Design and Composition of 3D Geoinformation Services

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Forced by Google Earth the topic of geoinformation has become mainstream. As 80 per cent of all digital information carries a spatial reference, there is a great opportunity for using geographic information as a basis for gaining insight into these data, for more efficient processing, and for developing new applications on the basis of such information. Especially 3D geoinformation gets more and more important for a variety of application domains. For enabling the interoperable access and processing of geoinformation, standards organizations as the Open Geospatial Consortium have specified different services and data description languages. This work gives an introduction to the field of 3D geoinformation services and points out open questions that arise from using geoservices. The focus is on the visualization aspects and the consequences for service design and integration with existing and future geoservice-based systems.

1 Introduction

Geoinformation is used in a lot of contexts and is a factor for economic success. To facilitate geoinformation, to integrate it in different applications and to see things that were not obvious before, means to create value. 3D geoinformation supports this creation of new insights into data and processes. For activating the capabilities of geoinformation it must be collected, processed, and distributed efficiently for being used effectively. Service-based architectures are a concept for achieving this integration of geoinformation and geographic information services offer the technology to implement them. In modern times geographic information becomes main stream for a variety of applications in very different domains. The main issue of this development is to activate the value that is contained in geographic information, combine it with processes and other information, and so to generate added value.

The underlying vision of this work is the development of 3D geoinformation services with the objective of activating the inherent potential of geoinformation by its integration in 3D geovirtual environments.

This paper takes a look at the topic of geoservices and how they can be used to create higher-level functionality. Chapter 2 discusses geoinformation and points on the usage of internet mapping and geodata infrastructures as a possibility for distributing geodata and correlated functionality. Chapter 3 is about geoservices themselves and how they can be assembled, about geoservices standards, and open research questions in this field. Chapter 4 describes the current project work for the OGC Web Services Initiative, Phase 4, which is about interoperability between different geodata and between different vendors. In the conclusion an outlook on further research is given.

2 Geoinformation and Geovisualization

2.1 Geoinformation

Geodata is data about concrete or abstract objects, terrain shapes and infrastructure elements on the earth surface. The common property of geodata is their spatial reference. It is estimated that about 80% of all information has a spatial reference, which can be used as a basis for processing and visualizing such data. Considering the context of meaning and usage, geodata becomes geoinformation that has spatial properties (geometry and topology) and semantic properties (semantics and thematic attributes):

- *Geometry* includes information about the shape and position of geoobjects. Geometry can be given, e.g., as points, lines, or polygons.
- *Topology* describes the spatial relationship between different geoobjects, e.g., adjacency or containedness.
- *Semantics* describes the meaning of a geoobject in a concrete context, e.g., if it is a road, runway, or building.
- *Thematic data* describes non-spatial properties of geoobjects, e.g., building material or speed limits for roads, number of occupants or household income, or temporal attributes as year of construction.

The semantic classification is essential for the proper application of geoinformation. Hierarchical classification allows abstraction and enables user- and task-oriented processing of geoinformation.

Geoinformation is collected by a variety of organizations. Public authorities are committed by law to collect and maintain geodata. On the other hand, commercial organizations gather geodata for their own purposes or for others. This results in a huge and distributed amount of heterogeneous geoinformation which is not inherently interoperable because of varying purposes, coverages, different measurement methods, classification schemas, storage formats, spatial precision or timeliness.

Geoinformation is an essential system component for an increasing number of applications and systems as for facility management, logistics, security, telecommunication, disaster management, location-based services, real estate portals as well as entertainment and education products.

2.2 From GIS to GDI

2.2.1 GIS and Internet-Mapping

Geographic Information Systems (GIS) are software systems for collecting, storing, managing, analyzing, and visualizing geospatial data. For a long time, GIS have been monolithic systems, which allowed the users to work efficiently with the data. Geoinformation is distributed over these systems and extra effort is necessary for reaching a consistent data state. Additionally, multitudes of applications need extra effort for administration.

Today, large network bandwidth and distributed application platforms as they are provided by application servers and browser-based front-ends allow a distributed GIS which consists of a GIS server and appropriate GIS clients. According to the functionalities and the separation of concerns of server and client, Fitzke et al. (1997) propose five categories of web-based geoinformation systems, see Table 1.

Table 1: GIS categories and their provided GIS functionality.

Category of web-based GIS	Provided functionalities
Geodata server	Data management
Map server	Data management, visualization
Online retrieval system	Data management, visualization, retrieval
Online GIS	Data management, visualization, retrieval, GIS analysis
GIS function server	Visualization, retrieval, GIS analysis

Internet-Mapping and real Web-GIS (which must include GIS analysis functionality) help to integrate the geoinformation that is further distributed in a company. It is no longer stored locally but in a central database. This prevents data redundancies and inconsistency. Furthermore a central GIS server and simple web based clients reduce the effort for software administration.

2.2.2 Geodata Infrastructures

Worldwide, there are efforts to establish so-called geodata infrastructures (GDI). The term GDI is not a well defined one. It can be described to conclude all entities that serve in the provision, transportation, and processing of geoinformation. The primary goal of these infrastructures is to make the collected but widely distributed geoinformation available for re-use in administration and economy. In Germany, there are several regional GDI projects, as in Berlin, Brandenburg or North Rhine-Westphalia. Above those, Germany installed a national GDI project which itself is covered by the European GDI project INSPIRE. Geoinformation services play an important role in these geodata infrastructures as they are often used to enable the access to geodata. As geoinformation services often base on standards they support the interoperability of geoinformation and between different participants in the geodata infrastructure.

In the context of GDIs, there are still a number of open questions about legal issues, the organization of this infrastructure, its architecture, and the geodata that shall be provided – e.g., who is allowed to participate in the infrastructure, how to participate, or how much it would be.

2.3 3D Geovisualization

Visualization "is concerned with exploring data and information in such a way as to gain understanding and insight into the data [and] to promote a deeper level of understanding of the data under investigation and to foster new insight into the underlying processes […]." (Brodlie et al., 1992)

So, geovisualization is the visual representation of data with a special reference, respectively. Not only spatial objects and processes but also those objects and processes that can be transformed into spatial geometry are target of geovisualization.

