Design of a 3D virtual geographic interface for access to geoinformatin in real time

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1 ABSTRACT

In 1999, the County of Northern Jutland in Denmark became a national project for implementation of Information & Communication Technology (ICT) in local government. It was supposed to become the Lighthouse for others in the implementation of ICT, e-learning and e-democracy. The idea about a digital region struck this part of Denmark at it has struck many other places in Europe and around the world. At about the same time the first ideas about a virtual geographic interface was initiated and launched as one of the projects at the newly build Virtual Reality Centre of Aalborg University. Later named as VR Media Lab. The Centre for 3D GeoInformation was opened in 2001 and the main purpose of this facility is to extrude the region from 2D to 3D. Through the means of traditional geoinformation such as building footprints, geocoding, building and dwelling register and a DTM the region will be build as a 3D model. The purpose of this 3D model is not only to provide a visual presentation, but also to use it as a real 3D GIS - for both queries through the use of a 3D model and for visualisation of geoinformation in 3D. This paper will present the design framework for the 3DGI system and also give some examples of future use of these kinds of multi-dimensional geographic interfaces.

1.1 North Denmark Digital Lighthouse

The decision to appoint the County of Northern Jutland as the digital lighthouse for the rest of Denmark was taken in 1999. The same year the local university (Aalborg University) could celebrate its 25th anniversary. The innovative research environment that was a spin-off from the activities at the university had proven to be a strong factor in the local community and even at a regional scale. It had e.g. resulted in a research and development cluster for mobile telecommunication. Also many other branches at the university had proven to be successful at both national and international scale. Together with the fact that many of the local municipalities also had shown a great deal of interest in digital administration, these aspects were the primary reasons for the government to give the region status as a Digital Region.

Figure 1: The County of Northern Jutland is app. 6.000 km2 and have 500.000 inhabitants

The objective of the Digital Region was to create the future networked society and try out experiments aimed at tomorrow's ICT society. The activities in the Digital Region were divided into four main categories:

b) ICT Infrastructure

c) ICT Industrial Development, E-Business and ICT Framework conditions for the industrial sector

d) Qualification and Education

e) Digital Administration

The main project ran from 2000 to 2003 with a budget of DKK 510 mill. (€ 69 mill.) and a funding from the government of DKK 170 mill. (€ 23 mill.) granted by the Ministry of Science, Technology and Innovation.

First priority of the initiative was to explore the potentials of the network society for all citizens of North Denmark. This was done via 89 various ICT projects. Among these projects a great deal of them were focusing on e-government. Two main areas were present under e-government: "Service, political authority and efficiency" and "Citizens, democracy and information". The aim of the projects from the first category were focussing on integration of ICT in the administration with examples reaching from citizen self service (electronic forms etc.) to advanced online GIS solutions. The projects within the second category were focussing more on involvement of users in local democracy initiatives. That could be the digital village or participation in spatial planning. This paper will especially focus on the first type of applications and stress the need for an underlying spatial infrastructure to support the use of 3d geovisualisation in the digital administration.[1, 2]

1.2 ICT in Local Government

Before the mid-1990's, citizens only had very few alternatives to choose from when they wanted to confront the local administration. Either they used the phone and called in to the local administration, or they showed up to meet the person they wanted to communicate with. In both these alternatives it required a synchronous action between the citizen and the official. The final option was to write a letter to the administration, which could be a demanding task for citizens who were not very used to write letters in a formal way. The Internet has brought new alternatives for both synchronous and asynchronous communication, where information also can be reach outside officehours and where electronic media have presented new ways of communication between citizens and the local government. This has meant a broad range of different solutions for communication through this reasonable new media [3]. It has also meant a gigantic growth rate for the amount of information being available on electronic form. The problem is not the amount of information available, but how to find the exact information you are looking for. There is definitely a need for new types of interfaces for finding your way through the vast amount of information available.

2 THE MAIN IDEAS BEHIND 3DGI

Different research activities at the end of the 1990s under the management of GISplan [1, 2] also displayed the need of new user interfaces and possibilities of interaction in relation to the work with GI. First of all this need was about breaking with the traditional settings of the GI work, where the representation of the data model usually took place in 2D (in the map), and about introducing different suggestions of the representation of the third dimension.

