Centre for 3D GeoInformation - Towards a New Concept for Handling Geoinformation

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SUMMARY

The rapidly increasing computer power has made it possible to work with 3D in geographical information systems. In connection with data capture, storing, analysis and visualization it is possible to work with representation of objects in three dimensions in all processes. This fact really challenges the surveying community, which since the development of the trigonometric surveying largely has been working with two-dimensional systems - for many years analogously and during the last few decades digitally. During the latest two decades focus has increasingly been on the third dimension.

Furthermore, the international standardization of data and communication triggered by the Internet and related technologies challenges the national and international surveying community.

The challenge is that the profession has to replace large parts of the scientific and theoretical foundation of its professional efforts. The toolbox is going to change its data handling, which places heavy demands on the educational institutions, on research and on practice. This requires close co-operation between universities, profession and research.

At Aalborg University in Denmark researchers from the Department of Development and Planning have started a co-operation with private companies from the Danish map and geodata industry to solve the task of providing and developing knowledge that can contribute to a professional problem solution within a 3D environment for geoinformation. In this co-operation between private companies and the university also the Danish Mapping Agency takes part. The aim is to develop a joint 3D model for the entire North Jutlandic region and to carry out software and product development of 3D models for different purposes. This has to take place in traditional surveyor fields, but it is also the intention to develop new products from the map and geodata industry and for the rapidly increasing market for 3D models.

The partnership around this co-operation is organized in the Centre for 3D GeoInformation, which is a knowledge centre placed in the science park of Aalborg University.

In addition to the development of competence to model and process 3D geo-objects the centre also has a teaching task in connection with PhD studies and teaching of surveying students during their last year of study.

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1. INTRODUCTION

The technological development is changing the surveying profession at all levels. The fundamental professional challenges with problem solutions within land and property management are probably the same. But all the tools that surveyors and planners use are changing with a so far unseen speed.

Together with the classic GPS the new surveying methods, earth observation, laser scanning, etc. imply quite new theoretical and practical methods and procedures for surveying and mapping.

Virtual Reality, the games and the modern military communication technologies mean that object representation is organized with other data models. In practice this means that Internet-based standards for data description and exchange become daily tools, and all our earlier data systems have to be reorganized to handle object-oriented three-dimensional object representation.

The data distribution is rapidly changing the professional environments. Pervasive computing implies that our surveying instruments are changing. Together with wireless communication this means that updating of register and fieldwork fuse into quite new procedures for integrated digital management.

The adaptation to these new tasks neither the profession, the education nor the research can manage on their own. This requires new partnerships between education, research and the trade. The knowledge production now is so comprehensive because current adaptation and development is part of the professional problem solution. Tasks have to be solved with new methods all the time. This means that none of the usual actors can manage the task on his own. Co-operation is therefore the method.

At Aalborg University a knowledge centre has been established, the aim of which is to focus on the adaptation to these new 3D technologies and the Internet-based data transmission in different categories of networks. The National Mapping Agency in Denmark and two private companies are participating. One more is currently taking part in the science centre. The strategy of using partnerships to organize and finance partnerships is beginning to take shape.

2. STEPS TOWARDS THE CENTRE FOR 3D GEOINFORMATION

Different research activities at the end of the 1990s under the management of GISplan (Bodum, Afman et al. 1998; Bodum and Kjems 1998) 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 (Sørensen, 1999).

Already in1989 (Raper 1989) 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 a variable as 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 (Pilouk 1996; Zlatanova 2000), but not until the latest years has 3D GIS been adopted as part of the research agenda for geovisualization (MacEachren and Kraak 2001). The latest contributions to this part of the research within GI indicate that the subject is topical in many places (Raper 2000; Breunig 2001).

During the last ten years the media technology has changed enormously, too. This development really speeded up with the introduction of network-based server-client technologies like for example the Internet (Bodum 1999). At the same time it has opened a large number of interesting initiatives in the multimedia field, which may for example be seen from (Shiffer 1995; Dykes 2000). 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. The first introduction was followed by VRML 2 at SIGGRAPH in 1996, 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.

3. STARTING THE CENTRE FOR 3D GEOINFORMATION

A number of inspiration sources for the 3DGI project have already been pointed out, and with the ongoing activities at that time (1999) it was obvious to start the work by gathering partners and formulating superior ideas for a future project for the use of 3D in relation to GI.
The final inspiration for the project emerged fairly spontaneously, when in August 1999 VR Media Lab was opened with the presentation of the different arenas of visualisation. With focus on landscape simulations both in panorama and CAVE it was suddenly evident that it had to be possible to create a virtual geographical infrastructure for an entire region and use this as index for much different thematic geoinformation. A spatial user interface would create new possibilities of presenting relatively large data quantities. This would mean that the

trade, the politicians and the citizens would gain access to a new medium, which could present often very complicated connections in a readily understandable way. This medium can be used within regional planning, marketing of the region (tourism, trade resources, competence and knowledge or visualization of more abstract forms of information (including for example environmental and traffic information).