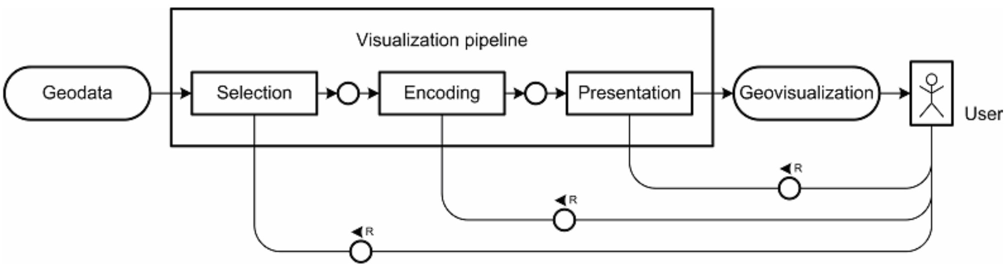


Figure 1: Geovisualization pipeline. (Based on Spence 2001.)

According to Spence (2001), the process of visualizing geoinformation can be organized in the geovisualization pipeline which contains the selection, encoding, and presentation stages (Figure 1):

- *Selection stage*: The geodata that shall be visualized are reformatted, integrated, processed and selected accordingly to the task to fulfill. Result is a model of the geodata.
- *Encoding stage*: The selected geodata is transferred into a geovirtual model. Thereby the geodata is mapped on a computer graphics representation (model objects and attributes).
- *Presentation stage*: Images of the computer graphics model are synthesized into the final geovisualization that is perceptible by a human user.

The geovisualization pipeline provides the interaction of the user with the visualization system which is quite demonstrative for a GIS. E.g., it enables the user to load other geoinformation, to influence the visual encoding (e.g., colors or map symbols), or to switch between different views or to move the virtual camera.

As traditional GIS applications dealt with 2D geoinformation, 3D geoinformation became more and more important for a variety of applications in the last years and has found its way into GIS.

3D geovirtual environments (GeoVE) are capable of representing urban spatial and geo-referenced data, including terrain models, building models, vegetation models as well as models of roads and transportation systems. A GeoVE can be used in the obvious way for representing city objects of the real world, but it also can be utilized as a platform for the integration of abstract geoinformation, such as noise level information or visibility information.

Compared to 2D geovisualization, 3D geovisualization deals with large amounts of geometry data or texture data and needs special computer graphics techniques and intensively uses the computer graphics hardware. An other important issue is the enablement of interaction with the GeoVE, such as navigation which is the most important interaction technique as it enables the user to move through the GeoVE for gathering the contained geoinformation.

On the other hand well known methods in the field of 2D geovisualization, e.g., cartographically generalization, can not be applied to 3D geovisualization easily.

3 Geoinformation Services

3.1 Service-oriented Computing

After object-oriented and component-oriented programming, service-based computing is called to be a new programming paradigm using possibly distributed and network-connected services as more abstract functional entities on a more architectural view on a software system. Software architectures considering this programming paradigm are called service-oriented architectures (SOA) and are pushed to the markets by a variety of vendors, currently. From a management viewpoint, a SOA is a management concept which targets on a flexible IT infrastructure which is aligned to the business goals and can be easily adapted to the changing business environment. From a technical viewpoint a SOA is a software architecture concept which bases on the usage of software services.

ISO 19119 (2005) defines a service as a collection of operations which are accessible through an interface and allow a service consumer to evoke a behavior of value at the provider offering the service. For enabling the service consumer to find and utilize the service functionality, the service interface must be described and published in a standardized way. Therefore, the service repository is defined as a third participant in a SOA. Figure 2 shows these SOA participants and the described publish-find-bind interaction pattern.

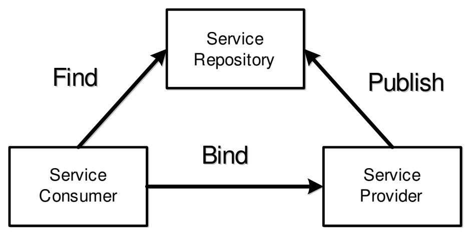


Figure 2: SOA participants and publish-find-bind pattern.

The service consumer uses the described service interface to invoke the service's functionality – the concrete service implementation is hidden. This leads to a loose coupling of the application entities in a SOA, increases their reusability and supports interoperability.

The standardization of interfaces and exchange formats allows to combine services in ways that are not predefined and to assemble the service functionality for achieving larger tasks. Service composition is described by service orchestration or service choreography – this is the service combination from a higher system top view or from the local service view, respectively. The consequence of service composition is that the involved service providers may also act as consumers of the functionality that is provided by other services.

XML web services are one possible service implementation for building a SOA. They use technologies as Web Service Description Language (WSDL) for describing the service (e.g., how to invoke), UDDI for publishing the service, SOAP as a message exchange protocol over HTTP as transport protocol.

Representational State Transfer (REST) is another concept for implementing service-based systems. It bases on the idea of resources which are defined by unified resource locators (URL). REST supports a binding to HTTP only. The HTTP operations GET, PUT, POST, and DELETE are used for interacting with the resources, e.g., for retrieving representations of a resource, creating new resources, or deleting them.

3.2 Geoservices

In the context of geoinformation, services offer the possibility to provide widely distributed geoinformation in an interoperable manner and facilitate the reuse of data and functionality in a variety of applications. Geoservices support the various forms of web-based GIS but also are important components of a GDI. So, geoservices offer the possibility to integrate geoinformation into business process, e.g., for spatial data mining or decision support (Andrienko 1999, 2005).