Already in 1989 [4] showed many examples of the use of 3D in the visualization of GI. At this time the representation of the third dimension was a question of visualizing an attribute to a perspective reproduction of a 2D continuum. This gave new ways of showing geographical information, but in relation to the data organizing there was no new approaches. Several others have also been engaged in describing the bases of a 3D GIS [5, 6], but not until the latest years has 3D GIS been adopted as part of the research agenda for geovisualization [7]. The latest contributions to this part of the research within GI indicate that the subject is a topic in many places[8, 9].

The Internet has opened a large number of interesting initiatives in the multimedia field, which may for example be seen from [10-13]. Also the Digital Earth Initiative has acted as a very large source of inspiration to the foundation of 3DGI.

Another important step towards 3DGI has been the intentions of being able to link geoinformation and the very 3D-geometry model. This has primarily required a standardised 3D model description. Already in 1995 VRML (Virtual Reality Modelling Language) was introduced on the basis of the proprietary object-oriented model format Open Inventor from SGI. VRML was introduced as a standard for exchange of 3D information, and different browsers quickly appeared on the market. VRML 2 at SIGGRAPH in 1996 followed the first introduction, and in 1997 it was even authorised as an international standard for 3D contents at the Internet under the name VRML 97. The interest in VRML implied that the format was the basis for the preparation of a proper suggestion of a 3D format for GI. This format has had the working title GeoVRML and has actually been the basis for the work that has now led to GML (Geo-XML) and parts of the newest format X3D, which is also XML-based. It is evident that new initiatives in this field can only be started with reference to the new standards for a formalised description of 3D

2.1 Purpose of 3DGI

The purpose of the centre is to gather knowledge and competence during the process of creating 3D models of cities and landscapes for organizing and presenting geoinformation applications.

This will be done by:

- collecting competence and knowledge within the field by arranging seminars/conferences, establishing international research networks and by employing researchers within this particular field
- collaborating with companies, who already possess the most recent competence within VR and three-dimensional urban and rural models or are interested in acquiring this
- establishing a VR user interface for looking for position-fixed information in the northern part of Jutland
- creating a geographical model of North Jutland, which can form the basis of digital visu-alization and the marketing of the resources of the region
- developing a basis of knowledge and documentation for the use of a geographical communication concept covering the northern part of Jutland, adapted to the expected in-creased band width in digital transmission media (Fixed and Mobile Nets) and as a framework for developing virtual environments
- forming the basis for future research and for building up regional knowledge within lo-cation-based services (field registration with mobile units). Augmented reality (a mixture of 3D models and reality), three-dimensional user interface and the use of broadband for mobile knowledge services.

2.2 VR and GIS

Virtual Reality and GIS is a fairly new cocktail due to the general differences in concepts. Where VR has been concentrated around the creation of virtual environments and realtime visualisations, GIS was defined from a 2d concept with the third dimension described as an attribute to a specific location. On a world scale [14] have investigated the different available solutions. A number of very early adoptions of the Virtual Reality technology can also be found [2, 6, 11, 15-21].

One of the new aspects in the project is the user interface, based on intensive use of Virtual Reality (VR) and 3D. By creating a virtual threedimensional (3D) model of reality and then use it as an index for many other types of information, it becomes possible to use the general human ability to familiarize with the surroundings and navigate through space.

The Virtual Reality metaphor describes a conceptual model where reality meets virtuality. This becomes a navigable 3d space where existing objects are mixed with simulations of urban planning projects or regulations. The different solutions for Augmented Reality and for tangible interfaces also belong to this category [22].

A spatial user interface will create new possibilities for presenting reasonably large amounts of data. This means that business communities, politicians and the citizens will gain access to a new media, which is able to present frequently very complicated contexts in an easily accessible way. This media can be used within local and regional planning, marketing of the region (tourism, commercial resources, competence and knowledge) – and also to visualize more abstract forms of information (such as environmental and traffic information). The goal will thus be establishing a pioneering project, which will be the central force for the very latest knowledge about the combination of VR and GI technologies.

