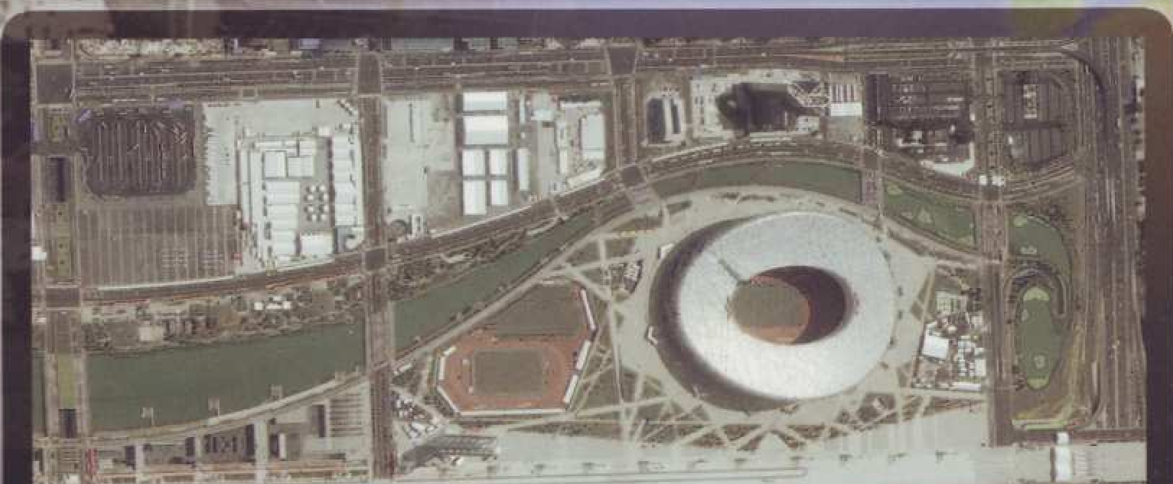
ISSN 1686-6576

IJG

International Journal of Geoinformatics

Vol. 4, No. 3, September, 2008



Beijing 2008 Olympic © GeoEye

Geoinformatics International

AGIT Association of Geoinformation Technology

From Editor-in-Chief,

Dr. Nitin Kumar Tripathi

It is a pleasure to release the September 2008 Issue of International Journal of Geoinformatics. This issue contains articles from technology segment as well as its application from internationally diverse authorship. Dr. Soichiro Hara and Dr. Chris Seeger are working hard on developing the Special Issue on Health GIS that is scheduled to be published in December 2008.

The year 2008 has already shown us several catastrophic events such as Nargis Cyclone in Mayanmar, Earthquake in China, Horrifying Dam burst and floods in Northern India. Geoinformatics community has to play greater role in providing the information to decision makers and also conduct research/ study in impact assessment. Association of Geoinformation Technology (AgIT) invites scientists/ engineers/ industry to submit papers on disaster mapping and management for the upcoming conference on git4NDM (December 1-2, 2008) in Bangkok. Organisers promise that top people from related areas and decision makers from user segment will be assembled in Asian Institute of Technology to ponder over a strategy to be better prepared to face such disasters. A hardcopy proceedings will be distributed during the conference and also a special issue of the selected papers be published.

I welcome four new members in the Editorial Board: Dr. Mazlan Hashim, UTM, Malaysia, Dr. Alan Forghani, Dr. Chi-Ren Shyu and Dr. Papatheodorou Constantinos. I am sure their vision and guidance will bring new positive directions and contribute towards the growth of the Journal. I also thank outgoing Members of the Editorial Board: Dr. Chong –Hwa Park and Dr. Lee Sanghoon for their contributions and guidance. I am sure they will continue to help the International Journal of Geoinformatics as a reviewer and mentor.

Authors may consider sending articles for the special issue on Positioning Systems and location based services for the coming special issue next year.

Best wishes for the coming festival season,

Nitin Tripathi

INTERNATIONAL JOURNAL of
GEOINFORMATICS

INTERNATIONAL JOURNAL OF

GEOINFORMATICS

Volume 4, No. 3, September, 2008

International Journal of Geoinformatics (IJG) is a peer reviewed journal and has an International Editorial Board. It is published four times a year: March, June, September and December.

It is cited by many renowned indexing and abstracting services such as Elsevier GEOBASE, EBSCO, Geoscience Australia, British Library, Scopus, Swets and GIS Development. Past issues older than one year are available "Free" online: http://www.j-geoinfo.net

For any general query please contact us at:
INTERNATIONAL JOURNAL OF GEOINFORMATICS
P.O. Box 44, Klong Luang,
Pathumthani - 12120, THAILAND
Tel: +66-2-963-9148, Fax: +66-2-501-1677

Send all your inquiries at: info@j-geoinfo.net
Contact for advertising and subscription at promotion@j-geoinfo.net.