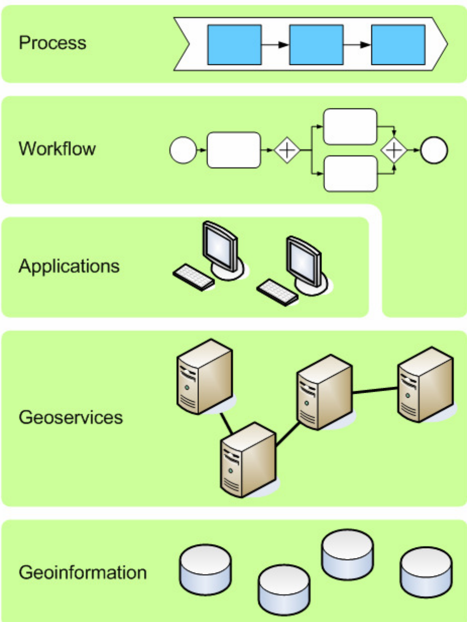


Figure 3: Geoservices in the context of SOA views.

Figure 3 denotes the integration of geoinformation and geoservices in the context of business integration. It is made up of the following entities:

- *Business process* which is an abstract description of a set of steps for reaching a business goal: It is the "means by which one or more activities are accomplished in operating business practices." (ebXML 2001)
- *Workflow* which is the "automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules." (Workflow Management Coalition 1999)
- *Applications* which allow a user to be part of the process execution in a special workflow step.
- *Geoservices* which might be dedicated for the use in a workflow in an automated manner or might be consumed by application clients for human interaction.
- *Geoinformation* which are distributed over a multitude of sources and can be accessed via services.

Geoservices can be categorized according to their functionality. Typical geoservice types are:

- *Geodata services* which provide geoinformation, e.g., road network information.
- *Portrayal services* which provide visualizations, e.g., maps.
- *Processing services* which, e.g., provide transformations of geodata or may synthesize new geoinformation.

Especially for geodata services, the service repository should allow the service consumer to search for specific geoinformation (e.g., roads or building information) in a specific spatial area which could be defined by a bounding box. Service composition is another major topic for geoservices.

3.2.1 Interoperability

The utilization of geoservices advances the interoperability of different geoinformation-sources and the possibility to integrate geoinformation in a new context for gaining new insights. Interoperability is a challenge in discovering, accessing, and using geoinformation. For solving these challenges geoservice-based systems offer meta information, standardized service interfaces and standardized data models.

On a conceptual level Bishr (1998) distinguishes the following three categories of interoperability problems in GIS:

- *Semantic heterogeneity* characterizes the different understanding of features of the real world. E.g., a road network is a network structure for routing but a set of laminar objects.
- *Schema heterogeneity* characterizes differences in the structure of the model. E.g., geoobjects are modeled on a class level in one system and as attributes in another system.
- *Syntactical heterogeneity* characterizes differences in the exchange format on the one hand and in the geometric representation on the other hand – e.g., the storage of road network as vector data vs. the storage as raster data.

Gröger and Kolbe (2003) point out additional interoperability problems concerning geometry and topology of single geoobjects as they can be caused by different spatial reference systems, or errors in measurement, digitizing or generalization. These problems of geometrical and topological interoperability can be further subdivided into geometrical and topological inconsistencies, problems arising from multi-scalar representations, and problems caused by geodata infrastructures as data inconsistencies.

3.2.2 Geoservice Chaining

In the field of geoinformation services, service composition is described by the term service chaining. Alameh (2003) offers three architecture patterns for service chaining that base on chaining patterns that are provided by ISO 19119 (2005), see Figure 4. The main difference in this classification is the issue of control about the service chain workflow and the visibility of the involved services for the user:

- *Client-coordinated service chaining*: The user has full knowledge about the participating services and controls the workflow of the service chain.
- *Workflow-managed service chaining*: The user knows about the involved services but invokes a workflow management service which controls the workflow of the service chain.
- *Static chaining using aggregate services*: The user does not know about the participating services. They are hidden by an aggregate service which controls the workflow.

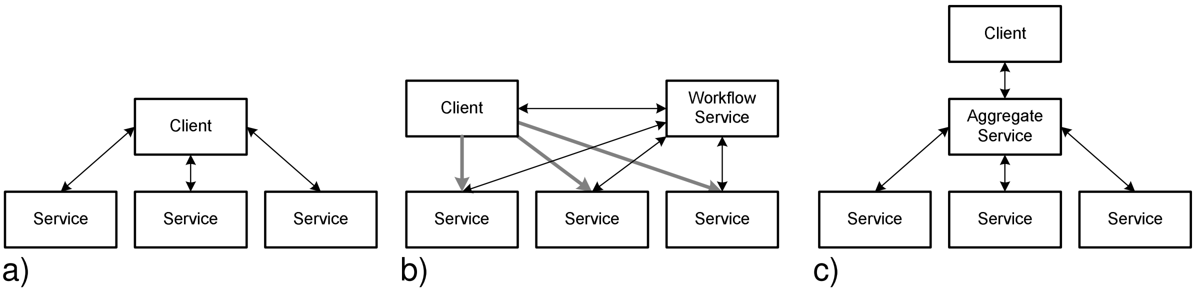


Figure 4: Service chaining patterns: a) Client-coordinated service chaining; b) Workflow-managed service chaining (grey: client "knows" about services); c) Static chaining using aggregate services.

These composition patterns correspond to service orchestration, as a central manager (client, workflow service, or aggregate service) has the responsibility for the service chain execution. Furthermore, the patterns can be adapted in the sense, that one service forwards the response directly to another service. Such service nesting is more efficient as possible large data must be transferred only once.

Especially for geoservices, composition is an important issue for the integration of different geoinformation. Chainable geoservices are, e.g., coordinate transformation services, routing services, or generalization services.

E.g., one possible geoservice chaining might result from the integration of different geodata sets into one visualization: a) Two different geodata services provide road network information in different coordinate reference system. b) A processing services has to transform both geodata sets into the same coordinate reference system. c) A portrayal service can use this geodata for synthesizing a map visualization.

3.3 Standards for Geoservices

3.3.1 OGC Web Services

Several organizations are active in the field of geographic standards. Those are, e.g., the International Organization for Standardization (ISO), the Open Geospatial Consortium (OGC), the Federal Geographic Data Committee (FGDC), or the European Committee for Standardization (CEN).

The OGC is a non-profit, international standards organization which develops and promotes standards for geospatial services. The OGC has defined several implementation specifications for services and for data exchange formats. Furthermore a row of discussion papers is waiting for becoming an OGC specification. The following list gives an overview on some of the well known, often used, and interesting OGC specifications and discussion papers.

