Applications and Solutions for Interoperable 3d Geo-Visualization

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ABSTRACT

3D visualizations of spatial objects are employed in an increasing number of applications from the areas of (urban) planning, city marketing, tourism, and facility management. Further application fields could be entered, if distributed spatial objects could be integrated on the fly into one 3d scene. We argue, that this integration can only be successful (and in some cases only be possible) if it does not mean to copy and concentrate all data into one monolithic system.
In this article we sketch promising new applications and examine their technical requirements. We discuss how these issues can be addressed by the use of interoperable geo web services, following the standards proposed by the OpenGIS Consortium, the ISO, and the initiative Geodata Infrastructure North Rhine-Westphalia (GDI NRW) in Germany. To overcome current limitations we introduce a new web service for the 3d visualization of spatial data. The presented application scenarios are a result of the feasibility study "Virtual Regions in the Rhine-Ruhr area 2006" which has been carried out on behalf of the state government of North Rhine-Westphalia in Germany.

1. INTRODUCTION

3d city and landscape models reveal a high information potential for a variety of application fields in the private and public sector. Besides the well-known applications in the fields of architecture, urban and transport planning, surveying and mobile telecommunication, 3d models become increasingly important in the fields of city and regional marketing (e.g. representation of regions, municipalities, companies and Football World Cup locations), tourism (recreation, culture), telematics (pedestrian and car navigation), civil protection (flood protection, noise and pollutant dispersion, disaster management), real estate management (broker, banks, assurances), and facility management.
Most applications typically need various geoinformation from different data providers. E.g. an architecture firm requires for the planning of a new shopping mall digital 3d geoinformation in terms of a small scaled and low detailed city model covering the whole planning area, which will support the identification of appropriate locations. The 3d objects also have to be related to socio-economical 2d geoinformation. When the appropriate location has been found, detailed architectural resp. building models with detailed texturing are necessary for the target area in order to be able to demonstrate the integration of the shopping mall with its environment by 3d visualization. Difficulties arise, because spatial data sets are not only scattered over different public and private data providers, but also use different models, data formats, and levels of detail. Because of these heterogeneous conditions, integrated 3d visualization of these data resources proves to be complicated. Indeed, a general strategy for interoperable 3d geo-visualization in the context of geoinformation systems is still missing.
At large, the widespread and sustainable use of 3d geoinformation in the mentioned application fields is hindered by high pricing, limited data availability, missing 3d analysis instruments, diversity of formats and processing systems, and insufficient access mechanisms. Above, data actuality and quality of 3d models often is low, because in many cases 3d city models have been acquired for specific projects only and were not updated afterwards.
However, users require immediate data access, means for the interoperable integration of different 3d geoinformation in different levels of detail, tools for 3d analysis and further data processing (based on data storage using databases, general purpose 3d GIS with functionalities like visibility analyses etc.) as well as solutions for interactive visualization and presentation. Furthermore, aspects of model integrity, security, data updating (and its costs), 2d-3d-integration, real time visuali-

zation and texturing (highly resp. less detailed, photo-realistic or pseudo textures) are of utmost importance for the quality and user acceptance of 3d geoinformation systems.
It is the aim of the initiative Geo Data Infrastructure North Rhine-Westphalia (GDI NRW) to improve the availability, use and distribution of spatial data and thereby enable the geoinformation market in NRW and beyond. The GDI NRW realizes an open network bringing together geoinformation producers, value adders, brokers and users. By the application of web service technology the spatial data from public and private sources can be registered, queried and visualized in an interoperable way (Bernard et al. 2003). The Initiative GDI NRW was founded in 1999 as a public private partnership between data providers, software manufacturers, users, and participants from academia and administration. The CeGi Center for Geoinformation GmbH manages the operative business of the GDI NRW. Interoperability of distributed data resources is the key issue wrt. spatial data infrastructures. To ensure interoperability the GDI NRW adopts (and is also involved in the development of) international standards of the OpenGIS Consortium and the ISO/TC 211 (see Altmaier and Müller 2002, GDI NRW 2003, CeGi 2003a, OGC 2003, ISO 2003).
To overcome the above mentioned specific problems of 3d data handling and visualization, the Special Interest Group 3D (SIG 3D) has been founded as a working group in the GDI NRW. For more than a year it is working on the development of user-oriented concepts for the interoperable integration of different distributed 3d spatial data resources of public and private providers. The general idea is to avoid central data storages and monolithic, proprietary applications. Instead, 3d spatial data should be kept at its sources and made accessible via standardized interfaces using web services (see Kolbe 2003, Gröger and Kolbe 2003).

2. DEMANDS AND CHANCES FOR DISTRIBUTED 3D GEOVISUALIZATION

In the feasibility study „Virtual Regions in the Rhine-Ruhr area 2006“, which has been carried out by CeGi GmbH until July 2003 on behalf of the state government of North Rhine-Westphalia, Germany, current and future application fields for interoperable 3d GIS and 3d visualization have been identified and rated (see fig. 1). The investigations are based on numerous and comprehensive interviews with experts coming from business, administration, organisations and research institutions focused on their role as a provider resp. user of 3d geoinformation.

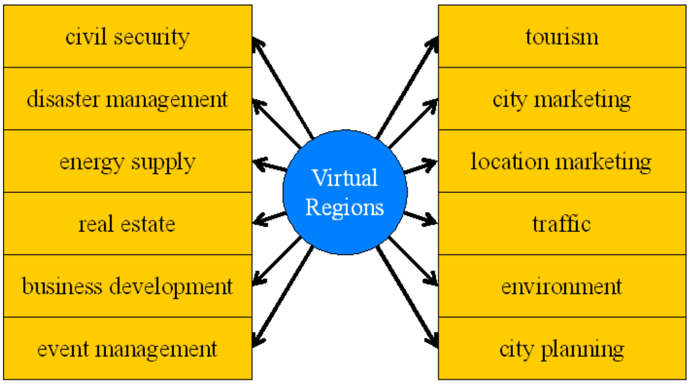

Figure 1: Application fields of virtual regions with special focus on 3d visualization identified in the feasibility study (CeGi 2003b).