Font Cover Page
Beijing 2008 Olympic, China. © GeoEye

Applying Dynamic Segmentation and Linear Referencing Systems over the Web

Papatheodorou K.,[1] Evangelidis K.,[2] Symeonidis P.,[3] and Kaskalis T.[4]

[1]Department of Geoinformatics and Surveying, Technological Education Institute of Serres
Terma Magnisias, 62124 Serres, Greece, E-mail: conpap@teiser.gr

[2]Head of Transportation & IT Systems Division, TRIAS S.A. Consulting, 39 G. Seferi Str. 54250
Thessaloniki, Greece, E-mail: kevan@trias.gr

[3]DRAXIS Environmental Technology, 63 Mitropoleos Str., 54623 Thessaloniki, Greece
E-mail: symeonidis@draxis.gr

[4]Department of Technology Management, University of Macedonia, Loggou-Tourpali, 59200
Naousa, Greece, E-mail: kaskalis@uom.gr

Abstract.

Linear Referencing Systems and Dynamic Segmentation have been very well documented and developed in numerous desktop GIS-based applications. However, there is still enough room for research and development inside this ever evolving technology area, considering the progress occurring in the field of spatial database and internet mapping services. In this respect, this paper aims to present MANSION (MANaging Spatial InformatiON) a prototype system that exploits dynamic segmentation capabilities, through web map services and spatial databases. For demonstration purposes, custom applications have been developed, for data entry and information retrieval of point or linear data events related to transportation networks. Prior to developing the above services, other critical parameters have to be conFigured the most important ones being a) the Reference Network, b) the Topological Framework and c) the Linear Referencing Method. In the future, MANSION will be further extended to handle more detailed spatial information applicable to a wide range of real world situations occurring in numerous Geoinformatic Network applications in Geology, Hydrology and Telecommunications etc.

1. Introduction

For a wide range of applications dealing with spatial events occurring on geoinformatic networks (e.g. hydrological, telecommunication, transportation or facilities networks), some types of spatial data involved in these events, may be referenced across the network links (ESRI, 1995). Such data may represent events that can be further categorized either as linear, thus occurring on a specified part of a link defined by a measured starting position and a measured ending one, or as point events in case they happen on specific measured positions of a network link (Nyerges, 1990). Technically, the whole procedure works as follows: A core process offered by contemporary Geographic Information Systems (GIS) tools, called Dynamic Segmentation transforms linearly referenced events stored in a table, into features that can be displayed and analyzed on a map (Dueker and Butler, 1997). Prior to this, a Linear Referencing System (LRS) is applied providing a) the geoinformatic network also termed as reference network, consisting of linear features with a unique identifier also known as routes, b) a Linear Referencing Method providing a common measurement system along the routes and c) datasets, containing the measurements representing the spatial events to be referenced (Sutton, 1997 and Vonderohe and Hepworth, 1996). Several examples could be mentioned indicating the usefulness and the applicability of the above technique in various fields of expertise:

- In geologic surveying and in certain types of geophysical investigation (GPR investigations for instance) linear referencing can be used to store information regarding certain points along the geologists or the instruments trace respectively, on the ground surface,
- In hydrological networks, linear referencing can be used to store information from field monitoring stations along the rivers' reaches. In such connections the term river addressing is used more commonly (Balstrøm et al., 2004).
- In a water conveyance system "using a linear addressing scheme to create dynamic segmentation of a waterline would present an opportunity to represent pipe segments as an event table with specific geometry from the linear address scheme" (Marsh, 2003)

ISSN 1686-6576 / © Geoinformatics International

- In the case of a transportation network, linear events occurring on a route may represent the pavement condition on segments of this route represented by a series of from-to couples along with a pavement quality value. Point events may be for example accidents occurring in specific positions of a route (Miller and Shaw, 2001 and Choi and Jang, 2000).

