to stabilize the emergency situation and reduce the possibility of secondary damage.

Federated database is a type of meta-database management system (DBMS) which transparently integrates multiple autonomous database systems into a single federated database. The constituent databases are interconnected via a computer network, and may be geographically decentralized. Since the constituent database systems remain autonomous, a federated database system is a contrastable alternative to the (sometimes daunting) task of merging together several disparate databases.

Framework is a basic conceptual structure used to solve or address complex issues.

Generalized Search Tree (GiST) is a data structure and API that can be used to build a variety of disk-based search trees. GiST is a generalization of the B+ tree, providing a concurrent and recoverable height-balanced search tree infrastructure without making any assumptions about the type of data being stored, or the queries being serviced. GiST can be used to easily implement a range of well-known indexes, including B+ trees, R-trees, hB-trees, RD-trees, and many others; it also allows for easy development of specialized indexes for new data types.

Generic data model is a generalization of conventional data models. They define standardized general relation types, together with the kinds of things that may be related by such a relation type.

Geographic Information System (GIS) is a system for creating, storing, analyzing and managing spatial data and associated attributes.

Global Positioning System (GPS) is a U.S. space-based global navigation satellite system. It provides reliable positioning, navigation, and timing services to worldwide users on a continuous basis in all weather, day and night, anywhere on or near the Earth.

Interoperability is a property referring to the ability of diverse systems and organizations to work together (inter-operate).

Interpolation is used to estimate a value of a variable at an unsampled location from measurements made at other sites.

Map Matching is a process to identify the correct segment on which a vehicle is travelling and to determine the location of a vehicle on a segment.

Minimum Bounding Rectangle (**MBR**), also known as **Minimum Bounding Box (MBB)**, is an expression of the maximum extents of a 2-dimensional object (e.g. point, line, polygon) within its 2-D (x, y) coordinate system, in other words $\min(x)$, $\max(x)$, $\min(y)$, $\max(y)$. The MBR is a 2-dimensional case of the minimum bounding box.

Moving Objects Database (MOD) is a special type of Spatiotemporal Database which manages moving objects over time.

Linear Referencing is the method of storing geographic locations by using relative positions along a measured linear feature. Distance measures are used to locate events along the line.

Spatial Database is a database that is optimized to store and query data related to objects in space, including points, lines and polygons.

Spatiotemporal database is a system that manages both space and time information. Basically, spatiotemporal databases are a generalization of spatial databases, which include features of variating coordinates in space, or of otherwise temporal variation of spatial data, e.g. of moving objects, residing temporally in spatially defined locations.

Topology is a set of rules which define the relationship between points, lines, and polygons.

Trajectory can be defined as the path described in space and time by a moving object

Unified Modeling Language (UML) is a standardized general-purpose modeling language in the field of software engineering. UML includes a set of graphical notation techniques to create visual models of software-intensive systems.

Wide Area Augmentation System (WAAS) is a navigation aid developed by the Federal Aviation Administration to augment the Global Positioning System (GPS), with the goal of improving its accuracy, integrity, and availability.

LIST OF SYMBOLS

α	-	Heading direction
β	-	Set of ontology
Ψ	-	Set of information in schema
d	-	Distance
km/h	-	Kilometer per hour
l	-	Length of vector
m/s	-	Meter per second
P_F	-	Future estimated position
P_L	-	Latest location update
P_N	-	Current location
t	-	Time
t_F	-	Future time
T_L	-	Latest time update
t_N	-	Current time
v	-	Velocity
V_L	-	Latest velocity update

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