2.1. Overall chances of distributed 3D data resources

According to the results of the feasibility study, an interoperable system of distributed 3d data resources provides the following chances and advantages (CeGi 2003b):

2.1.1. Interoperability and compatibility

By ensuring interoperability of data formats and systems the users can access arbitrary 3d spatial data sources in a homogeneous way. It allows the application of the same analysis and visualization tools for different data sets. The retrieval of appropriate geoinformation is supported by a metadata information system, which currently is developed for NRW. Although there already exist numerous international standards of the OpenGIS Consortium for data access and visualization (OGC 2003), some technical issues like the realtime exploration of 3d scenes over the internet presently only can be realized by proprietary software applications. Therefore, the questions concerning the right balance between standardisation and proprietary systems as well as concerning the capability of 3d GIS functionalities and 3d visualization services (e.g. static or dynamic visualisation) have to be discussed. In the medium term, only a mixture of standard-based and proprietary solutions can be realized. However, each application of standardised services, formats and modeling improves the system's overall compatibility and the compatibility of providers and possible users.

2.1.2. Multiple use and sustainability

Interoperability and compatibility offer multiple usage of geoinformation as well as the creation of added value and more convenient data updating, and thereby assure the sustainability and quality of 3d data resources. In many cases the acquisition of 3d geoinformation has been project-based (especially in projects that were focused on 3d visualization only), which means that database storage, further data processing, re-use and data updating are not assured. Mostly, a one-time investment is done without considering long-term and sustainable re-use possibilities. Therefore, in the context of sustainability the question arises, if in the different application fields the focus is rather on 3d presentation, realism and aesthetics or on 3d GIS and analyses.

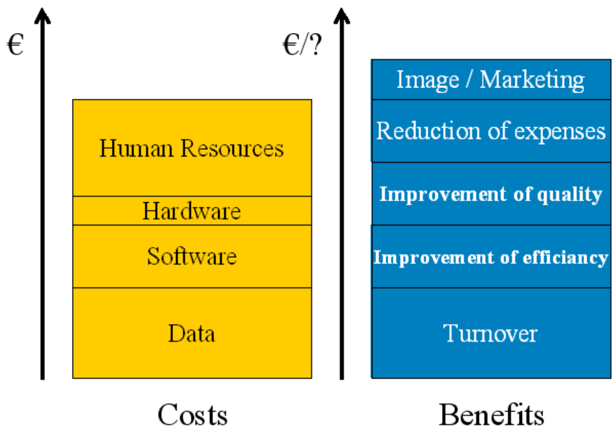

Figure 2: Cost/benefit factors of distributed 3d geoinformation systems (CeGi 2003b)

2.1.3. Improvement of work flow and efficiency

The sustainable use of distributed 3d spatial data resources induces synergy effects by avoiding repeated work due to redundant data storage and analyses. Thus it brings facilitation of work and improvement of efficiency (see fig. 2). This includes the shortening of internal processes by providing fast data access (e.g. improved use of geoinformation in municipal administrations), improved visualization of urban planning projects, more transparent and curtated planning procedures, improved citizen participation processes or simplification and automation of work flows, which allow a higher accuracy and the balanced load of process components.

2.1.4. Chances of refinancing

Interoperable 3d geoinformation systems show market, economisation and refinancing potentials. In the long run, only such applications running on a spatial data infrastructure can be successful, which reveal real market potentials, i.e. there is a strong demand on the market by users, or a specific need and long-lasting sale possibilities based on the applications' direct and indirect economisation and refinancing possibilities (see fig. 2).

2.1.5. Public Private Partnership

The complex technical, socio-economical and administrative conditions concerning the sustainable realization of the spatial data infrastructure in NRW require the participation of economy, administration and academia (Public Private Partnerships). Only by collaboration and concerted decision making the existing deficiencies and limitations can be overcome.

2.2. Special chances of 3D visualization

3d visualization reveals chances and advantages in the following respect:

- It provides graphical presentations of and insights into states, procedures and processes.
- It supports analysis, decision making, management and planning and thereby improves work flows and efficiency in different application fields.
- Most technological issues concerning 3d visualization are clear. There already exist various solutions for 3d visualization. Whereas most of them are proprietary applications, their technological basic concepts can be transferred when developing standards for the visualization, access and retrieval of distributed 3d data resources.

2.3. Application fields for 3d geo-visualization

In the following the chances and advantages of distributed 3d data and visualization systems will be highlighted for the different application fields (cf. fig. 1). The analytical and management support of 3d visualizations in the government and business sector takes an important role. 3d applications in the customer sector, like e.g. location based services on mobile phones and personal digital assistants (PDAs), are presently only of marginal importance. Generally, multiple-shift usage as well as economization potentials of 3d data and applications also depend on the way the underlying data is stored (e.g. locally in files versus databases or 3d geoinformation systems).

In the sector of site and city marketing, tourism and business development, 3d visualization enables the presentation of business locations, municipalities, touristic sites and industrial areas (see fig. 3). These presentations serve e.g. for captive marketing activities, municipal advertisement of recreation and tourism locations, evaluation of aesthetical aspects of city planning as well as for the marketing of trade areas and industrial buildings. Marketing for sporting events as well as recreation infrastructures like bicycle paths, museums and exhibitions are counted among the tourism sector. Aim of the business marketing is the acquisition of investors for e.g. trade and industry, companies, fairs, architects, hotels, restaurants, public transport, real estate providing companies.

Especially in the sector of event and building management, 3d visualization supports the management aspect, e.g. concerning the facility management of industrial buildings, event locations and public establishments. Site models are used for calculations of area- and volume-oriented services like commercial cleaning, seating, assurance value determination or fire fighting activities as well as for security surveillance concerning electricity and gas systems, partially in conjunction with external location based services.

In the sector of city, traffic and regional planning, the 3d vizualisation of distributed 3d data resources facilitates the improvement of plan visualization as well as the support of decision making, analyses and planning activities. It comprises e.g. the visualization of building structures, civil engineering, and visibility applications concerning urban landuse planning and building permission procedures as well as monument protection and greenspace planning (tree and greenspace register). 3d visualization contributes in this sector especially to the improvement of work flows and efficiency, first of all in the context of municipal administrations, e.g. by process simplification, higher degrees of citizen participation in planning procedures, more transparent decision making in planning processes, more reality-like presentations of planning alternatives (analysis of impacts), early rejection of non-realistic alternatives or well-founded support of council decisions. An active participation of citizens includes e.g. the examination of planning alternatives over the internet by a standard web browser integrating annotation and decision possibilities. 3d GIS, high data actuality and updating as well as an on-demand access to distributed data resources are essential in this application field.