The above techniques have been very well documented and applied in numerous desktop applications; significant efforts are being spending, mainly by enterprises upgrading their products, on developing linear referencing for web-based applications (Stickler, 2003). Such way, users not only submit descriptive data and view map data through browser-based clients but they are also able to use other means of information transmission (mobiles, personal digital assistants etc.). However, there is still enough room for research and development inside this ever evolving technology area, considering the progress occurring in the sections of spatial database and internet mapping services. Based on the above the present paper aims to introduce MANSION (MANaging Spatial InformatiON), a prototype system developed by DRAXIS (Environmental Technology, http://www.draxis.gr) and TRIAS (Transport Research Information and Application Systems, http://www.trias.gr). The system exploits dynamic segmentation capabilities, through web map services and spatial databases. For the evaluation of system functionalities and for demonstration purposes, custom applications have been developed, for data entry and information retrieval. In the future, customised web-based applications will be further developed to handle spatial line or point events applicable to a wide range of real world situations (eg: road safety, fleet management, incident management). The system is developed based on the Microsoft (.NET framework) and ESRI software platform since it utilize spatial databases (ArcSDE for SQLSERVER) and Web Map Services (ArcGIS Server). As a result MANSION's main differentiation as compared to existing web-GIS servicing applications is its capability to provide core GIS functionalities provided by Linear Referencing Systems over the World Wide Web. Furthermore, for real-world cases related to established linear networks (e.g. transportation or facility networks) MANSION provides the capability of digitizing point and/or linear features laid upon these networks, with numerous advantages as compared to existing works: the end-user may simply fill in textual values referring to point locations or starting and ending locations along a line and these values are consequently transformed to point or line features respectively; in addition, there is no need to develop digitization tools or to purchase spatial editing licenses thus significantly reducing system deployment cost.

2. MANSION Design

MANSION aims to provide an internet-based platform through which spatial information originated from several and different sources will be referenced within a base network. Prior to adopting contemporary GIS and web-based tools the following generic design steps have to be performed:

- Reference Network Specification
- Topological Framework Identification
- Linear Referencing System Adoption

The above steps, generic though, depend on the case for which they are performed. For example, different topological rules govern a Telecommunication Network than a Hydrological one. Or, the identification standard, adopted for a transportation network may have different applications on the fundamental linear and point entities, than those faced on a Sewer Network. For the purposes of presenting MANSION the case of transportation network was adopted, to which transport-related spatial events are referenced. Below, the above mentioned steps are analyzed as regards the selected case.

2.1 Reference Network Specification

Reference Network provides a fundamental network structure which may generate multiple views of the transportation network, hosting multiple linear referencing methods, multiple transportation modes for routing and analysis and multiple mappings at various scales (Curtin et al., 2001). Reference Network was built under the framework set by a proven transportation identification standard, the NSDI (National Spatial Data Infrastructure) FGDC (Federal Geographic Data Committee) standard. According to FGDC transportation networks are formed by inherently topological objects (node and links) and provide network based valuable information such as feasible origin-destination paths, and decision points along those paths. The transportation network can then provide the base for building upon it other application layers including linearly referenced points and linear events (NSDI, 2000).

2.2 Topological Framework Identification

In general, topology defines the spatial relationships between the feature classes of a network.

In other words, topology models how spatial features share geometry, and provides a mechanism for establishing and maintaining topological relationships between these features (Zeiler, 1999). Topology rules may be incorporated in data modeling during logical design of a system. In the physical level topology rules may be deployed, through the Database Management System. In the GIS proven ESRI framework topology is embedded in the core GIS software processes and is reflected to a series of topology rules (ESRI, 2004). Five rules were identified to be applicable to transportation networks:

2.2.1 Line must not self overlap

The first topology rule is used in cases where each elementary segment composing a line feature should not occupy the same space with any other elementary segment of the same line. In terms of a transportation network this means that the road segments composing a road feature should snap themselves and should snap, intersect and overlap with segments of other road features. Figure 1.1 provides a spatial representation of features a) complying and b) not complying with the first topology rule.

2.2.2. Line must be single part

The second topology rule is used in cases where a line is required to be composed of a single series of connected segments. This rule is applicable on transportation networks where each linear spatial feature (e.g a metro line) should not be appeared split in more than one sequence of connected elementary segments. Figure 1.2 provides a spatial representation of features a) complying and b) not complying with the second topology rule.

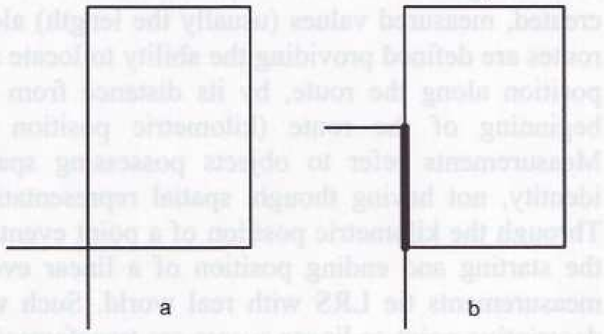


Figure 1.1: Linear feature a) complying and b) not complying with 1st topology rule

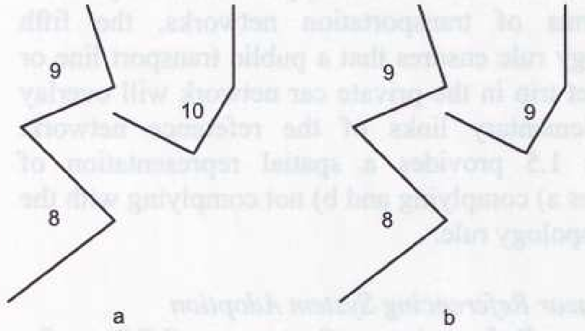


Figure 1.2: Linear feature a) complying and b) not complying with 2nd topology rule

