Present status of 3D GIS

An increasing number of applications need advanced 3D tools for representing and analysing real world. At present, many software packages can handle a wide range of spatial problems. However, is the functional 3D GIS already a reality? This paper tries to find the answer by analysing both software available and efforts of researchers. An overview of several commercial systems and a 3D case study provide knowledge about 3D functionality offered in the market. The most significant achievements in the 3D research area concerning 3D structuring and 3D topology portray the current research status and delineate new research topics.

Introduction

Currently, the most often quoted areas of human activities waiting for 3D solutions are 3D urban planning, environmental monitoring, telecommunications, public rescue operations, landscape planning, geological and mining activities, transportation monitoring, real-estate market, hydrographical activities, utility management and military applications. But the role of geo-information in all kinds of business processes is also getting quite transparent. Terms as “location-specific information” and “location-based services” become a part of the daily business language to denote the link between the virtual world of information (transactions, events, internet communication) and the real world of information (customers, inventory, shipping). Most business transactions rely on information systems as the geo-information is critical for many of them. Once the developments in the 3D GIS provide a compatible functionality and performance, the spatial information services will evolve into the third dimension. Here, we attempt to summarise the current status of 3D GIS development and suggest topics for further research and implementations.

3D GIS in the market

Nowadays, 2D GISs are widely used to handle many 2D GIS issues in a very efficient manner. However, the same kind of systems fail to operate if more advanced 3D tasks are demanded. There are already few systems available in the market that can be categorised as systems providing 3D solutions. We analysed four of them that constitute the largest share of the GIS market, i.e. *ArcView 3D Analyst, (ESRI), Imagine VirtualGIS (ERDAS), GeoMedia (Integraph Inc.)* and *Geomatica (PCIGeomatics).* All the systems provide excellent tools for 3D visualisation, animation and navigation through 3D textured models (Figure 1, 2). Most of them offer sufficient tools to manipulate 2.5D data such as surface generation, volume computation, draping images, terrain inter-visibility, etc. Access to data distributed on different servers is also greatly improved. All the systems revealed still little provision of 3D GIS functionality in terms of 3D structuring, 3D manipulation and 3D analysis. The full 3D geometry (the z-coordinate is basically an attribute), 3D topological relationships and 3D analysis are still areas to be entered by the general-purpose GIS vendor.

Many other vendors (developing basically CAD, GIS and DBMS packages) realise the increased importance of geo-information and seek for appropriate solutions to maintain and analyse spatial data. A logical consequence of all the attempts is the agreement on the manner for representing, accessing and disseminating spatial information, i.e. the OpenGIS specifications. As a result, an increasing number of DBMS offer already storage, retrieval and analysis of spatial data. A growing number of CAD vendors develop tools to utilise the storage benefits of DBMS. Among all, we selected *Oracle Spatial 8i* and *Microstation Geographics iSpatial* to investigate the current status of the implementations. We completed a case study with 20021 buildings from the city of Vienna. The idea was to test the DBMS&CAD integration against query, visualisation and editing. Our experience is briefly summarised bellow.

Both packages follow closely the OpenGIS concepts, i.e. a *geographic feature* has spatial characteristics that are represented by geometric and topologic primitives. Oracle Spatial 8i has implementied 2D geometry types (point, line, polygon). Semantic characteristics of a feature are organised in GeoGraphics iSpatial, as one significant part of the information (semantic hierarchy, links to geometry types) is maintained at a database level. However, the notations (table names, columns, object definitions) have very specific application-oriented meaning. If the user decides to keep the database and change the CAD package, he/she will need to create the feature-geometry link from scratch.

Real 3D geometric types are missing but the description of 3D data is possible. The Z value is maintained together with the X,Y values, i.e. it is not an attribute. Since the topological primitives are not implemented yet, real possibilities to analyse 3D data in GeoGraphis iSpatial and Oracle Spatial 8i are still missing. Tools in GeoGraphics iSpatial to create 2D topological layers or tools in Oracle Spatial 8i to perform spatial operations are provided but they operate with only X,Y coordinates. Some of the operations accept X,Y,Z coordinates but computations are still in 2D (Figure 3).

Apparently the greatest benefits of the DBMS-CAD integration are in the area of visualisation and editing of data. As frequently commented, the amount of data to be visualised in 3D increases tremendously and requires supplementary techniques (LOD, on-fly simplification, etc.) for fast rendering. Having 3D data stored in a database, the user has the possibility to extract only a limited set of data (e.g. one neighbourhood instead of one town) and thus critically reduce the time for loading. Locating, editing and examining a particular object become also quick, simple and convenient. Indeed, the elements that can be edited correspond to the geometry representation in Oracle Spatial 8i, e.g. the 3D topology of buildings cannot be preserved (Figure 4).