For this reason it was decided to start the preparation of an application to the European Regional Development Fund for Industrial Development (goal 2), and in the autumn 2000 the application was prepared and sent by Esben Munk Sørensen, Research Professor, Lars Bodum, Associate Professor, and Erik Kjems, Research Professor and Centre Leader of VR Media Lab. The application was aimed at establishing a knowledge centre for the use of 3D technologies in relation to the work with geoinformation. In the application it was written that "the knowledge centre thus has to be established both as a centre for a spearhead project, where the very newest VR and GIS technologies are investigated, used and developed further, at the same time as an intended distribution of the technology to the trade, learning environments and other social groups takes place."

4. PURPOSE OF THE CENTRE FOR 3D GEOINFORMATION

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 visualization 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 increased 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 location-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.

A Centre for 3D GeoInformation will be an exploratorium in several dimensions. This exploratorium is created partly by gathering knowledge and competence at an internationally high scientific level and partly by developing and conducting a three-dimensional model of the

North Jutland region. The Centre will then be able to form basis for developing VR technology for the benefit of research and development, strategic functions, operational functions and the mass market in the region of North Jutland.

5. CURRENT THE CENTRE FOR 3D GEOINFORMATION

A number of activities has already been started under the management of 3DGI. In the autumn 2001 an international workshop with the subject VR + 3D GI was in combination with PhD-courses. Furthermore, a network has been started within the subject. Under the management of the Network Centre of Aalborg University several network meetings with very different subjects have been held. Throughout this networking activity new partnership on special issues is organized and is effecting further projects between university and partners outside the academic community.

In a research context many exciting activities are going on, too. One of the most important subjects for this research is the very basis for the establishment of the spatial data description. This subject, which is not only addressed in Aalborg, has had our full attention for the last months, as these fundamental structures are a condition of being able to work with geographical information in a quite new way. Therefore we have chosen to concentrate the presentation of the research work at 3DGI on exactly these considerations in this article.

6. ORGANISING SPATIAL DATA

The GIS that we know today has developed since the 60s. The tools of analysis, the functionality and not least the user interface have undergone a dramatic change since then and latest within the last 10-15 years. Systems with line addressing have been replaced by ordinary window-based navigation. The use of GIS varies a lot, and the number of users and the diversity among the users are growing constantly. Case workers, who a few years ago would not dream of using GIS and for that matter did not know what GIS was, are today deeply buried in presentations generated on the basis of exactly GIS. In this way the use varies, not only among a variety of professional groups, but also among users, who have a more or less good knowledge of the structure, fundamental functionality and applications of the GIS. Hopefully supplementary training will increase the general level of understanding.

One thing which has not changed so dramatically during the latest decades in that connection is the way in which we handle data in GIS. The data model has traditionally been surface-based, i.e. two-dimensional. The fight for the closed polygons and the abolition of spaghetti maps, which are not fit for GIS purposes, finally seems to have succeeded. The systems use topological descriptions to handle the geographical data for GIS purposes. The way this is done is different, but the basic idea is the same. This way of controlling geographical data is well-tested, and the algorithms used for analysis or only for searching are tailored for this data organizing. This has among other things meant increased speed all along the line.

7. FROM GIS TO A SPATIAL VIRTUAL WORLD

When in the Centre for 3D GeoInformation we wish to use established registers and traditional map products as basic data we thus have a good foundation of having them organized. The challenge arises, when we wish to describe a data model which is closer to reality, i.e. describe elements in the landscape as "real" elements and not only representations. In this way a building becomes a building and not only a surface with a thematic description. The building becomes an object. At first it sounds evident that we try to describe the world as it really looks. Why make so many dodges around standards, symbolic notation and simplified representations? The answer is, however, simple, as using a data model means simplifying, compressing the data quantity and increasing the abstraction so that in the geographical world it is possible to process large areas with relatively simple geometrical algorithms. So of course it is common sense to do it.

Concurrently with the untiring increase of the computer power and the storage capacity new possibilities are opened, as this increase gives us the opportunity of using more bits to describe the world, at the same time as we do not necessarily have to wait longer to have answers to our questions. The advantage of using more bits for description of the single objects means less simplification, less compression and a reduced level of abstraction. This means that we do not have to interpret as much from the presentations as earlier, as we can use presentations that are more intuitive and self-explanatory. Fundamentally it is our clear hope that exactly the spatial three-dimensional description and presentation becomes more intuitive as user interface for geographically related information. Certainly, the symbolic, flat description will be greatly preferable to many just as we have learned the alphabet to be able to read. But to others, especially outside the professional circle, a new world will probably open up.