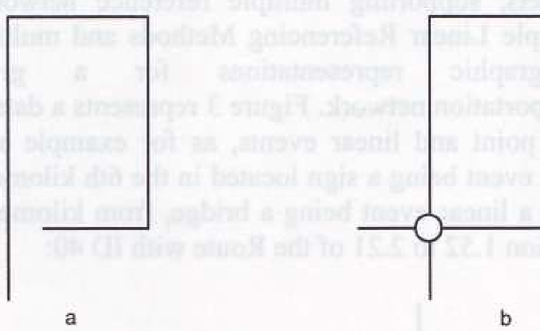


Figure 1.3: Linear feature a) complying and b) not complying with 3rd topology rule

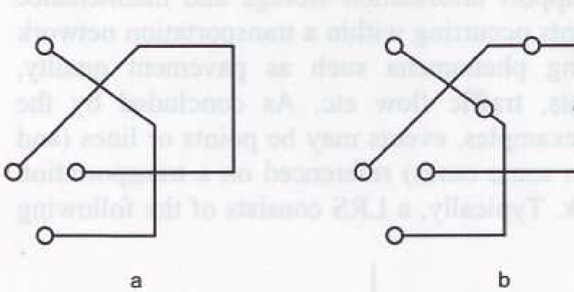


Figure 1.4: Point features a) complying and b) not complying with 4th topology rule

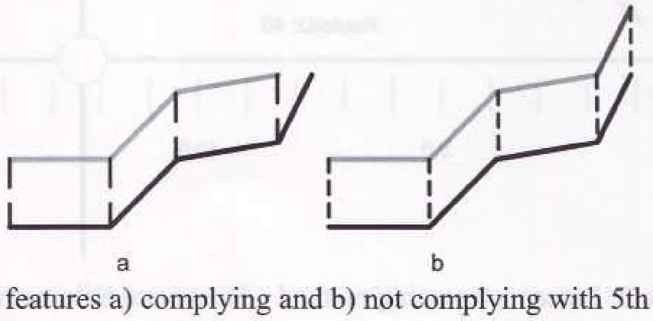


Figure 1.5: Linear features a) complying and b) not complying with 5th topology rule

2.2.3 Line must not self intersect

In transportation networks the third topology rule ensures that one and only Road feature cannot intersect with itself. If this happens, then there should exist more than one Road features. In addition, the ends of a road feature can only touch themselves. In any case such constraint governs every transportation identification standard like FGDC. Figure 1.3 provides a spatial representation of features a) complying and b) not complying with the third topology rule.

2.2.4 Point must be covered by endpoint of Line

In transportation networks the fourth topology rule ensures that there will not be a transport junction as a result of at least two road centrelines intersection. Figure 1.4 provides a spatial representation of features a) complying and b) not complying with the fourth topology rule.

2.2.5 Line must be covered by feature class of Line

In terms of transportation networks, the fifth topology rule ensures that a public transport line or a preset trip in the private car network will overlay the elementary links of the reference network. Figure 1.5 provides a spatial representation of features a) complying and b) not complying with the fifth topology rule.

2.3 Linear Referencing System Adoption

Linear Referencing Systems (LRS) for transportation networks have been developed to maintain information related to transport infrastructure (U.S. DoT, 1998 and NCHRP, 1997). LRS support information storage and maintenance for events occurring within a transportation network including phenomena such as pavement quality, accidents, traffic flow etc. As concluded by the above examples, events may be points or lines (and areas in some cases) referenced on a transportation network. Typically, a LRS consists of the following components (Sutton, 1997 and Vonderohe and Hepworth, 1996):

- A transportation network,
- A linear referencing method and
- measurements

The transportation network is structured according to FGDC identification standard, previously discussed (NSDI, 2000). The Linear Referencing Method provides the basis for determining a location within the transportation network by use of a defined route and the distance along that route from some known location (Curtin, 2001). The method adopted for the purposes of MANSION makes use of the route and the kilometric position and is depicted in Figure 2. The routes are generated by grouping elementary links of the transportation network, based on an identification key attribute (e.g. the route connecting two towns, or the route connecting to intersections). Once, routes are created, measured values (usually the length) along routes are defined providing the ability to locate any position along the route, by its distance from the beginning of the route (kilometric position 0). Measurements refer to objects possessing spatial identity, not having though, spatial representation. Through the kilometric position of a point event, or the starting and ending position of a linear event, measurements tie LRS with real world. Such way descriptive point or linear events are transformed to spatial point or linear features respectively. Finally, measurements may correspond to multiple event datasets, supporting multiple reference networks, multiple Linear Referencing Methods and multiple cartographic representations for a given transportation network. Figure 3 represents a dataset with point and linear events, as for example a) a point event being a sign located in the 6th kilometer or b) a linear event being a bridge, from kilometric position 1.52 to 2.21 of the Route with ID 40:

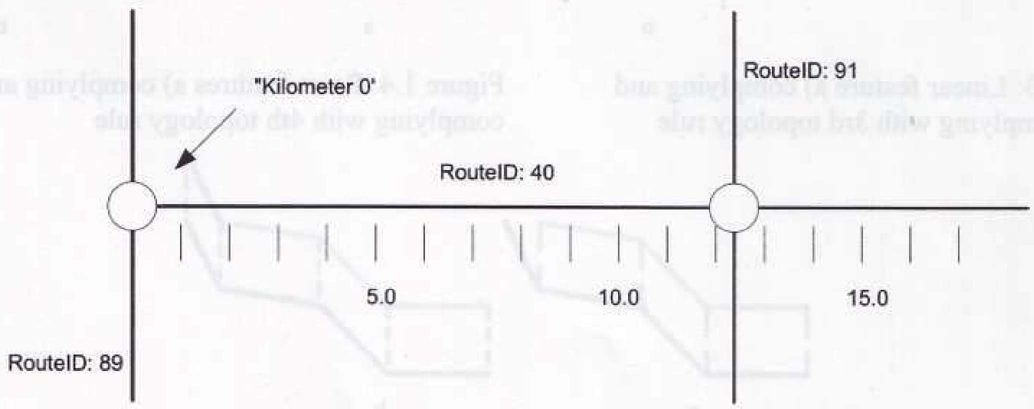


Figure 2: Linear referencing method – Route and Kilometric position

ROUTEID	KIL_POS	EVENT
40	6	SIGN
91	12	ACCIDENT
.	.	.
.	.	.
.	..	.

a

ROUTEID	F_KIL_POS	T_KIL_POS	EVENT
89	2	8	HOV
40	1, 52	2, 21	BRIDGE
.	.	.	.
.	.	.	.
.	.	.	.

b

Figure 3: a) Point events table and b) Linear events table

3. MANSION Deployment

3.1 System Architecture

MANSION comprises various subsystems and connectivity modules, the most important being the following ones:

- The Geographic Database (GDB) subsystem, maintains any kind of spatial and non-spatial information regarding the network under consideration. This subsystem may be continuously updated and accessible to the events editor end-users through customized applications and the appropriate telecommunication infrastructure (TCP/IP, 3G).
- The Web Map Services (WMS) subsystem distributes requests to GDB, performs core GIS services and it finally produces the map image, to be published via the Web Server.
- The Web Server (WS) subsystem publishes cartographic information on the WWW. The WS receives requests by the end users locates the requested data and sends it back to the client application

Figure 4, provides a representation of MANSION architecture.

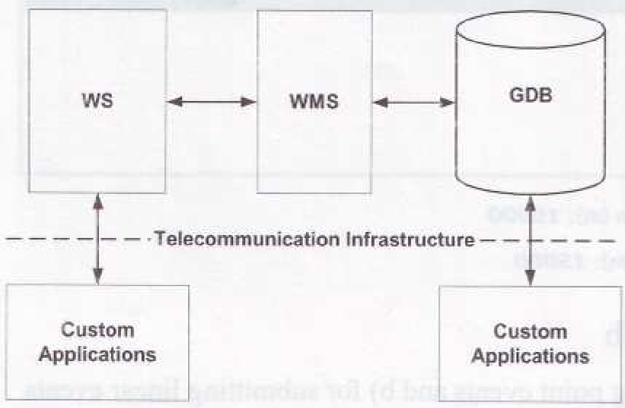


Figure 4: System architecture

3.2 System Modules

A pilot implementation of MANSION concerning Road Networks is the Road Events Management System, an application consisting of two modules: ROAD EVENTS EDITOR and ROAD EVENTS VIEWER.

The application is available at http://www.draxis.gr/roadevents. A snapshot of MANSION introductory graphical interface is provided in Figure 5.

3.2.1 Road events editor

The REE module of MANSION provides the capability of entering or modifying Road Network related data possessing spatial identity, not having spatial representation of their own, though. Such data may be considered either as point or as linear events and may be referenced across the Road Network, through their exact kilometric position, or their starting and ending positions respectively. Possible events referenced across the Road Network may include, traffic accidents, pavement condition, incidents, weather conditions and other points or segments of interest. REE end-users may interact with the Geographic Database through user friendly browser-based applications and manage any kind of information related to the submitted events. Figure 6 provides a snapshot of REE module graphical user interface for submitting a) point events and b) linear events.