Together with other partners within this field of research, 3DGI expects to clear the path for new 3d datamodels that are required to get the best integration between VR and GeoInformation. This could really move the main focus from the 2d map and give more attention to the development of new methods for investigation and visualisation of our geographical resources in many new ways.

3 DESIGN ISSUES

Given the main idea, the purpose and some general considerations about GIS, VR and 3d, the next step in the development of a 3d virtual geographic interface, was the system definition. A system for multidimensional geo visualization is, in contrast to an ordinary GIS system, which at most handles surfaces, a system that can store, retrieve, analyze, simplify, generate, and visualize spatial data. Furthermore it must allow user interaction with these data. The system must be able to handle "soft" real-time demands as well as being application and device adaptable - that is the system has to be module based and object oriented so it can be adapted to PDA's, PC's, mobile units and so on, without requiring alterations to the code of the applications. The system has to be collaborative so that more than one user per session can experience and interact in the same virtual world. The system is expected to be build around one or more database technologies, used in a scalable and distributable system, in which large amounts of data will be present (magnitudes of about one TB), powerful server hardware and fast 3D graphic hardware. The system is part of a research project and for that reason the users are not specified ahead of time. The user group is potentially vast from system- and application programmers and administrators to users of applications in the system.

3.1 3D Mapping

The 3D map will create new possibilities for presenting reasonably large amounts of data. This means that business communities, politicians and the citizens will gain access to a new media, which is able to present frequently very complicated contexts in an easily accessible way. This media can be used within local and regional planning, marketing of the region (tourism, commercial resources, competence and knowledge) – and also to visualize more abstract forms of information (such as environmental and traffic information). The goal will thus be establishing a pioneering project, which will be the central force for the very latest within 3D and GI technologies.

The ultimate challenge for 3D mapping has been to develop an integrated system where the 3D objects including attributes and behaviors are kept in a database, which at the same time would be accessible for different kinds of queries and visualizations. The application that are outlined in this paper, will have the goal to both fulfill these demands and at the same time be the source for a real-time VR simulation of urban and rural areas.

The development of the datamodel for 3D mapping is an important part of the research program that has the objective to utilize the third dimension within the geoinformation society in a way so that it becomes more common to use 3D simulations and visualizations in both the public administration (as a tool) and in the many different medias that we use to plan, navigate, seek information, organize and learn from in our lives. Within some years it should be just as natural to use 3D maps as we feel it is today when we make use of traditional 2D maps.

Most geographical datamodels are being constructed with the purpose to support the traditional representation of geoinformation as a 2D map. One of the best examples is the registration of property. The traditional cadastral map is a topological 2D map with attributes, and the purpose of this map is to document the juridical rights to the property. But in urban areas this concept is not sufficient. The utilization of the third dimension through high-rise buildings and complex infrastructural constructions has made the traditional data models inadequate in respect to modern planning support systems. Beside that, there is now a greater demand for more quality in the visualization of new planning initiatives.

3.1.1 Separate 3D and GIS solutions (type 1)

There are many possible ways out of this. In this paper three different data-models will be presented and a reason for why it has been decided to use the most demanding data-model in the 3D mapping project will be described later. They can be classified in three different groups of solutions. The first type of data-model is a divided solution with two separate systems with a dedicated link between the systems. One for the traditional geo-information (generic GIS) where all the 2D maps and respective attributes are kept in a proprietary system and the 3D modeling of the city is done in a CAD-related environment. The systems might use same coordinate system and are therefore capable of doing spatial queries both ways. This means you will be able to navigate in one map and still follow the spatial movement in the other. The solution is not sufficient when it comes to real GI queries since the data structures in the two geometric representations are very different.