8. THE DATA MODEL

By describing the world as the spatial reality surrounding us, an alarming complexity is opened, where elements cannot only be described through points, lines or polygons with well-defined mutual relations. When objects are to be described with a spatial geometry and representation, it does not only require some new thinking, especially when the objects are to be used in connection with a GIS. We have been working with spatial models in connection with visualizations, 3D animations and latest virtual reality for several decades. But there is an enormous jump from simple 3D modeling and a model that typically has a limited extent and model description, which uses simple file formats with limited capacity, to a 3D model, which shall contain knowledge about itself and relations to its surroundings - which in principle has to cover the entire globe.

Even if we try to describe our spatial model of the world in an attempt to approach the real world, we still have to simplify the model, as we must make a choice about the detail level of the object description. It is relatively simple to take a position. If for example we take a building, we have to decide how many details we wish to include. Is every roof window or windbreak to be included? We would like to. As mentioned previously, we start from existing map products and registers, which among other things contain information about the spatial extent of the objects. In the Danish Building and Dwelling Register we can find information about the building, like number of floors and roof construction, which immediately gives an idea of how to represent this building spatially. The problem in using different sources of information may be that there is conflicting information. The information in the Building and Dwelling Register may for example indicate that a building has a flat roof, but our laser scanning from the area suggests that the roof have a rise. The choice here will of course at first be in favor of the laser scanning. In other cases it may be necessary to look at time stamps, tolerances or other metadata. The analysis has to run 100% automatically as far as possible. A set of rules will be built for a small expert system, which in time can be extended with new knowledge and new algorithms.

One of the special focus areas is modeling spatial legal objects. This subject is for cadastral surveyors of great importance, because the technology is near to ready for modeling objects I real 3D. The 3D technologies based on Virtual Reality will made it possible to describe ownership to spatial legal object as there are understood in reality, where property rights always is related to three dimension. Ownership to land, buildings, easements, rights to pass (road) is all in three dimensions i in the real world. The challenge is not only to develop theoretical concepts for describing the model, but also develop procedures for object-oriented updating and real-time visualizations in virtual environments. Research on these issues is being prepared. This research includes organizational and institutional aspects because every existing data model and representation of property units and rights is reflecting the specific national history on cadastral registration and land use management and the connected institutional history.

9. DIFFERENT EXAMPLES OF VISUALISATIONS IN THE CENTRE FOR 3D GEOINFORMATION

The practical organization of the work in the knowledge center will be organized as a number of partial projects that partly cause prototypes, algorithms and documents for the final system structure, which shall be the basis for the functionality of the object-oriented system. The following are examples of such projects, which are a mixture of PhD study courses and isolated projects:

- Feature extraction from aerial scanning (LIDAR)
- Organizing 3D object representation using XML-based standards
- Data modeling and queries for 3D geographical data
- 3D cadastre
- Qualification of 3D geovisualization
- Ground laser scanning and modeling 3D objects
- Exchange of data between XML and RDBS
- Landscape visualization in 3D and temporal analysis

The coming year will give rise to further projects based on partnerships between research and companies in the private sector all preparing the incoming professional challenges to handle within and with 3D objects following the line to a more sustainable and communicative world.

10. FINAL REMARKS AND FUTURE PERSPECTIVE

At the moment when a real element is reproduced as an object in the model, it may in principle get its own "life". By using an object understanding like the one known from the object-oriented programming language, we have the idea build the single objects of the model, which again is made up by other partial objects. If we take the example about a street lighting, which does not only consist of a numbered point in the map, we have a pylon, an overhang and fittings, which again contain a strip light that has a certain producer as source and an expected life, etc.

It has been written that all the things that we surround ourselves with in everyday life must have an own life - pervasive computing - or rather an IP number, a CPU, a little storage capacity, probably one or more sensors as well as a GPS unit for the mobile units. The refrigerator that takes care of the shopping, the company's telephone system that knows where the telephone shall ring, or the car, which reports itself stolen, are examples which have been developed. This kind of intelligence is partly transferred to the objects we know from the traditional GIS. As the data model describes all parts as objects, it is possible to handle objects with these dynamic properties and show changes in the model. In this way the street lighting will report back, when it has been run down or the lighting unit is defective. These systems are working, and we could of course continue guessing about the future and describe a future use of an object-oriented GIS, but this will happen later. Information will continuously be placed on the homepage of the project, and the Knowledge Centre for 3D GeoInformation can be visited at http://www.3dgi.dk.

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BIOGRAPHICAL NOTES

Esben Munk Sorensen is Research Professor at Aalborg University and at The Danish Forest and Landscape Research Institute which is a sector research institute under the Ministry of the Environment. He his Master of Science in Surveying, Planning and Land Management (1981) and PhD in Rural Development and Physical planning (1988). Until 1998 he was an associate professor at the Department of Development and Planning, Aalborg University. Since 1989 he has been Editor in Chief of the Danish Journal for Mapping and Land Use. Since 1992 he has been Research Director on several large research projects within land administration, geographical information management (www.3dgi.dk and www.property.dk) and virtual learning environments (www.villl.auc.dk). He has published widely, nationally and internationally within these topics. Presently he is responsible director for The Centre for 3D GeoInformation at Aalborg University.

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