3.2.2 Road events viewer

The REV module of MANSION dynamically provides a real-time presentation of any point or line event submitted through REE module. It also depicts, any descriptive information related to a requested point or line event. However, the module may be extended to provide, in tabular or other display forms, the results produced by complicated queries submitted to the Geographic Database. A snapshot of the REV graphical interface depicting the inserted point and linear events is provided in Figure 7.

4. Conclusions and Further Developments

Dynamic Segmentation and Linear Referencing have been examined in detail and applied in Geoinformatic Networks during the last decade. MANSION makes use of these core GIS techniques over the Web by exploiting the progress occurred in spatial database and internet mapping services.

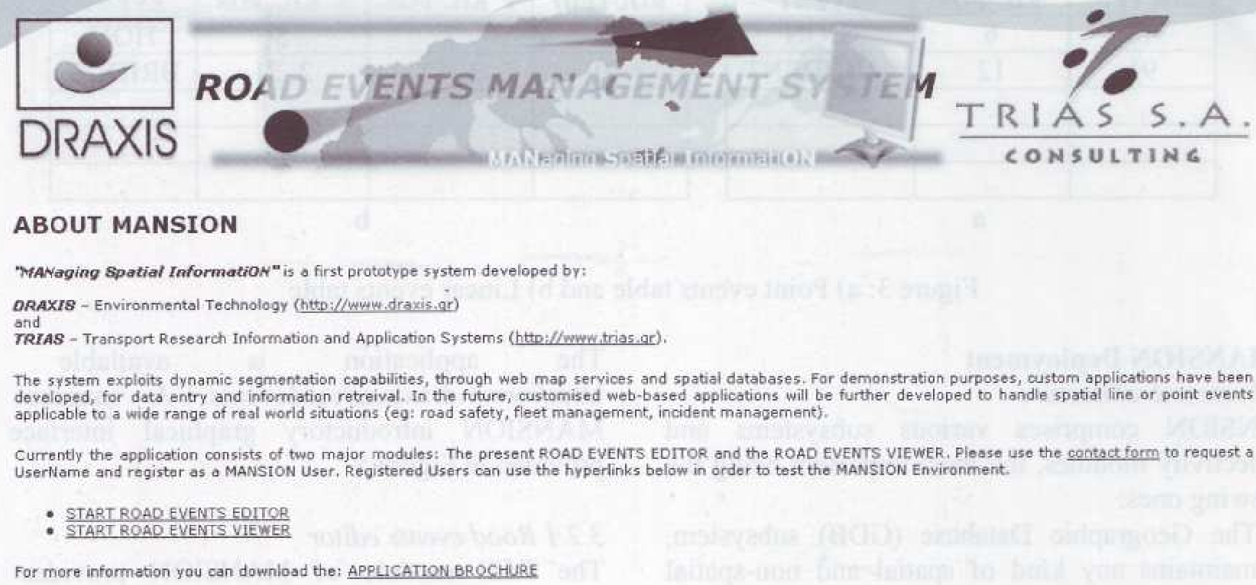
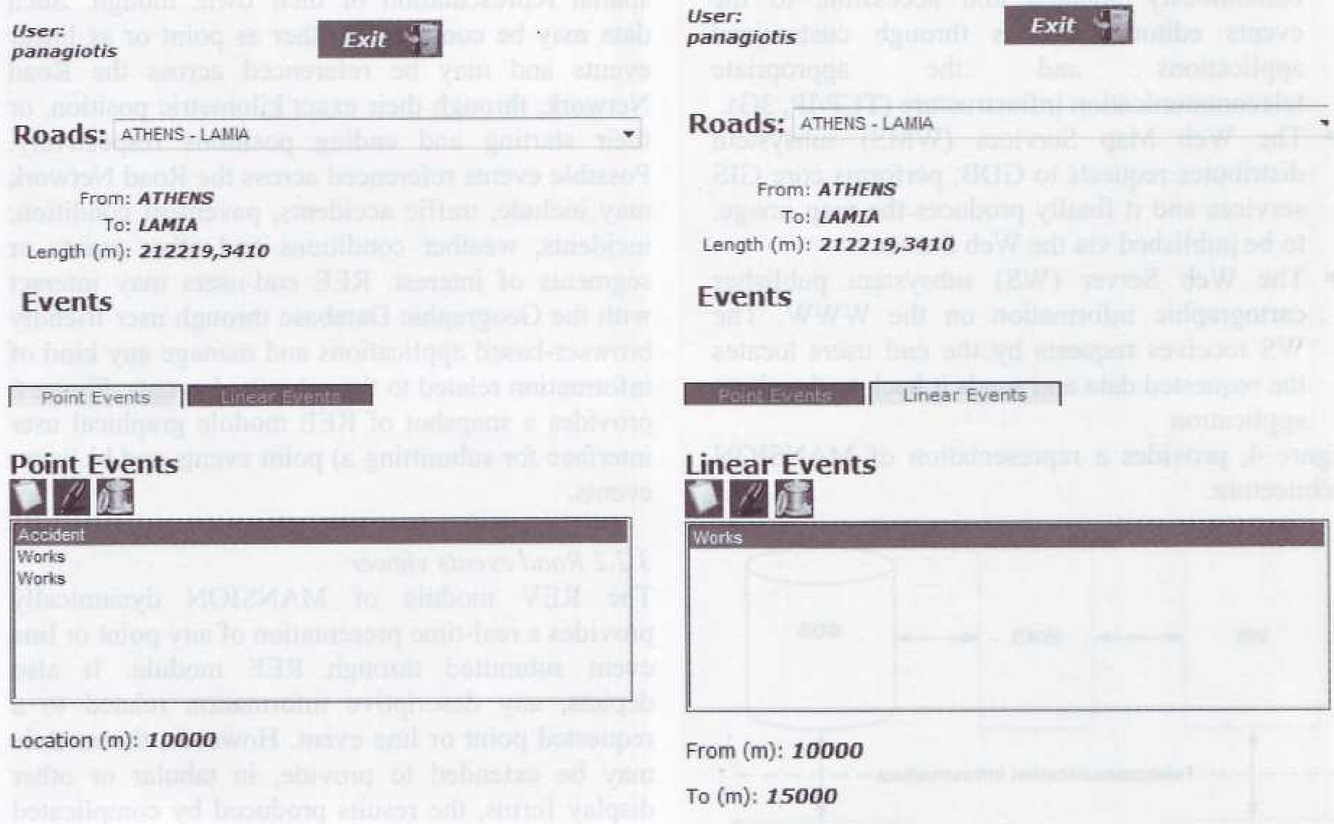