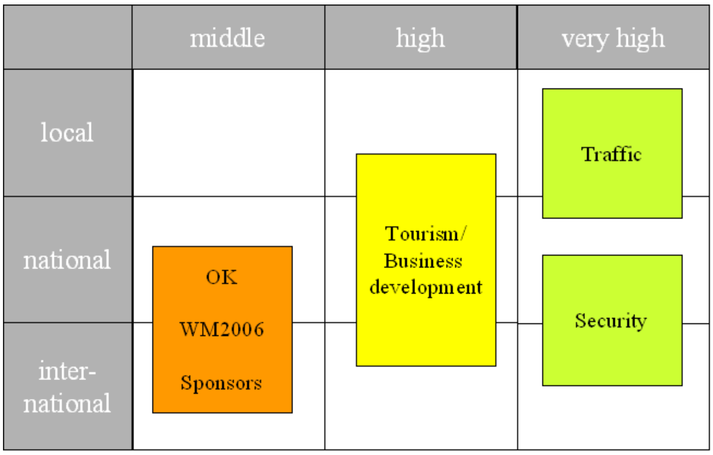

Figure 3: Approximated added value of 3D application fields concerning the football world cup 2006, tourism and business development as well as traffic or civil security (CeGi 2003b).

Concerning the sector of traffic and transport, 3d visualization is employed in telematic applications like pedestrian and car navigation systems (see fig. 3). Currently, manufacturers of navigation systems are acquiring 3d spatial data for the most important and famous landmarks in Europe which will be integrated in their navigation systems in the future. The sector of traffic and transport relies on high availability and interoperability of continuously updated, georeferenced 3d data.

In the environmental sector 3d visualization is used especially for the presentation of analyses results. Dispersion models are employed for analyses of noise characteristics, air flows and emission dispersions. 3d visualization is also used for view determinations in the context of urban planning (new building projects, shadow and lighting effects). Presentations of water bodies in flood protection simulations and aspects of coastal and mudflat protection (waterway and port protection through monitoring of mudflat geomorphology, seismology and geology) employ 3d visualization as well. Furthermore, 3d visualization can be used in the fields of landscape planning and environmental protection.

In the sector of disaster management and civil security, 3d visualization assists in decision making, like e.g. in Decision Management Systems supporting the evacuation of event locations (e.g. football stadium). The advantages of interoperable distributed data storage, of high data actuality and of fast data access are of utmost importance in this application field (cf. fig. 3). In case of emergency, a quick situation management and surveying by the help of visual adhoc integration of distributed geoinformation resources can be vital.

In the sector of supply engineering (energy supply, sewerage), an improvement of management aspects is provided by 3d visualization. This comprises the usage of site models for the establishment and surveillance of sewerage, water and energy systems (e.g. visual indication of disruptions). Last but not least, 3d visualization facilitates the quality evaluation of sites and locations (property assessment, real estate assessment or landuse register in combination with current market values, guiding private value, real estate values and property market rates).

2.4. Scenarios for integrated 3d visualization

If 3d spatial data are stored decentralized at different places, the totally covered space is fragmented. In his work on the consistency of distributed 2d spatial data resources Laurini distinguishes between *zonal* and *layer fragmentation* (Laurini 1998). For 3d data zonal fragmentation means a partitioning of the modeled 3d space where different resources contain spatial data of different regions resp. subspaces. Layer fragmentation describes instead situations where distributed data sets represent different aspects / elements of the same space (and in 2d maps are kept in different layers). According to this distinction two scenarios for integrated 3d geo-visualization for distributed 3d city and region models can be developed.
The so-called *mosaic scenario* (see fig. 4) manages the 3d visualization of large areas. 3d city and site models from different sources are embedded at the time of presentation into a regional model and are visualized together. This scenario is especially suited for building region portals, where area-covering presentation is needed on the one hand, and possibilities for detailed examination of locations of interest should be given on the other hand ("zoom in to the level of 3d building models").

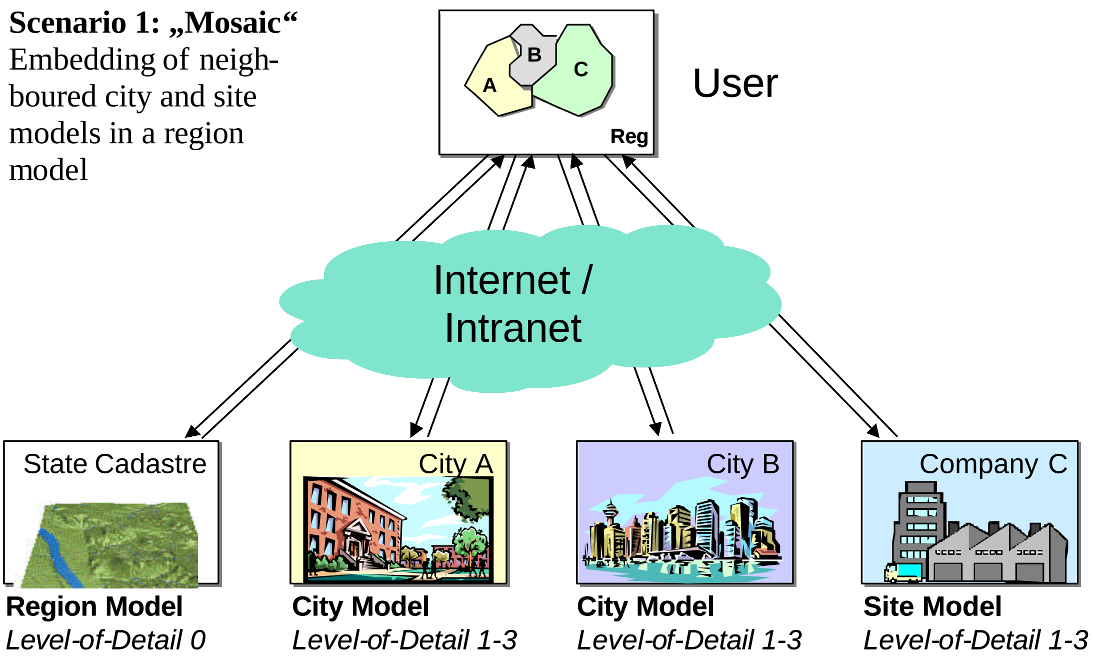

Figure 4: Different neighboured city and site models are integrated mosaic-like in conjunction with a region model in order to obtain large-area 3d scenes.