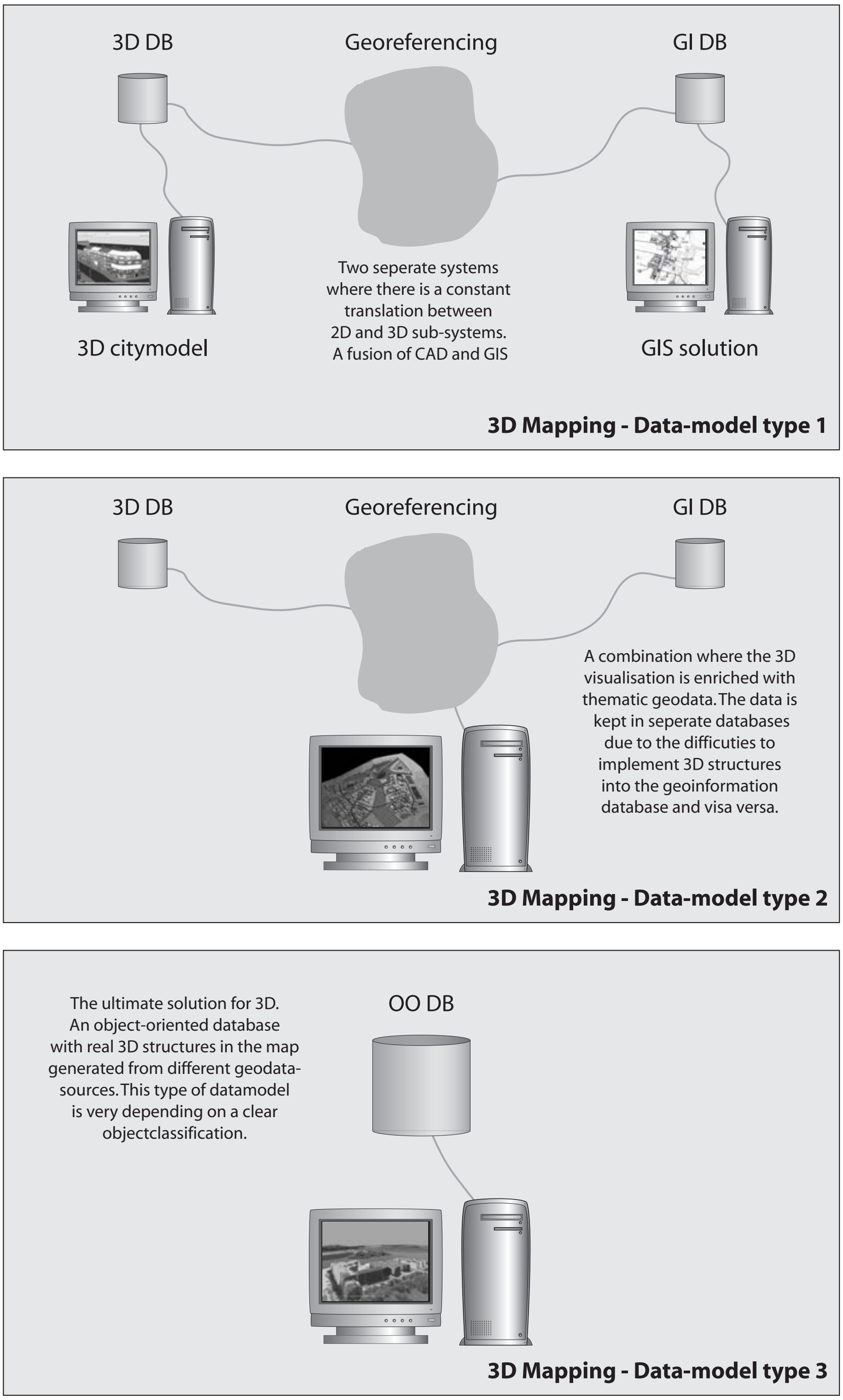

Figure 2: The different 3D mapping solutions can be generalized into three different data-models. Most common solutions are the type 1 and 2 solutions. Type 3 is still an issue for basic research and development. There are no commercial type 3 solutions available yet.

3.1.2 Combined systems (type 2)

This type of system is the most widespread solution at this time. Here it is possible to query and visualize the two different data-types within each other's environments. The link between the two systems is build as a georeferencing application. The systems are normally capable of exchanging data between 2D and 3D. By mapping the features over a dedicated surface representing the terrain, the 2D data is visualized in the 3D models. These features can even be elevated through the use of height attributes in the 2D database. There are several commercial systems that have been build over this data-model.