3D GIS in the research

The research in 3D GIS is intensive and covers all aspects of the collecting, storing and analysing real world. 3D analysis and the related issues (topological models, frameworks for representing spatial relationships, 3D visualisation) are mostly in the focus of investigations. The 3D topological model is the key issue, since it is related to the representation of a large group of spatial relationships, e.g. inclusion, adjacency, equality, direction, intersection, connectivity. Although the large number of 3D models reported in the literature, the research is concentrated around few basic ideas, as the level of explicitly described spatial relationships varies. Each suggested 3D model exhibits efficiency and deficiency with respect to a particular applications and operations to be performed. Mechanisms for representing spatial relationships are yet another “hot area” of investigation. OpenGIS consortium has adopted two frameworks known as Egenhofer operators and Clementini operators based on the 9-intersection model. Although the topology is considered the most appropriate mechanism to describe spatial relationships, the study on applicability of other mathematical frameworks continues.

Advances in the area of computer graphics have made visual media a major ingredient of the current interface in the communication and interaction with computers. Therefore the research related to the visualisation of real world 3D data is mostly “shifted” to the computer graphics society. Many viewers and browsers as stand-alone applications and plug-ins have been developed to quickly visualise and navigate through 3D models. New algorithms and implementations are reported daily. The design criteria, however, are fast rendering techniques based on internal structures rather than utilisation of database representations. *TerraExplorer* (*SkyLine*), the current leader for visualising large 3D textured data from real world with acceptable performance, also requires data restructuring (Figure 5).

Another significant area of 3D GIS research is devoted to Web applications. The Web has already shown a great potential in improving accessibility to 2D spatial information (raster or vector maps) hosted in different computer systems over the Internet. The first attempt to disseminate and explore 3D data, i.e. VRML, appeared to be rather “heavy” for encoding real geo-data due to the lack of a successful compression concept. Despite the drawbacks, the language became a tool for research visualisation. Researchers could concentrate on data structuring and analysis and leave the rendering issues to VR browsers offered freely on Internet. GeoVRML (VRML extended with geo-nodes) and Geographic Modelling language (GML) are another promising opportunities for representing 3D data on the Web. Based on XML concepts, GML provides larger freedom, flexibility and operability than VRML.

Discussion

The study on the commercial systems showed clearly that the functional 3D GIS is not an easy task. The 3D progress in traditional GIS packages is mainly in the area of data presentation and surface analysis. DBMS&CAD&GIS developers have rapidly adopted OpenGIS specifications but the focus is mostly on the geometry. 2D topological representations and operations as well as the real 3D geometry type are still to be implemented.

The third dimension with respect to topological issues is still in the hands of the researchers. Although quite significant number of works devoted to 3D structuring, the consensus on a 3D topological model is not achieved yet. Still a lot of 3D GIS functionality is left for addressing. 3D buffering, 3D shortest route, 3D inter-visibilities are some of the most appealing for investigation. Integration of object-oriented approaches with the 3D GIS raises new research topics toward standard object descriptors and operations at a database level.

3D GIS requires appropriate means not only for visualising and exploring 3D textured models but also for building and storing them. Observations on the demand for 3D City models show user preferences for photo-true texturing. Currently, a limited number of packages offer means for mapping images onto geometry (e.g. facades). Trading photo-true texture requires a variety of topics to be considered, e.g. standardisation of parameters for image-geometry references and image organisation at a database level.

The significant step, however, is made. Developers and researchers from different areas have united their efforts toward developing a 3D GIS. The understanding of GIS is changing. Instead of a monolith, desktop, individual system, GIS is becoming an integration of strong database management (ensuring data consistency and user control) and powerful editing and visualisation environment (inheriting advanced computer graphics achievements).

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Further reading

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Biographies of the authors

Dr. S. Zlatanova is a Researcher at TUDelft, The Netherlands. Her interests are on 3D GIS: object reconstruction, data structures, spatial relationships and visualisation.

Dr. Alias Abdul Rahman is the Director, Center for Geographic Information and Analysis (CGIA) and also attached to the Department of Geoinformatics at Universiti Teknologi Malaysia. His interests are mainly on 3D GIS, DTM, and spatial data structuring and modelling.