Figure 5: The road events management system Web Application available at http://www.draxis.gr/roadevents/



a b

Figure 6: The road event editor interface a) for submitting point events and b) for submitting linear events.

MANSION, as a prototype, aims to become a generic system, applicable to any utility network. However, defining critical parameters as the Reference Network and the Topological Framework is a project specific process, meaning that it differentiates from a Geoinfromatic Network to another (e.g. form Hydrogeology to Transportation).

By putting together specifications governing the spatial entities involved in most networks is the first step to creating a generic framework. In addition the customised web-based applications may be further developed to handle more detailed spatial information applicable to a wide range of real world situations in various fields of expertise.

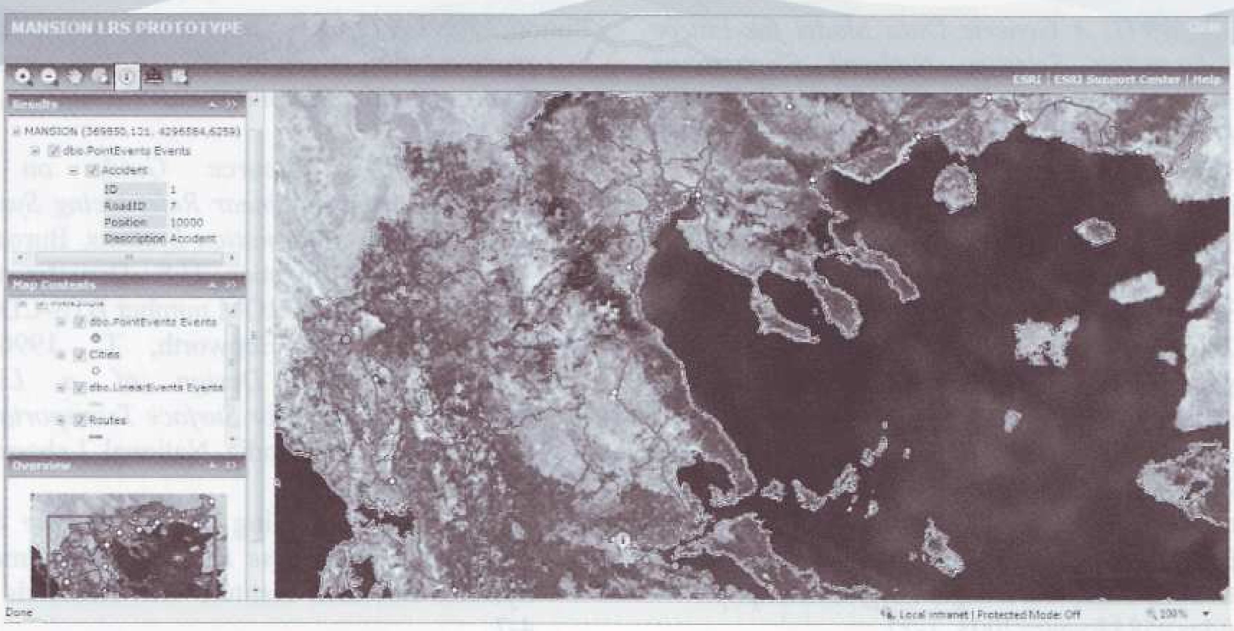


Figure 7: The road events viewer interface

As regards, MANSION functionality and expandability, the progress occurring in the GIS servicing technologies make possible to transfer desktop GIS over the Web. Therefore it is possible to incorporate capabilities such as modifying the geometry of the reference network elements and subsequently reflecting automatically the changes to all the related event tables. Concluding, MANSION salient contribution in this ever evolving field of GIS applications includes without being limited: a) extension of the existing and proven capabilities of GIS internet services beyond map publishing or other basic functionalities such as optimal route identification, with integrated advanced core GIS functionalities provided by Linear Referencing Systems, b) provision to end users, with primitive easy-to-use feature editing capabilities applicable to established linear networks c) provision to developers and application owners with the capability of enhancing their applications cost effectively and d) initiation of a generic framework for incorporating common specifications governing a wide range of real world Geoinformatic networks.

References

Balstrøm, T., Mernild, S. H., and Hasholt, B., 2004, *Linear Referencing to Assist the Classification of Natural and Regulated Danish River Systems,* 19th European User Conference for ESRI Users, Institute of Geography, University of Copenhagen, Denmark, [online] Available: http://www.euc2004.dk/papers/papers_web/ID003_Thomas_Balstrom_LinearReferencingEUC2004_v2.pdf, 1, 2.

Curtin, K. M., 2001, *The UNETRANS Data Model,* ESRI International Users Conference (Transportation Specialist Meeting), San Diego, CA, 17.