In the *hierarchy scenario* (cf. fig. 5) visualization is focused on a specific area for which different providers at different locations contribute 3d spatial data. A typical application would be the integrated presentation of a 3d city model consisting of spatial objects with different degrees of detail. For example, while building models may be delivered by the city's land registry office and the digital terrain model is retrieved from the state's survey office, company B provides vegetation and other 3d objects like traffic signs/lights that are needed to increase the degree of realism. Above, a company C might contribute a highly detailed 3d model of a place of interest like a museum or a stadium which interior is also modeled and therefore can virtually be entered and explored. The addition of thematic 3d spatial objects also belongs to the hierarchy scenario.

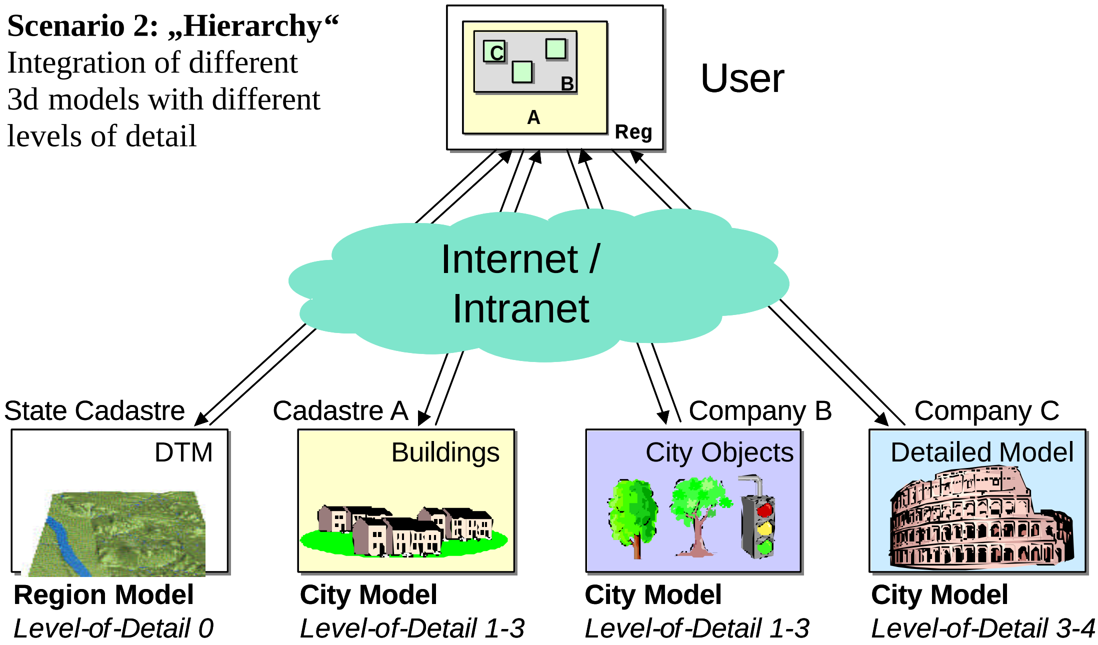

Figure 5: 3d models with different levels of detail are combined and embedded into a region model in order to obtain complex 3d scenes.

Applications may also combine aspects from both scenarios. However, these applications always have in common that spatial data is kept at their sources by their owners who provide online access by standardized interfaces. The advantage is that spatial data have not to be copied into a central system, but will be retrieved at the time of presentation from the different providers. By avoiding redundant data storage it is ensured that every 3d visualization is based on the latest data. Above, this approach allows exact accounting of the 3d spatial objects that are actually used in presented 3d scenes.

3. INTEROPERABLE 3D GEOVISUALIZATION OVER THE WWW

After the description of the different application scenarios the technical issues regarding their realization have to be discussed. Several municipalities and companies nowadays already have built up virtual 3d city models. Since none of the commercially available geoinformation systems provide full support for the representation, storage, analysis, and visualization of 3d spatial objects yet (see Zlatanova 2002 et al.), existing 3d city models typically are stored and maintained in CAD systems, visualization systems, or special systems for 3d building registration. If different 3d models have to be visualized together in one scene, difficulties arise because of the fact that the majority of these systems lack the ability to manage distributed data resources. In most cases transient integration of distributed 3d model components is not supported and only can be realized by importing all model components into the current project. The latter procedure reveals following disadvantages: first, data integration possibilites are limited by the import capabilities and project size restrictions of the system. Second, the continual accumulation of spatial data within one (monolithic) system steadily increases the dependence on this specific system. If concentration of spatial data is not possible, e.g. due to technical, legal or licensing issues, or should be prevented in general, mechanisms for the management of distributed spatial data resources have to be employed.
Another aspect of data integration that will be considered in the following concerns the type of the objects to be combined. The obvious approach is to retrieve the spatial data from the distributed

data resources and to generate a joint 3d visualization from the set of incorporated spatial objects. The alternative way is to generate partial graphical representations for the spatial objects at their sources and to combine these instead of the spatial data themselves. The most prominent example for the latter strategy is the Web Map Service proposed and specified by the OpenGIS Consortium. It allows to retrieve 2d maps (i.e. raster images) from different sources and systems. The maps can easily be combined in a web client (e.g. a web browser) by simply overlaying the raster images (see Beaujardière 2002). Thus, for the purpose of integrated (2d) visualization maps are combined and not the underlying spatial data.

3.1. Geo-visualization using web services

Concerning the presentation of spatial data the OpenGIS Consortium follows the line of (Haber and McNabb 1990). They introduced the concept of the visualization pipeline, which describes visualization as a multi-level process starting from non-graphical object representations stored in a repository (e.g. a database) and ending with the final presentation of graphical entities on a display device. In the OpenGIS framework presentation of spatial data is discussed under the term portrayal and is realized in a four level portrayal pipeline (see Doyle and Cuthbert 1998). The lowest level is built by the spatial data resources. In a selection step the interesting objects are retrieved. The second step transforms the selected spatial objects to a graphical representation, i.e. the spatial objects are mapped to display elements. In the third step the generated display elements are rendered to an image, which in the final step is displayed to the user by an appropriate output device (cf. fig. 6).