Geography Markup Language (GML) GML is an encoding specification for geodata in XML for storing, exchanging, and processing geographic information.

CityGML Currently, CityGML has the status of a discussion paper in the OGC standardization process. It is a GML-based format for the description of 3D geovirtual environments. This means geometry and topology but also the semantics of city model objects. This semantics is not provided by the abstract GML specification. Such semantics are, e.g., building, wall, door, water body, etc.

Web Map Service (WMS) The WMS defines the creation and display of map-like views of distributed data. The WMS supports the following operations:

- GetMap requests a map for a defined bounding rectangle with specified information layers included, and in a specified graphical style.
- GetFeatureInfo is an optional operation. It provides additional information about the geographical features that in a map at a special pixel position.

Web Feature Service (WFS) The WFS provides an interface to data stored in GML. It allows a service consumer to retrieve and manipulate these geoinformation. Among others the WFS provides the following operations:

- GetFeature is the operation for retrieving feature instances.
- DescribeFeatureType is the functionality to describe the structure of every feature that can be retrieved from GetFeature.
- WFS might offer transactions, which are composed of requests for data modification: Create, Update, Delete.

Web Coverage Service (WCS) The WCS is capable of providing geospatial data as "coverages" which are raster data sets. Different from WMS this are not image data per default but raw geographical data that can be interpreted by the service consumer. Important operations of the interface are:

- DescribeCoverage describes the coverages that are named by parameter.
- GetCoverage enables the access to coverage data. Parameters are coverage size, coverage format and interpolation.

Web Catalogue Service (WCS) Web Catalogues serve for discovering OGC web services and retrieving service metadata.

Web Terrain Service (WTS) The WTS is a perspective view service – this is, it provides 3-dimensional views of geovirtual models which may include terrain, buildings, vegetation, etc.

Web 3D Service (W3DS) The W3DS is a service for 3D geodata. It provides 3D a scene graphs which is a computer graphics model that must be rendered for retrieving imagery that can be perceived by the human.

Filter Encoding The Filter Encoding specifies an encoding for filter expression in XML. Filter encodings are used as functions for obtaining a subset from a set of objects. Filter encodings can be used in variety of OGC web services for reducing the result set, e.g. when specified together with the WFS operation GetFeature.

3.3.2 The Google-Way

Google Earth is an application for accessing and visualizing different types of geoinformation, as orthophotos, terrain models, city models, or infrastructure elements as roads or airports. It allows to include own paths or models into the scene and to fly directly to a town or landmark. Considerable building models can be easily created with Google SketchUp, an easy to use sketching tool for building construction. These models can be imported and positioned into Google Earth by the usage of the simple data transfer format KML which is an easy description for building sites.

Google Maps is another geodata view client. The browser-based viewer provides detailed ortophotos of the earth surface and offers an alternative map view. Additionally, Google offers the Google Maps API which enables programmers to access the Google Maps service and to integrate maps into their own homepage. The Google Maps API offers additional functionality as positioning arbitrary map symbols, add own information layer or even to integrate map layers from an OGC web map service. A lot of people used the possibilities of the Google Maps API and created their own geovisualization, called mashups. An example is the georeferenced map display of apartments to rent enriched with additional information – see Figure 5.

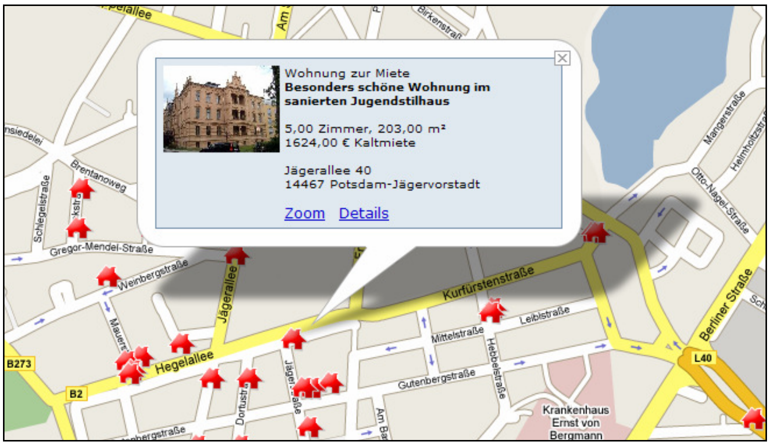


Figure 5: Mashup of Google Maps and apartments for rent. (mapits.de)

Google Earth and Google Maps are successful products that enable everybody to use geovisualization and so have set up a quasi standard in the field of service geoinformation processing and visualization. The mashups with Google Maps generate an added-value to the users. Both are excellent examples how to integrate and facilitate geoinformation for gaining insight.

3.4 The OGC Portrayal Model

The geovisualization pipeline that was introduced in 2.3 corresponds to the OGC portrayal model which is shown in Figure 6. This model is annotated with some possible participants covering different functionalities of the pipeline. (Schmidt et al. 2003).

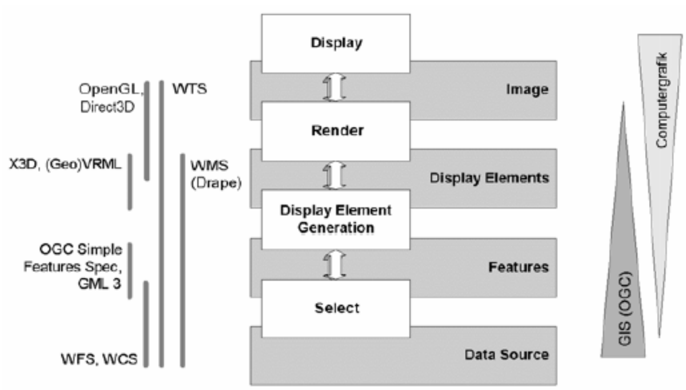


Figure 6: OGC portrayal model; modified by Schmidt (2003).