Curtin, K., Noronha, V., Goodchild, M. and Grisé, S., 2001, *ArcGIS Transportation Data Model Reference,* ESRI and Regents of the University of California, [online] Available: http://support.esri.com/index.cfm?fa=downloads.dataModels.filteredGateway&dmid=14, 18, 19, 22.

ESRI, 1995, *Dynamic Segmentation—A Powerful Tool Representing Linear Attributes and Events*, An ESRI White Paper, ESRI White Paper Series, 2.

ESRI, 2004, *ArcGIS Desktop, Computer Software Help,* © ESRI.

Dueker, K., and Butler, J. A., 1997, GIS-T Enterprise Data Model with Suggested Implementation Choices. *Journal of the Urban and Regional Information Systems Association* 10(1):12-36.

Choi, K., and Jang, W., 2000, *Development of a Transit Network from a Street Map Database With Spatial Analysis and Dynamic Segmentation,* Transportation Research Part C 8 (2000), 129-146

Marsh, P. C., 2003, A Pipe Network Data Model for Defect Tracking 26th Annual Conference and Exhibition: *A Geospatial Odyssey,* GITA Conference, 3.

Miller, H. J. and Shaw, S. L., 2001, *Geographic Information Systems for Transportation: Principles and Applications,* Oxford University Press, 3-13.

NCHRP, 1997, *A Generic Data Model for Linear Referencing Systems,* National Cooperative Highway Research Program, Research Results #218, Transportation Research Board, National Research Council, Washington, DC, 28.

NSDI Framework Transportation Identification Standard, FGDC-STD-999.1-2000, 2000, *Public Review Draft,* Ground Transportation Subcommittee Federal Geographic Data Committee.

Nyerges, T. L., 1990, Location referencing and highway segmentation in a geographic information systems, *ITE Journal*, 60(3) 27-31.

Stickler, G., 2003, *Moving Dynamic Segmentation to the Server: Linear Referencing for Web-Based Applications,* 2003 GIS-T Symposium, Available:http://www.gis-t.org/session.php?index=584&year=2003, 1-27.

Sutton, J., 1997, Data attribution and network representation issues in GIS and transportation, *Transportation Planning and Technology*, 21, 25-44.

U.S.DoT, 1998, *Resource Guide on the Implementation of Linear Referencing Systems in Geographic Information Systems,* Bureau of Transportation Statistics, U.S. Department of Transportation, CD-ROM number BTS-CD-22.

Vonderohe, A., and Hepworth, T., 1996, *A Methodology for Design of a Linear Referencing System for Surface Transportation,* Research report, Sandia National Laboratory, Project AT-4567.

Zeiler, M., 1999, Modeling our world. *The ESRI Guide to Geodatabase Design,* Environmental Systems Research Institute Inc., Redlands CA, 4-7.