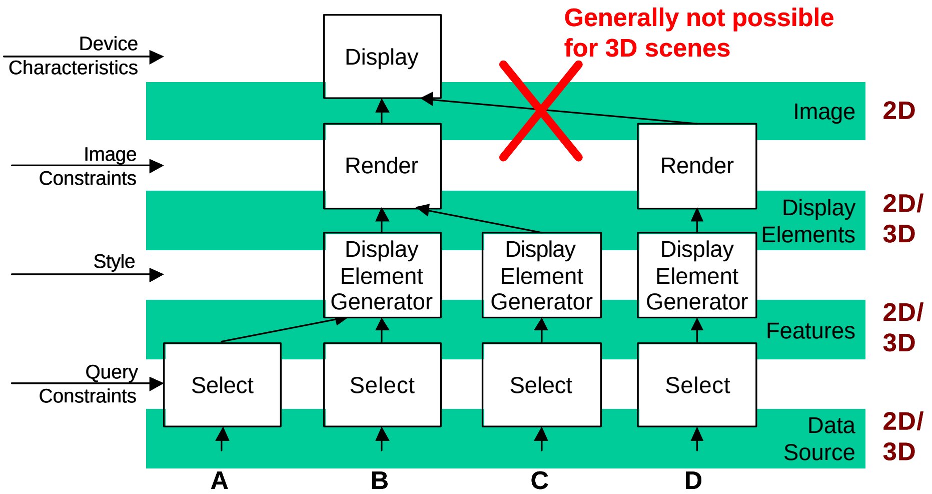

Figure 6: The component structure of the portrayal pipeline allows the integration of data on different levels in order to obtain an integrated visualization (Doyle & Cuthbert 1998). Besides on the image level objects can have both two or three dimensional geometries.

As can be seen from figure 6 the merging of data from different sources can take place at different levels of the visualization pipeline. After the selection of the spatial objects to be presented the data from path A are merged into path B, where for the objects from both A and B display elements are generated. Further display elements from path C are integrated before an image containing all graphic elements from A, B, and C is rendered. At the time of presentation another image can be integrated from path D as an overlay to the previously generated image. The latter approach is often used for the stacking of (2d) web map layers delivered from distibuted web map services. The advantage is that the services that are to be combined only have to be compatible on the level of map graphics (JPG, TIFF or PNG in most cases), but not on the levels below. This allows the integration of maps from different systems that otherwise have nothing else in common.

Unfortunately, 3d visualizations cannot be integrated on the image level, since rendered images are only 2d. If two systems render views of the same scene, these images may not simply be overlayed, because the lower image can show objects that are nearer to the camera as the objects in the upper image. Nearer objects then might be covered by the rendered objects in the upper image. Therefore, 3d integration has to take place earlier, i.e. on the level of display elements. For proper integration of different sets of display elements then it is necessary that they have 3d geometries and use the same spatial reference system.

The components of the portrayal pipeline have not to reside on the same system; they can be distributed over the internet. However, in client-server applications the lower level components are typically realized by one or more servers while the remaining visualization tasks are handled by the client. According to their complexity clients are classified into thick, medium, and thin clients (cf. figure 7). Thick clients communicate on the feature level with the server. The advantage is that the client is free to realize any – including very complex – visualization and interaction schemes. The major drawback wrt. to web applications is the need of a special web browser plug-in which implements these schemes. The plug-in has to be downloaded and installed by users before they can start with the visualization and interaction. Medium clients also need a plug-in for 3d visualization. However, if the display elements are represented using international standards like VRML, X3D or SVG, existing standard plug-ins can be used. The advantage of medium clients is that 3d plug-ins typically provide functionalities for realtime rendering and navigation and therefore allow a high degree of interaction. Thin clients only have to cope with rendered images. Thus, the most important advantage of thin clients wrt. to thick and medium clients is that they do not need any plug-in and can be used by standard web browsers on practically every computer system. However, since images are static, possibilities for interaction and navigation in the presented 3d scene are strongly limited.

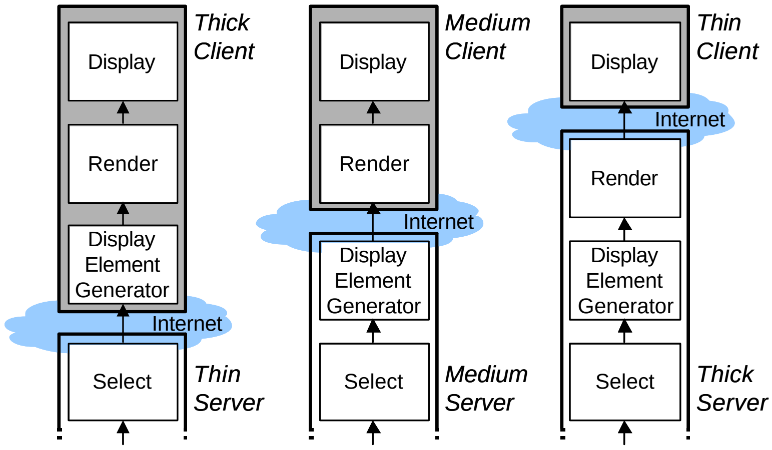

Figure 7: Different balancing schemes wrt. visualization tasks between client and server.

The decision which client model is appropriate for what application depends on the specific application scenario on the one hand and the availability of appropriate data and services on the other hand. If 3d visualization plays only a minor role, for example, when a 3d view of a sports arena has to be shown in an online ticket service application, a thin client should be used. In such scenarios it should be avoided that users have to install a plug-in in order to be able to use the system. Otherwise they most likely will leave the system and buy their tickets in another shop. If the application focus is instead on interactive exploration, at least a medium client has to be used. If no service for the generation of 3d display elements is available, even a thick client has to be implemented.

In the OGC model the different components of the portrayal pipeline are realized as web services. Web services are autonomous application servers. Their functionalities can be accessed and programed by standard web interfaces (see Gottschalk et al. 2002, Curbera et al. 2002). In contrast to web servers they are only employed for the communication between applications and therefore offer no (graphical) user interface. Communication typically is based on XML data formats. Further characteristics of web services include the capability of self-description, system encapsulation, loose coupling, locational transparency, and the possibility of their composition to a network.