3.1.3 Object-oriented solution (type 3)

The ultimate solution for a 3D data model is build over an object-oriented database. The difference from traditional systems is very big. Traditional geoinformation databases are developed over the relational data-model. The relational database has its strength with simple geometric forms because of the tabular structure for the organization of data. As long as we only have polygons, lines and points, it is no problem to keep the data in the relational data-model, but as soon as we go from 2D to 3D we multiply the complexity with a very high number. At the same time the amount of data is exploding because we need to see more detailed visualizations and we need textures at the same time. This requires a lot from the database. It is both necessary to find an efficient way to create a spatial index for the database, so that objects can be found and retrieved for visualization purposes and at the same time we need the database to be very fast for real-time visualization purposes. Furthermore there are issues such as Level-Of-Detail (LOD) and orientation of the individual objects to consider. The considerations are numerous and the only way to get through this will be by working closely together with others that have the same goals to reach.

The object-oriented database requires a very detailed object-classification to work correctly. It is not decided how this classification should be generated, but since there are other projects working on 3D mapping, it would be obvious to participate in this work and develop this as a collaborative effort. The goal is not to invent our own object-classification, but to join and encourage the use of open standards for both the database but also for the visualization and later for the distribution of these maps to everyone.

3.2 System Architecture

The next step in the development of an object-oriented solution for the system would be to outline the conceptual datamodel or the system architecture for a 3DGI. As shown in figure 3, this model consists of 4 parts: 1) The Object Building/Construction, 2) The Object Database, 3) The Data Representation and 4) The Viewer.

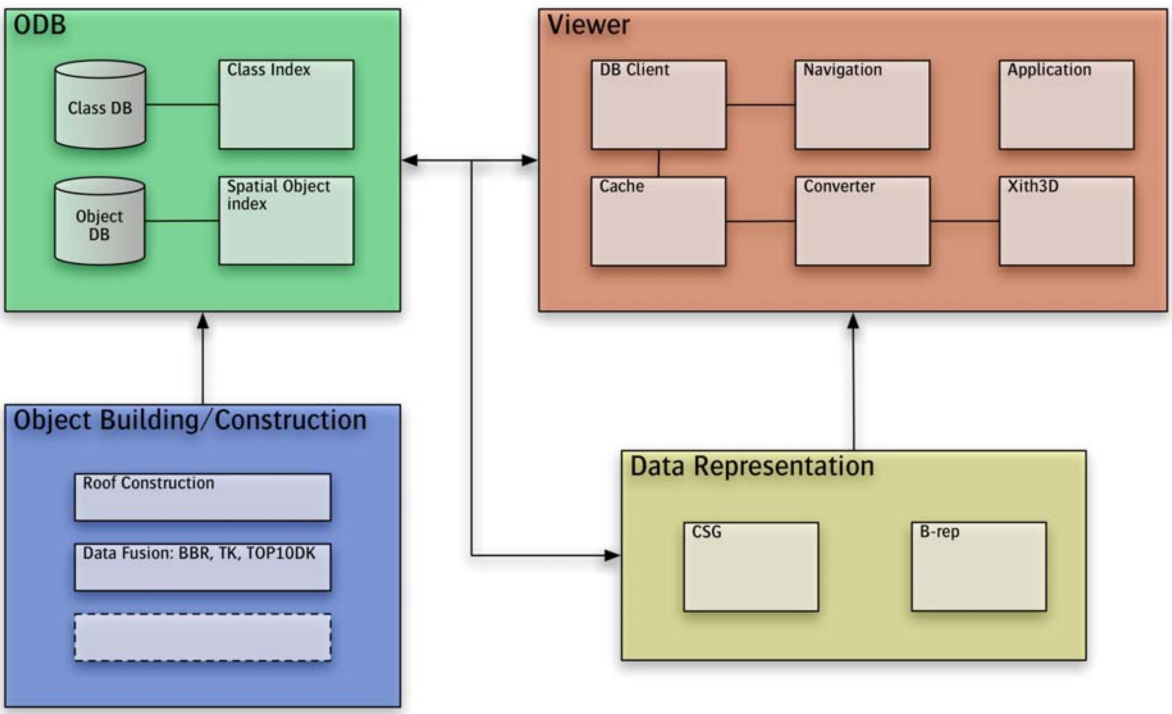

Figure 3: The system architecture for the 3DGI object-oriented system for 3D Geovisualization