The OGC defines portrayal as information presentation to the human – portrayal elements may be either images or display elements. Corresponding to this, the OGC defines providing portrayal services and consuming "application services" as part of their OWS service framework (Percivall 2003). Application services may be either application servers, or application clients.

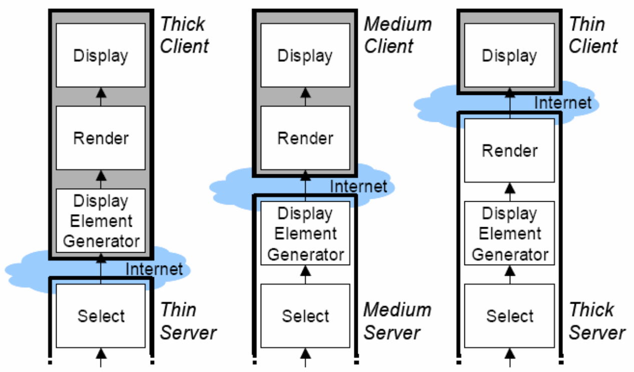


Figure 7: Partition concepts of the visualization pipeline in service-based systems. (Altmaier and Kolbe 2003)

The application of geoservices for geovisualization raises the question of the separation of rendering concerns between service provider (portrayal service) and service consumer (application service), this means between server and clients. The OGC Portrayal model allows three partitions which are illustrated by Altmaier and Kolbe (2003) in Figure 7 for client/server architectures:

- Thick Client / Thin Server: The client request selected data from the server and performs the remaining steps of the geovisualization pipeline. This requires appropriate computer graphics capabilities of the client. A possible geoservice participating in this scenario is a WFS.
- Medium Client / Medium Server: The service provides computer graphical representations (e.g., a VRML scenegraph) to the client which has to synthesize images. Again the client needs computer graphics capabilities for rendering images. In this scenario the style of the resulting visualization is more in concern of the server. The W3DS is a possible participant in this scenario.
- Thin Client / Thick Server: All the visualization steps are performed by the server. The server defines the final visualization and the client must only provide capabilities for displaying the visualization to the end-user.

3.5 Open Questions

Figure 8 illustrates the topics that are relevant when addressing 3D geoinformation visualization via service-based systems. Vital parts of such systems are 3D geoservice providers and 3D geoservice consumer.

The service interface describes the service capabilities to the service consumer. The implementation of these capabilities is basing on the columns of modeling, rendering, and interaction:

- *Modeling* addresses the structure and organization of complex geoinformation.
- *Rendering* addresses the mapping of this geoinformation onto computer graphics elements relevant for geovirtual environments and the synthesis of images of this GeoVE. These images support the end-user in understanding the geoinformation and in getting insight into the underlying data.

- *Interaction* addresses the issue of navigation inside the GeoVE but also the manipulation of the presented objects and their underlying geoinformation and the analysis of these data which might lead to the generation of new geoinformation.

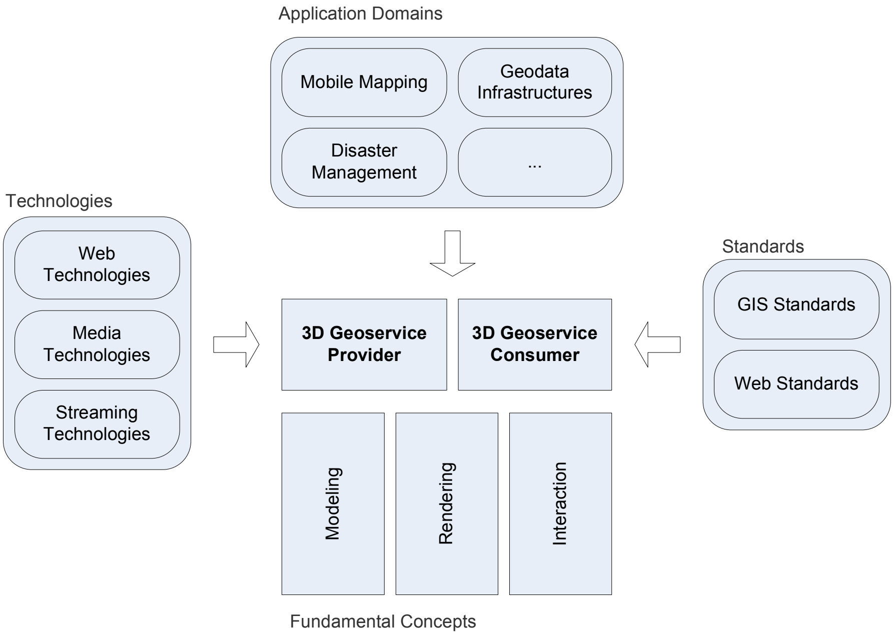


Figure 8: Context of geoinformation visualization in service-based systems.

As already described, this usage of geoservices is driven by a lot of application domains, as web mapping, disaster management, or the complex field of geodata infrastructures. According to the scenarios of these application domains, there must be appropriate services, which include the functional capabilities but also non-functional properties as availability, timeliness of the provided information or security issues. Especially for ad-hoc scenarios as they occur in the field of disaster management, it is important to have fast access to the most important information which means to avoid long-running information transfer but to provide easily consumable information units.

These computer graphics foundations are accompanied by additional technologies for making the rendering results consumable for the service consumer via web. Media technologies define the output and transport format of 3D geoinformation services. Hand in hand with those are streaming technologies which target on the efficiency of transporting geoinformation which could be images but also further processable raw geoinformation.

Additionally to these functionality oriented technologies, there must be further ones which allow the service provider to offer the service capability. These are web technologies as they are necessary for a service according to the simple service-oriented architecture. These are technologies for describing the service's capabilities, and make it accessible for service consumers. On a more concrete level, web technologies address protocols for message transport or security.