Dr. Morakot Pilouk is currently a Software Development Manager at ESRI, Redlands, California

Affiliation

Dr. Eng. Siyka Zlatanova, Delft University of Technology,
Thijsseweg 11, 2629JA, Delft, The Netherlands, s.zlatanova@citg.tudelft.nl

Dr. Alias Abdul Rahman, Department of Geoinformatics, Universiti Teknologi Malaysia,
81310 UTM Skudai, Johor, Malaysia, alias@fksg.utm.my

Dr. Morakot Pilouk, Environmental System Research Institute (ESRI),
380 New York Street, Redlands, California, USA, mpilouk@esri.com

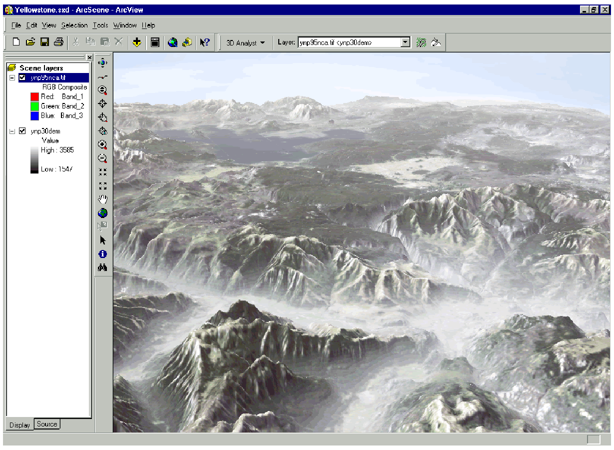

Figure1: *3D ArcScene: 3D Visualisation*

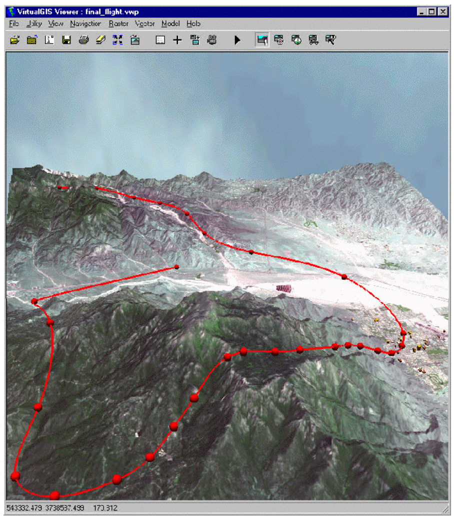

Figure 2: *Imagine Virtual GIS: 3D Animation*

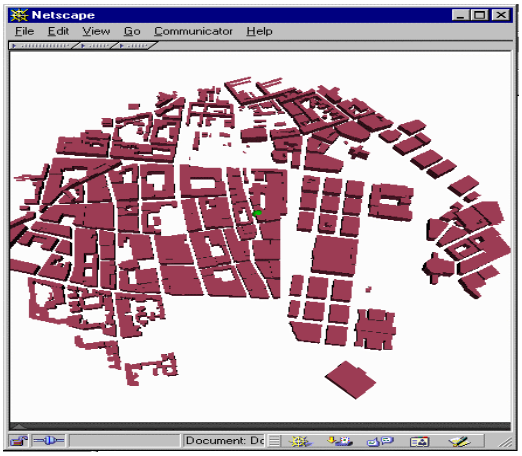

Figure 3: *Oracle Spatial operator SDO_WITHIN_DISTANCE applied for 3D data*

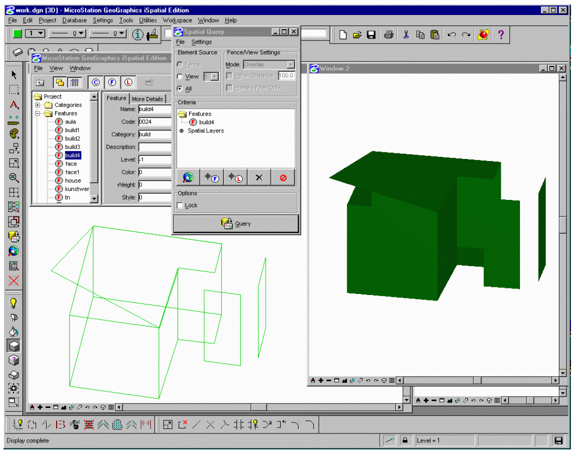

Figure 4: *Query, edit and post of a building*

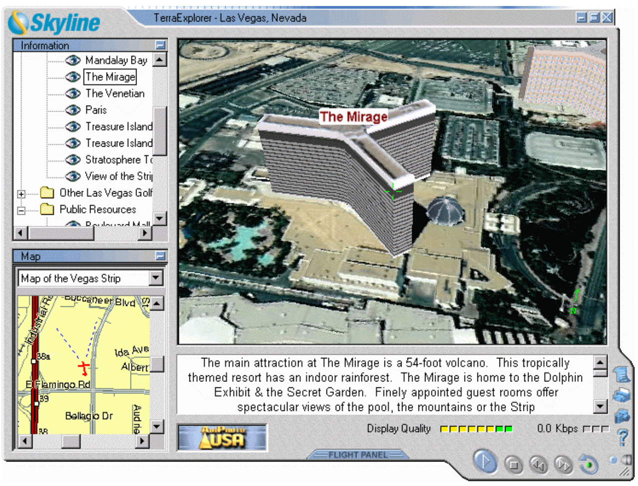

Figure 5: *Terra explorer: Real-time 3D navigation trough large textured 3D models*