3.2.1 Object Building/Construction

The first part of the process is a conversion of traditional 2D geoinformation to 3D objects. This will be done in separate steps for each of the object types. It will be too comprehensive to go through all the different types of entities. The final 3D model will consist of several very different object groups. Those will among others be: terrain, buildings, roads and vegetation. To give an idea about how e.g. buildings will be generated, a short description will be revealed here.

The information for the reconstruction of each building comes from several different sources. First of all it is nessesary to have a footprint of the building with very high precision. This can be provided from the highly detailed technical maps (1:1.000) from the municipalities. Secondly information about heights of buildings is extracted from LIDAR data that are available in urban areas. Then information about each specific building is found in the national building and dwelling register. Here is registered information about the specific number of storeys, type of building (residential, factory, shed etc.) type of use (housing or commercial), building material (for the best simulation of building texture) and type of roof. Several of these information's can be valuable for the correct reconstruction. The roofs are found through feature-extraction from the LIDAR data and even each individual unit (e.g. flats) in the building can be generated through a separate workflow also with information from the building and dwelling register. More specific details about this process will be documented in future publications.

It is obviously not an easy task to generate the database as 3D objects, since it involves a lot of very time-demanding modelling which is not general but very specific for each object type. It is a hope that this procedure in the future will be a part of the commercial map production.

3.2.2 Object Database

Some of the commercial database solutions were tested in the initial phase of the 3DGI project, which resulted in the conclusion that there were very serious shortcommings regarding the indexing of objects in 3D and regarding the nessecity to query the database in something very close to real time. The commercial databases were simply not fast enough for the purpose of 3DGI. This meant that a new object-oriented database was developed and beside the storage of the objects there is a database for the different classes. This means that new classes can be introduced very easily and that existing objects can be reclassified. Another important thing about a customised object-oriented database is also the ability to test and reengineer the database up against the viewer developed for 3DGI.

3.2.3 Data representation

Between the database and the viewer, there is a module for data representation. Each object is saved in the database in a parametric way. This way it is possible to generate either a boundary representation (B-rep) or a Constructive Solid Geometry (CSG) for the viewer. The plan is to keep an open architecture, where CSG and B-rep representation can live beside each other in the same model. Buildings can be a combination of CSG in the body of the building and B-rep for the roof, which is extracted from the LIDAR data. There are still many decisions to be taken especially regarding representation of the objects in the 3DGI system.

3.2.4 Viewer

The viewer should be both independable of certain hardware and very flexibel in use. To fulfil these demands it was decided to use Java for the development of the viewer. At the moment only a very early implementation of the viewer has been developed. This viewer is build around Xith3D [23]. The viewer will eventually also consist of navigational tools for interaction with the 3d virtual environment. Research is at the moment ongoing especially on these subjects.

3.3 Conclusion

It is our belief that the future geographic interface for geospatial information used in the coming digital administration will not be build around a 2D flat concept of the world, such as the well-known paper map, but around a conceptual virtual 3D environment, where the semantics are very much like the real world. When you want to known more about a specific location near you, it will only take you a short virtual trip through the model to go there and just ask the question in the system. Also the administration will gain from this change, since the interface can be used as a common virtual space for meetings, for introduction of new planning initiatives etc. But the road towards this ideal situation is not straight or without holes. It will take time and much more research before it will be possible to implement these systems in a broad scale.

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5 REFERENCES

[1] L. Bodum and E. Kjems, "Representations of Virtual Worlds," presented at Visual Reality, Bonn, Germany, 1998.

[2] L. Bodum, I. Afman, and J. Smith, "Visualisation of Spatial Planning with the use of new Media," presented at GISplaNET, Lisbon, 1998.