4 Interoperable 3D Geovisualization

4.1 Service-based construction of 3D geovirtual environments

4.1.1 Utilization of CityGML

"CityGML is a common information model for the representation of 3D urban objects. It defines the classes and relations for the most relevant topographic objects in cities and regional models with respect to their geometrical, topological, semantical and appearance properties. Included are generalization hierarchies between thematic classes, aggregations, relations between objects, and spatial properties." (CityGML web). CityGML provides an application schema for the Geography Markup Language (GML), which itself "is an XML encoding […] for the transport and storage of geographic information […] including both the spatial and non-spatial properties of geographic features." (GML 2004)

CityGML considers geographic features as, buildings, inner and outer building parts (walls, doors, windows or roofs), vegetation, and city furniture. For supporting regional models CityGML supports a TIN-based relief. In addition the visualization aspects, CityGML enables applications to use the structural and semantical properties for simulations, analysis or spatial data mining.

Because of its open format, the XML representation, the broad consideration of urban objects, and the support of not only geometric attributes, CityGML seems to serve as a good platform for the service-based integration of different geoinformation: CityGML can be used as an exchange format for city models and landscape models but also can be used for the exchange of other urban information: Considering its geospatial position an arbitrary information entity can be transformed into a specific CityGML object as it is described by CityGML which can contain or encode the attribute values of the abstract information entity.

The usage of CityGML as a basis for the provision of geoinformation can lead to new insights into existing geoinformation and to new geoinformation-based applications. Existing city- and landscape models can be used in new ways. As an example, CityGML models contain several aspects of a building information model (BIM). Its visualization might allow the end-user to have different views on the model for retrieving information about geometry, topology, paths, or different attributes. An other example is the utilization of the city models semantics for the development of new interaction techniques, e.g., for navigation in the GeoVE as it is described below (see 4.2.1).

By the help of CityGML and an appropriate transformation capability, complex geospatial information can be combined and transformed into a visual form that can be easily perceived and analyzed by human.

As CityGML is a GML application schema and deals with geographic features it can be retrieved from WFS. At all, geoservices dealing with CityGML could provide one or more of the following CityGML-related functionality:

- Retrieving CityGML
- Creating CityGML (e.g., from a database)

- Modifying CityGML
- Transforming CityGML (into another format)

For proving the potential of CityGML as an integration platform the following issues should be investigated:

- Usability of CityGML for the provision via WFS, especially the focused access to parts of the model
- Special view on performance of CityGML on-the fly creation, WFS access, and CityGML transport and processing
- Impact of relatively large data, possibilities of compression, web service access patterns
- Usability of CityGML in the context of building information model analyzes
- Possibility of incremental access to the CityGML model for improving the usability to the end-user

4.1.2 Integration of other geoinformation sources

In addition to the CityGML support for regional urban environments, additional information sources must be considered as WCS (e.g., elevation data, epidemiological data, environmental information, etc.), WMS (e.g., aerial photos, satellite photos), WFS which provide geographic features as GML, or other geographic information services.

A geovirtual environment might have to be constructed of several of these information sources. Thereby the different interoperability levels named in section 3.2.1 and additional properties of the GeoVE have to be regarded. This means extra effort for checking the information's meta data, performing necessary transformations and for setting up the GeoVE (e.g., scaling, coordinate transformation, adjustment of terrain size, correction of view parameters as near plane or far plane).

According to the OGC reference model (Percivall 2003) the single information sources are integrated by an application service, which might be an application server or a fat client, or by other geoinformation services which add value to the base information and provide this via service interfaces to other consumers.

4.2 3D Client Development

Geoinformation services provide distributed computing capabilities for being used in applications which do not posses the necessary data or processing capabilities. E.g., a 3D geoinformation service response may include an image of a 3D scene.

But accessing processing services or portrayal services needs time for finding or calculating the response, possibly for transforming it into an interoperable format, and especially for transmitting it to the service consumer.

If an end-user is involved into the system, this might be critical for the usability of the whole service-based system: When the user has to wait too long for an answer, he or she gets frustrated and might even decline the application. Thus we assume two things to be very important for the design and implementation of geovisualization services. These are on the one hand performance improvements for increasing the perceived speed of the application and on the other hand interaction improvements to handle the restrictions, to minimize them and to increase the overall usability of the geoservice-based system.

4.2.1 Interaction with 3D Geoservices

Interaction in 3D geovirtual environments targets on the analysis, editing, and navigation of the presented information space. The user interaction in geoservice-based GeoVE is not yet deeply investigated. We assume that we can find appropriate interaction techniques for such systems. Herby we will take into account the type of the presented information and try to utilize semantic information which is provided by CityGML models. We will also take into account the external properties of the service-based systems, e.g., the platform on which the services are running.

Possible interaction techniques that address these issues are a guided navigation which provides landmark based animation tours, semantic maps which allow the user to navigate step-by-step through the environment or the sketch-based navigation as it was introduced by Döllner et al. (2005). This sketch-based navigation is shortly described in the following paragraph.

Navigation as an example 3D geoservices interaction

As a key interaction, efficient navigation techniques are a crucial requirement in using geovirtual environments. Only navigation allows the user to explore and perceive the presented information. Darken and Siebert (1996) suggest three types of navigation tasks. These are naïve search, targeted search or exploration.

As one issue of interaction, navigation has to be considered in the context of portrayal services. Navigation integration is imaginable as an additional operation in portrayal services or as an extra service that attends to other service invocations.

As an example Döllner et al. (2005) have integrated the so-called sketch-based navigation technique into a movie-based portrayal service. This navigation technique uses pen-based strokes and gestures as input. These strokes and gestures are reprojected into the presented 3D scene and the intersections with the geovirtual environment are determined. Basing on the intersections and the navigation affordances of the hit geoobjects, an appropriate navigation handler is used which determines a camera path according to the input sketch and generates a corresponding navigation animation which is sent to the user immediately. This usage of the inherent navigation affordances of objects of the GeoVE has been further advanced by Döllner and Hagedorn (2006) the integration of visual navigation cues that give the user an experience of the pending navigation, e.g. arrows indicating the camera path and special symbols indicating directions where to look at – see Figure 9. Especially for the usability of 3D city models on mobile devices, this sketch-based navigation and the visual cues can provide an added value to the user.