3.2. Using OpenGIS data web services for 3D visualization

The OGC has specified a number of web services (OWS) for the work with spatial data. These services are categorized into data services, portrayal services, transformation services, and registry services. For the realization of 3d geo-visualization only the data services and the portrayal services will be considered in the following. Data services provide access to the spatial data. For example, the Web Feature Service (WFS) delivers geographic features in vector format that are represented using the Geography Markup Language (GML). Until recently, only 2d, non-topological spatial objects could be expressed by GML2. With the release of GML3 in early 2003 also 3d objects, triangulated irregular networks (TINs), 2.5d raster data as well as explicit topologic relations became representable (see Cox et al. 2003). The Web Coverage Service (WCS) is a data service that is specialized in providing access to raster data. For a WCS it does not make a difference, if the raster data represents digital height models or the different channels of aerial and satellite images.
Applications that employ OGC web services for 3d geo-visualization are rare up to now. Most likely this is due to the fact that no specification for a real 3d portrayal services has been released by the OGC yet. Therefore, applications have to use data services and must generate 3d visualizations on their own by implementing thick clients. May et al. describe in (May et al. 2003) the application FLUMAGIS (acronym for the German title "Flusseinzugsgebietsmanagement" which means the management of river catchment areas) and show which spatial objects can be served by what OGC data service. In this application the different objects like terrain, vegetation, water bodies, and the road network are visualized in 3d and can be explored interactively. For the implementation of the client application Java3D is employed.

3.3. Specific 3D visualization services

In contrast to data services the portrayal services deliver graphical representations of the spatial data and not the spatial data themselves. They typically cover the rendering and mapping components of the portrayal pipeline (cf. fig. 6). The selection of the objects to be presented may also be part of a portrayal service. Whereas for 2d visualization the Web Map Service (WMS) is already established 3d portrayal services are still at the beginning. With the proposal of the Web Terrain Service (WTS) the OGC is making a first step in the direction of 3d visualization. The WTS is described as an extension to the WMS that allows to show maps from non-standard viewing angles, i.e. not only 90° from above but also providing perspectively distorted views. Furthermore, 2d maps or orthophotos

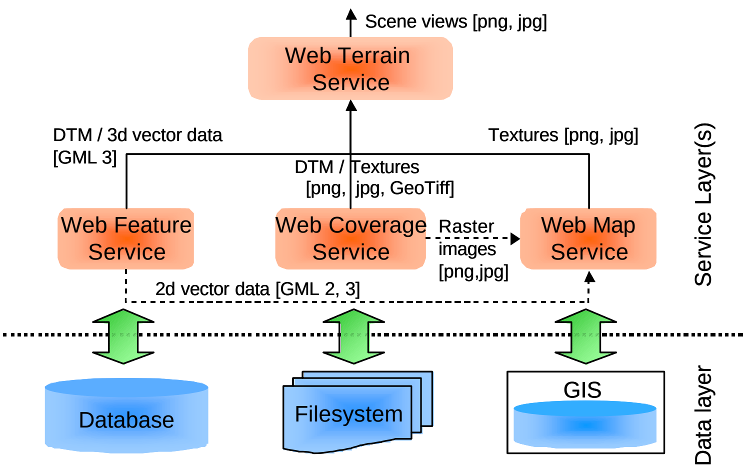

Figure 8: Realization of the OGC Web Terrain Service in the open source system Deegree (Deegree 2003). The left image shows how the WTS employs the OGC services WFS, WCS and WMS. On the right side a view of the western shore of the Rhine river in Bonn that was generated using the Deegree WTS is shown. Image: K. Lupp and Fa. Lat/Lon

can be draped over digital terrain models providing textured 2.5d views (cf. Singh 2001). The draft specification of the WTS considers only (raster) images for output media. It is currently not specified which input data types can be used, from which sources they may be obtained, and how the WTS should combine them in order to render the images. Although the WTS specification still has the status of an OGC discussion paper, a first implementation is already available in the framework of the Java based open source system Deegree (Deegree 2003). Figure 8 shows the architecture of the Deegree-WTS, especially which data services are used for the generation of images from 3d views.

The specification of the WTS currently does not explicitly considers the integration of 3d spatial data in the presented scene. Besides missing parameters like date and time, properties of the atmosphere, and predefinable background images the major drawback is, that the WTS is restricted to the generation of (static) images. Due to the problem of occlusions (see above), the images of different WTS cannot be combined in a thin client by simple overlaying. However, especially this aspect is responsible for the increasing success and acceptance of the Web Map Service in the WWW.

To bridge the gap between 3d visualization using OGC data services (and thick clients) and the portrayal service WTS (and thin clients) the SIG 3d of the GDI NRW is working on the specification of a new dedicated 3d portrayal service called Web 3D Service (W3DS). It is based on the proposal of the WTS and extends it by the explicit consideration of 3d features and the output of 3d display elements. The W3DS is capable of generating output both on the image and the display element level of the portrayal pipeline. This way, a medium client can fetch 3d display elements from different W3DS which then are merged and shown simultaneously.

The mandatory output data format of the W3DS is VRML97 (see VRML97 1997). GeoVRML and X3D may also be delivered as optional resp. future data formats (see Reddy et al. 2000). The reason why VRML97 is favored is that it is the most accepted and widespread standardized 3d graphic format and has successfully been employed in a number of 3d web GIS (see Zipf und Schilling 2003, Gaiani et al. 2002, Zlatanova 1999, Coors und Flick 1998). Above, numerous (and in many cases free) 3d browsers and web brower plug-ins for VRML97 are available. Furthermore, most commercially available GIS, 3d CAD and 3d visualization systems offer VRML export and import functionalities. These systems can be made interoperable on the visualization level, if specific W3DS adapters are implemented for them. Due to the fact, that most systems already contain