[3] D. G. Janelle, D. C. Hodge, and National Center for Geographic Information & Analysis (U.S.), *Information, place, and cyberspace : issues in accessibility*. Berlin ; New York: Springer, 2000.

[4] J. Raper, *GIS - Three Dimensional Applications in Geographic Information Systems*. London: Taylor & Francis, 1989.

[5] M. Pilouk, "Integrated Modelling for 3D GIS," Wageningen Agricultural University and ITC, The Netherlands, 1996.

[6] S. Zlatanova, "3D GIS for Urban Development," in *The International Institute for Aerospace Survey and Earth Sciences (ITC) and Institute for Computer Graphics and Vision*. Enschede and Graz: ITC and Graz University of Technology, 2000, pp. 222.

[7] A. M. MacEachren and M.-J. Kraak, "Research Challenges in Geovisualization," *Cartography and Geographic Information Science*, vol. 28, pp. 3-12, 2001.

[8] J. Raper, *Multidimensional geographical information science*. London: Taylor & Francis, 2001.

[9] M. Breunig, *On the Way to Component-Based 3D/4D Geoinformation Systems*: Springer, 2001.

[10] M. J. Shiffer, "Interactive multimedia planning support: moving from stand-alone systems to the World Wide Web," *epb*, vol. 22, pp. 649-664, 1995.

[11] M. Dodge, S. Doyle, A. Smith, and S. Fleetwood, "Towards the Virtual City: VR & Internet GIS for Urban Planning," presented at Virtual Reality and Geographical Information Systems, Birkbeck College, 1998.

[12] W. Cartwright, M. P. Peterson, and G. Gartner, "Multimedia Cartography," Springer, 1999, pp. 343.

[13] A. Fonseca and A. Câmara, "The Use of Multimedia Spatial Data Handling in Environmental Impact Assessment," in *Geographic Information Research - Bridging the Atlantic*, M. Craglia and H. Couclelis, Eds. London: Taylor & Francis, 1997, pp. 556-570.

[14] M. Batty, D. Chapman, S. Evans, M. Haklay, S. Kueppers, N. Shiode, A. Smith, and P. M. Torrens, "Visualizing the City: Communicating Urban Design to Planners and Decision Makers," in *Planning Support Systems*, R. K. Brail and R. E. Klosterman, Eds. Redlands: ESRI Press, 2001.

[15] R. Liggett, S. Friedman, and W. Jepson, "Interactive Design/Decision Making in a Virtual Urban World: Visual Simulation and GIS," presented at Fifteenth Annual ESRI User Conference, Palm Springs,CA, 1995.

[16] M. Batty and D. Howes, "Exploring Urban Development Dynamics through Visualisation and Animation," in *Innovations in GIS 3*, D. Parker, Ed. London: Taylor & Francis, 1996, pp. 149-162.

[17] A. Smith, M. Dodge, and S. Doyle, "Visual Communication in Urban Planning and Urban Design," pp. 35, 1998.

[18] M. Smith and P. E. Kollock, "Communities in Cyberspace," Routledge, 2000, pp. 323.

[19] R. Langendorf and C. Gables, "Computer-aided Visualization: Possibilities for urban Design, Planning and Management," in *Planning Support Systems*, R. K. Brail and R. E. Klosterman, Eds. Redlands: ESRI Press, 2001.

[20] E. Kjems, "VR for Decision Support and Urban Planning," presented at CUPUM 2001, Hawai, 2001.

[21] R. Nielsen, "Collaborative Spaces: Inhabited Virtual 3D Worlds," in *Virtual Space - Spatiality in Virtual Inhabited 3D Worlds*, L. Qvortrup, Ed. London: Springer-Verlag, 2002, pp. 171-189.

[22] J. Underkoffler and H. Ishii, "Urp: a luminous-tangible workbench for urban planning and design," presented at Human Factors in Computing Systems (CHI '99), Pittsburgh, PA, 1999.

[23] D. Yazel, "Xith3D Overview," http://xith.org/tutes/xith3d.pdf, 2003.