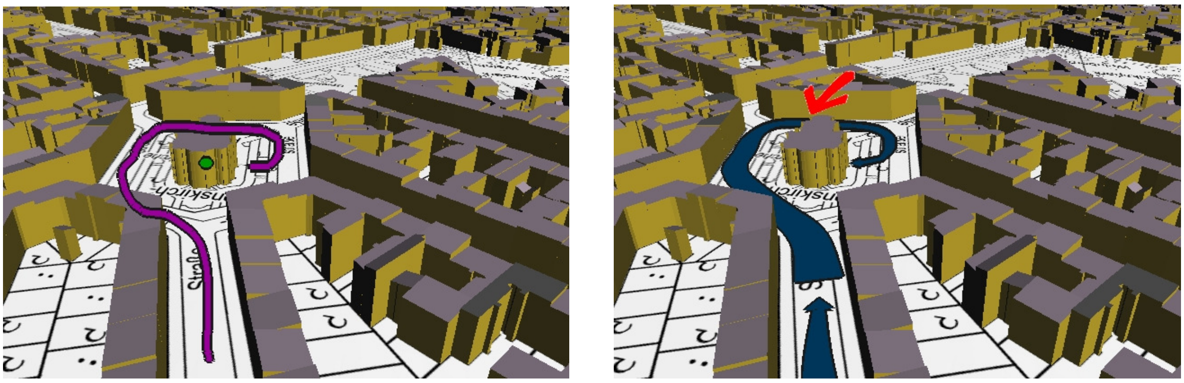


Figure 9: Example of a sketch-based navigation command (left) and the resulting visual cues integrated in the 3D scene. (Data: Official city model of the city Berlin, Germany.)

4.2.2 Performance improvements

3D geoservices provide integrated geoinformation as visualization for a variety of platforms, e.g. mobile devices. But for giving the user the feeling of control over the application, visualizations must be presented in a specific time and animations must be running with a specific frame rate. If model data are transmitted they should have small amount.

Under the conditions of limited bandwidth, we will investigate possibilities for improving the performance of 3D geoservice. This might include research in the following fields:

- Thinning of the 3D model: Elements of the city model that are obviously not interesting for the user are removed from the model for reducing the response payload.
- Generalization of the 3D model: Several single buildings might be summarized to a more general representation with less geometry which leads again to a reduced response payload. Currently generalization is a time consuming operation, so there must be a trade-off between effort and final speed improvements. As one approach generalizations could be pre-computed.
- For the provision of animations we will investigate different video encodings and the corresponding encoding and decoding processes.
- Data compression might be further useful for reducing the response payload. This can be done on the application layer with specialized compression methods or corresponding to the transfer protocol on transfer layer, too.
- Different transport mechanisms can be investigated in consideration of their throughput.

5 Integrative 3D Viewer Client

The OGC Web Services Initiative, Phase 4, (OWS-4) is an interoperability program set up by the OGC. The target of this initiative is to evaluate and advantage the interoperability of different OGC standards concerning services and data formats but also the interoperability of different vendors and their client and server implementations. We are working for the CAD/GIS/BIM thread of the OWS-4. This chapter reports the current efforts in OWS-4 and gives an overview on the scenario and the viewer.

5.1 Project overview

The CAD/GIS/BIM thread, deals with the interoperability of building information across the building lifecycle and also between information models from different communities:

- *Computer Aided Design* (CAD): CAD data provide a very detailed, geometry-oriented view on a building site which can be used for the construction of new buildings.
- *Geographic Information Systems* (GIS): GIS support a more general, not so detailed view on geospatial data. GIS data models include geometry, topology, and thematic attributes.
- *Building Information Model* (BIM): A BIM is a very rich and detailed view on a building. A BIM includes geometry and domain-specific information. E.g., a BIM includes information about the spaces of a building which might be rooms, corridors, floors. One example for a BIM is the Industry Foundation Classes (IFC).

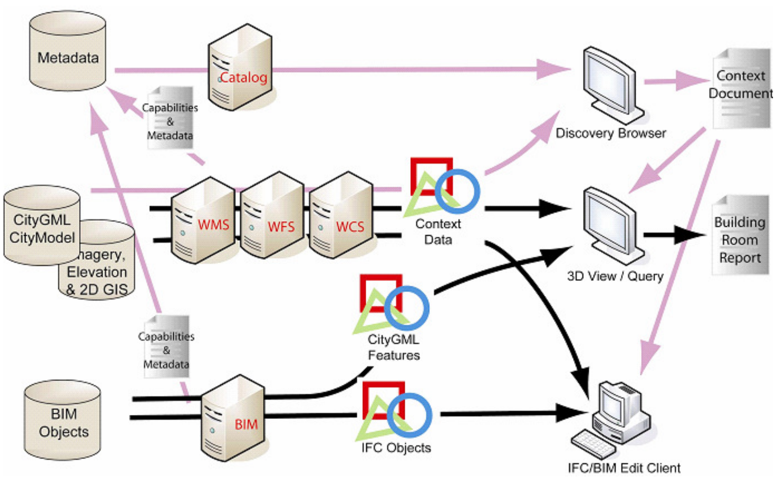


Figure 10: Generic solution architecture for thread CAD/GIS/BIM of OGC Web Services initiative, Phase 4. (Cote 2006.)

The overall scenario of the CAD/GIS/BIM thread is about the necessity of building up a field hospital in a military surrounding. From the scenario description (OWS4b) the generic architecture depicted in Figure 10 was derived. The scenario includes several actors and tasks: An analyst searches via discovery browser a metadata repository for retrieving first information about the occupied site. This information is recorded in a context document which later will be a basis for engineers to plan the hospital, a helipad, and surrounding sensors. Building models are provided by the so-called BIM server which will be realized as a special web feature service. This BIM server provides the building information model for editing in an appropriate BIM edit client which can store the edited model in the BIM server later. For getting an impression of the scene and enable further insight and assessment, the architecture provides a 3D view client which is capable of retrieving different geoinformation from different OGC web services (WMS, WFS) but also to access building information from the BIM server. This 3D view client is the contribution of our working group to OWS-4. With CityGML an additional building information exchange format is integrated and tested for interoperability.