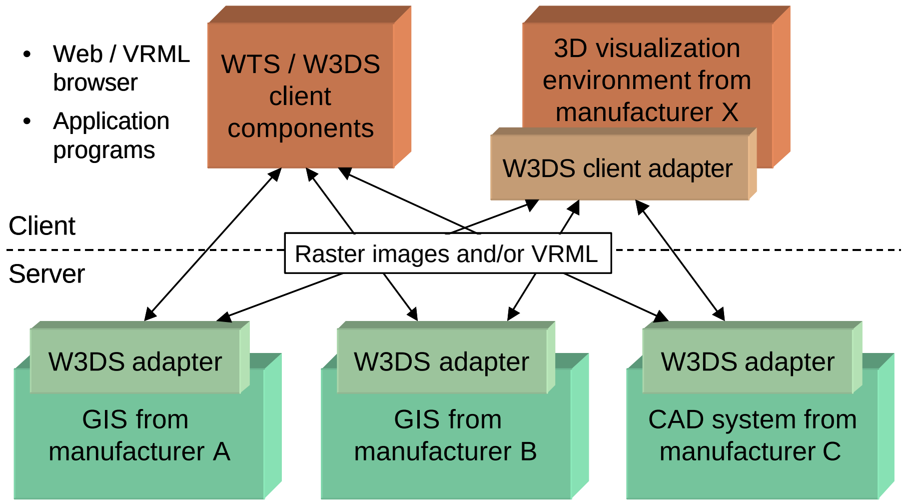

Figure 9: Integration of commercial GIS and CAD systems by extending the systems with W3DS adapters on the server-side and by W3DS client adapters on the client-side. Depending on the employed service (Web Terrain Service, WTS or Web 3D Service, W3DS) rendered pictures of the scene (2d images) or 3d scenes (e.g. VRML) are delivered to the clients.

VRML export functions the implementation of an adapter should only cause minimal effort. This way, the application scenarios shown in figures 4 and 5 can be realized without the prerequisite that the employed systems have to be compatible on the level of spatial data representation (see fig. 9).
Besides these aspects specific 3d portrayal services like the WTS and the W3DS have the following advantages in contrast to the usage of data services for 3d visualization:

- Easier access control and accounting, because in most cases the clients will only communicate with one service. If scene views from different 3d portrayal services are to be integrated, this can also be done by employing cascading portrayal services, i.e. one service may employ further portrayal services but will appear as one compact service to the client.
- For licensing and data privacy reasons often the access to spatial data is limited, but access to their graphical representation may be unrestricted. For example, public web maps like city maps can be accessed freely, but users usually do not have the rights to get the original spatial data from which these maps were derived. Analogously, no municipality would offer unrestricted access to its 3d city model on the feature level, but may provide public 3d portrayal services that deliver images or VRML.

4. PILOT 3D OF THE GDI NRW

In order to demonstrate and evaluate the possibilities of interoperable 3d geo-visualization described in the previous chapter, the so-called ”Pilot 3D“ has been started within the initiative GDI NRW. It realizes the concepts explained in chapter 3.2. and 3.3. in three specific application projects. These projects are focused especially on the marketing, tourism and business development sector, but the employed technology can be applied for aspects of planning, telematics and real estate business as well.
In the first project 3d city models for the two cities Cologne and Leverkusen are built up. 3d visualizations will integrate 3d building models, football stadiums, the airport and inner-city industrial buildings. The application scenario will provide possibilities for interactive route planning and online ticket services. With regard to the Football World Cup 2006, a 3d route planning system will be established connecting the event locations to special public and economic buildings. Starting points will be Cologne main station, the Cologne-Bonn airport and the motorway A1. Target points might be the RheinEnergy stadium in Cologne and the BayArena stadium in Leverkusen. On the way between these event locations further buildings can be integrated and accessed interactively. Sponsors can place their logos in the 3d model. Furthermore, a cooperation with the Cologne-Bonn airport, the public transportations and the Deutsche Bahn AG is possible. The target points can be explored interactively, functions like e.g. online ticket services showing the view from the booked place can be incorporated. Based on this project, a wide-area 3d city model of Cologne will be implemented and used for planning purposes in the future.
In the urban area of Düsseldorf as well as in the city and district area of Recklinghausen, virtual flights and visualizations of planned routes across the inner-city will be realized for demonstration, marketing, planning, and analytical aspects. A mosaic is developed consisting of already existing and newly registered building models (e.g. main station, industry buildings), special road objects, plants, and further 3d constructions, which all are covered with facade and ground textures. 3d visualizations as well as animations of the integrated 3d city model will be made accessible over the internet using web browsers and standard plug-ins. Additionally, planning information of different projects can be integrated, visualized and analysed in the steadily growing 3d city and landscape model. The 3d model can be used for information and presentation purposes as well as for the further data processing in various municipal and private sectors (e.g. city planning, traffic, environment, tourism, marketing).
In the third project integrated interoperable 3D models will be employed to improve planning processes and the participation of citizens as well as event management along the industrial culture route

of the Ruhrgebiet area ("Route der Industriekultur"). Illustrations of planned projects and their current states of realization along the former 9 kilometres railway line "Emscherbruch" in the Ruhrgebiet area will be integrated and visualized (e.g. extent of bycicle paths, redesign of bridge constructions). The publicity-effective activities, the long-lasting restructuring processes, and the rich availability of spatial data make this application especially suited for interoperable and interactive use of distributed 3d city and landscape models.

It is intended to present first results at the Intergeo fair 2003 in Hamburg. In the medium term, the availability of interoperable 3D visualization services should enable the integration of all 3d models from the different projects into one large visualization (e.g. a flight over North Rhine-Westphalia). Thereby, virtual 3d flights over large – probably even area-covering – areas of NRW could be realized, without concentrating the distributed spatial data into one dedicated system.

5. CONCLUSIONS AND FUTURE WORK

The usage of OGC web services offers different possibilities for interoperable 3d geo-visualization. With the Web Feature Service (WFS), Web Coverage Service (WCS), and Web Mapping Service (WMS) standardized components for the access to 2d, 2.5d, and 3d data have been specified by the OGC. Thus, application programs and web clients can fetch the needed spatial data via open interfaces and create appropriate 3d visualizations.

Furthermore, it was shown that interoperability between different systems does not necessarily has to be reached on the level of spatial objects and their data representations. If only the integrated 3d visualization of distributed spatial data is needed and no further integrated analysis and processing of the spatial data is required, the combination of different data sources can take place on the visualization level by the use of specific 3d portrayal services. The discussed services WTS and W3DS can be implemented with minimal effort on top of existing GIS and CAD systems and thereby allow an early adoption of the concepts of interoperable 3d visualization for software manufacturers. Since visualization functionalities are realized as OGC web services they easily combine with other OGC services like registry, security and accounting services. Thus, 3d portrayal services smoothly integrate into spatial data infrastructures.