5.2 3D View Client

5.2.1 Technical Basis

The 3D view client is implemented as a plug-in to the LandXplorer CityGML Viewer that itself is based upon the LandXplorer framework which is a real-time 3D geovisualization system. The LandXplorer system allows the creation, management, and visualization of large-scale 3D geovirtual environments. The system uses state-of-the-art real-time 3D computer graphics algorithms and offers efficient interactions with the geovirtual environment. This includes enabling/disabling of information entities, blending techniques for raster layers, access to object attributes, or a variety of navigation techniques. The CityGML Viewer is a software system that is capable of reading, loading, and writing CityGML data as they are described in the latest OGC discussion paper on CityGML (Gröger 2006).

5.2.2 Requirements

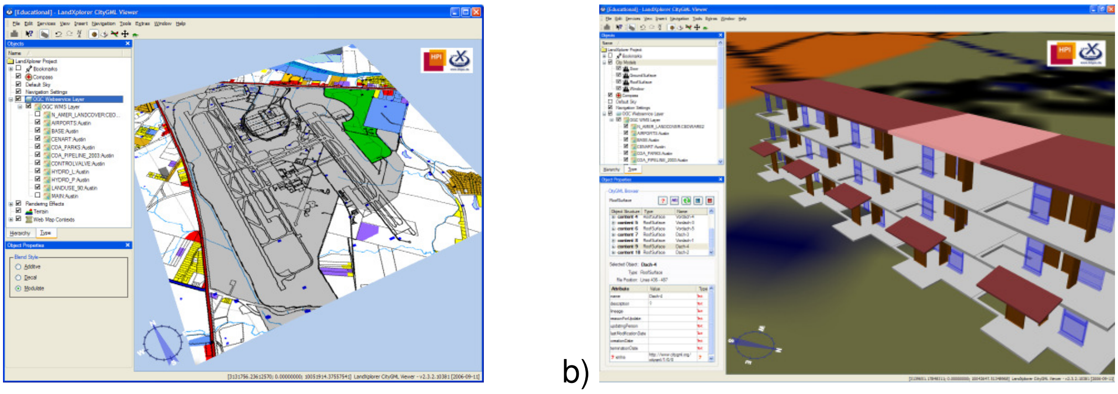
In addition to the already existing functionality of the LandXplorer 3D geovisualization system the following functionalities are needed to be provided by the 3D CityGML Viewer Client in the context of OWS-4:

- *Import, display, and activation of context documents*: Context documents describe which servers and which information entities to request. So context documents are a part of the run-time service binding. As the OGC has specified only a web map context document and context descriptions for other service types (WFS or BIM server) are pending, we have to define an own format for describing the binding and the functionality to request from the service providers.
- *Accessing WMS and WFS*: According to the OGC implementation specifications for WMS and WFS, we integrated a client stub for each of the service types.
- *Accessing CityGML from BIM server*: The BIM server bases on a WFS but has additional operations that must be considered for the client stub implementation. For web feature services a detection of the syntactical format (GML, CityGML) should be integrated.
- *Geodata processing*: One essential task for the integration of geoinformation from different providers is the projection into a unique spatial reference system by coordinate transformation. Furthermore the appropriate target spatial reference system must be determined.

- *3D geoinformation visualization*: For allowing a human user to get insight into the loaded data they must be visualized. As described this includes the mapping to a computer graphical representation which can be used by the 3D rendering system to synthesize a visualization of the integrated 3D scene.
- *Building room report*: In the described scenario, the building room report is necessary for the assessment of a building and it's capabilities for housing a field hospital.

5.3 Current Results

According to the proposal for participation in OWS-4 a demonstration implementation of the extended LandXplorer 3D CityGML Viewer Client has been provided to the OGC. The effort so far has been concentrated on the web context document processing, accessing WMS for retrieving map layers, accessing WFS for retrieving building model data in the CityGML format, and integration and visualizing these information.



a) b)

Figure 11: a) Combination of map layers from different WMS. b) Combination and integration of map layer information and feature data.

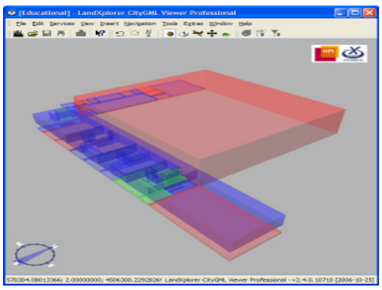


Figure 12: Visual room report. Color coding of building rooms according to the security state.

For describing which features to load and from which service they are provided, an arbitrary text format is used. It is leaned against the already existing Web Map Context specification. It is possible to load and execute a specific context description and load maps and CityGML features.

For the integration of geoinformation that are provided by different services, coordinate transformation is essential. This requires choosing a spatial reference system that can be applied to all data sets.

For some service requests the transfer volume is a very large one and so the synchronous service invocations are very time intensive. This will be a starting point for investigating techniques for optimizing the communication in the geoservice-based system.

Figure 11 shows an example view that is assembled from several single web map layer calls (a) and illustrates the combination of map layer information with feature data (b). In this special case the spatial reference systems had to be harmonized. Figure 12 shows the prototype of a visual room report. It enables to color the rooms of a building according to the value of a selectable attribute.

6 Conclusion and Future Work

The work so far has been about getting in touch with service-oriented computing, especially in the field of geoinformation. This included to get an overview about existing geoservices and their relationship to the common service-oriented architecture and to web services as a special and widely distributed form of implementing a SOA. It can be stated that service composition is important for achieving higher-level services with a higher value to the human user or another geoinformation processing system.

In the field of geoservices the OGC is a very active organization that targets on the interoperability of geoservices and geodata. The OGC has specified different services that cover different parts of the geovisualization pipeline.

The further work will bother with the processing of 3D geoinformation in geoservice-based systems. A focus will be on visualization services. As a new approach the interaction with visualizations, e.g., 3D GeoVE, will be investigated for integrating as a service. One issue in the assembly of higher-level functionality is the composition of services. This will be done in the field of 3D geoinformation services. As an outcome there will be concrete view clients using geoservices, concrete services processing 3D geoinformation, concrete service compositions of 3D geoservices, and derived and proved conclusions about the design and patterns for achieving this.

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