To demonstrate the benefits of distributed 3d geo-visualization three specific projects have been started within the "Pilot 3D" of the GDI NRW. Depending on the results of the pilot projects the SIG 3D considers to propose the Web 3D Services for discussion in the OpenGIS Consortium. Future challenges are:

- The identification resp. development of open streaming interfaces for realtime navigation in large 3d scenes over the internet.
- The protection of 3d object geometries against storage and refactoring when using VRML. A W3DS service provider should be able to prevent unauthorized usage.
- Besides interoperability on the visualization level also the exchange of complex 3d objects on the feature level should become possible. Municipalities have a strong interest in the definition of a standard for the representation of 3d city and region models (like the German standards ALKIS and ATKIS for 2d cadastre, see Seifert 2002).

These issues – especially the questions concerning the development of a standard for 3d city models – will be addressed in the near future. However, one of the main tasks will be to bring the potential of 3d visualization services to broader attention and to establish them as standard software components for spatially related applications in the public and private sectors.

6. REFERENCES

Altmaier, A., Müller, M. (2002): (in German) Geodateninfrastrukturen in der Praxis, In: DVAG (Hrsg): Standort – Zeitschrift für Angewandte Geographie, H.3/2002, Jg. 26, Bonn

Beaujardière, J. de La (2002): OpenGIS Web Map Service Implementation Specification (WMS), Version 1.1.1. OGC Document Number 01-068r3.

Bernard, L., Einspanier, U., Lutz, M., Portele, C. (2003): Interoperability in GI Service Chains – The Way Forward. In: Proceedings of the 6th AGILE Conference on Geographic Information Science in Lyon, France

CeGi (2003a): Center for Geoinformation GmbH. http://www.cegi.de

CeGi (2003b): Center for Geoinformation GmbH: Feasibility Study: „Virtual Regions along the Rhine and the Ruhr 2006" (in German, original title: Machbarkeitsstudie „Virtuelle Regionen an Rhein und Ruhr 2006") on behalf of the state government North Rhine-Westphalia. Dortmund. (in press)

Coors, V., Flick, S. (1998): Integrating Levels of Details in a Web-based GIS. In: R. Laurini, K. Makki, N. Pissinou (eds.): ACM-GIS '98, Proceedings of the 6th International Symposium on Advances in Geographic Information Systems, November 6-7, 1998, Washington, DC, USA.

Cox, S., Daisy, P., Lake, R., Portele, C., Whiteside, A. (2003): OpenGIS Geography Markup Language (GML 3), Implementation Specification Version 3.00, OGC Document Number 02-023r4.

Curbera, F., Duftler, M., Khalaf, R., Nagy, W., Mukhi, N., Weerawarana, S. (2002): Unraveling the Web Services Web. An Introduction to SOAP, WSDL, and UDDI. IEEE Internet Computing, Vol. 6, No. 2, March/April 2002

Deegree (2003): Open source implementation of service spezifications of the OpenGIS Consortiums. http://deegree.sourceforge.net

Doyle, A., Cuthbert, A. (1998): Essential Model of Interactive Portrayal. OpenGIS Project Document 98-061. http://www.opengis.org

Gaiani, M., Gamberini, E., Tonelli, G. (2002): A framework to use virtual worlds generated from real world 3D models as Work Tool for Architectural & Archaeological Restoration on the Web. International Journal of Design Computing, Vol. 4, University of Sydney Library

GDI NRW (2003): Initiative Geo Data Infrastructure North Rhine-Westphalia. http://www.gdi-nrw.org

Gottschalk, K., Graham, S., Kreger, H., Snell, J. (2002): Introduction to Web services architecture. IBM Systems Journal, Vol. 41, No. 2

Gröger, G., Kolbe, T. H. (2003): (in German) Interoperabilität in einer 3D-Geodateninfrastruktur. In: Tagungsband zu den Münsteranern GI-Tagen 2003, 26.-27. Juni 2003, IfGI-Prints, Universität Münster

Haber, R. B., McNabb, D. A. (1990): Visualization Idioms: A Conceptual Model for Scientific Visualization Systems. In: Schriver, B., Nielson, G. M. und Rosenblum, L. J. (Hrsg.): Visualization in Scientific Computing, IEEE Computer Society Press.

ISO (2003): International Standardization Organisation, Technical Committee 211. http://www.isotc211.org

Kolbe, T. H. (2003): (in German) Interoperable Modelle – Die dritte Dimension in der Geodateninfrastruktur Nordrhein-Westfalen. GeoBIT 5/2003, Wichmann Verlag.

Laurini, R. (1998): Spatial multi-database topological continuity and indexing: a step towards seamless GIS data interoperability. Int. Journal on Geographical Information Science, Vol. 12, No. 4

May, M., Schmidt, B., Streit, U., Uhlenküken, C. (2003): (in German) Web-Service-basierte 3D-Visualisierung im Umfeld der Raumplanung. In: Tagungsband des Symposiums für Computergestützte Raumplanung CORP 2003 (Geo-Multimedia 03), 25.2.-1.3.2003 in Wien

Reddy, M., Iverson, L., Leclerc, Y. G. (2000): GeoVRML 1.0 – Adding Geographic Support to VRML. GeoInformatics, Vol. 3, September 2000.

Seifert, M. (2002): On the Use of ISO standards in Cadastral Information Systems in Germany, FIG XXII International Congress, Washington DC, USA, April 2002

Singh, R. (2001): Open GIS Web Terrain Server (WTS), Version 0.3.2. OGC Document Number 01-061.

VRML97 (1997): Information technology – Computer graphics and image processing – The Virtual Reality Modeling Language (VRML) – Part 1: Functional specification and UTF-8 encoding. Part 1 of ISO/IEC Standard 14772-1:1997, VRML97.

Zipf, A., Schilling, A. (2003): Generation of VRML City Models for Focus Based Tour Animations. Integration, Modeling and Presentation of Heterogeneous Geo-Data Sources. In: Proceedings of the 8th Int. Symp. on Web 3D Technology Web3D 2003, March 2003 in Saint Malo, France

Zlatanova, S. (1999): VRML for 3D GIS. In: Proceedings of the 15th Spring Conference on Computer Graphics, 28.4.- 1.5.1999, Budmerice, Slovakia

Zlatanova, S., Rahman, A. A., Pilouk, M. (2002): Trends in 3D GIS Development. Journal of Geospatial Engineering, Vol. 4, No. 2, pp. 71-80.