Styling for Service-Based 3D Geovisualization[1]

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Styling geovisualizations means to control the geovisualization process, i.e., to define which geoinformation to include and how to visualize them. It is a crucial aspect for enabling flexible and adaptable geovisualization systems and applications as it allows authors and users to influence the visual appearance of the geovisualization and so to adapt it to specific tasks and preferences. Especially for the service-based implementation of geovisualization systems, it has to be specified how a service consumer can define the visual appearance of a geovisualization which might base on distributed heterogeneous geoinformation and might be synthesized by the combination of independent geovisualization services. This paper describes the styling of three-dimensional geovisualizations in two scenarios. First, a Web Perspective View Service (WPVS) for the generation of high-quality visualization of domain specific building information within its GIS context is described. Second, the Web View Annotation Service (WVAS) and its combination with a WPVS for the synthesis of textual annotated views are introduced. Both implementations are demonstrated for a 3D campus model.

1 Introduction

1.1 The Role of Visualization in High-Level Geoservices

Geoinformation resources and capabilities for geodata processing and geovisualization are increasingly distributed among various providers. Service-oriented computing is concerned with describing, finding, and using these capabilities for different processes, users, and tasks. In the field of distributed geoinformation systems we can distinguish between geodata access, geodata processing, and geodata visualization services. The Open Geospatial Consortium (OGC) has standardized a set of geoinformation services that define interfaces to these functionalities. Important OGC web service standards are the Web Feature Service (WFS) for geodata access, the Web Map Service (WMS) for 2D maps, and the Geography Markup Language (GML) for the interoperable description of geospatial and georeferenced data. The Web Perspective View Service (WPVS), a first

[1] This work has been published in part by Hagedorn and Döllner (2007) and Hagedorn et al. (2007). It has been adapted for the special purpose of this technical report.

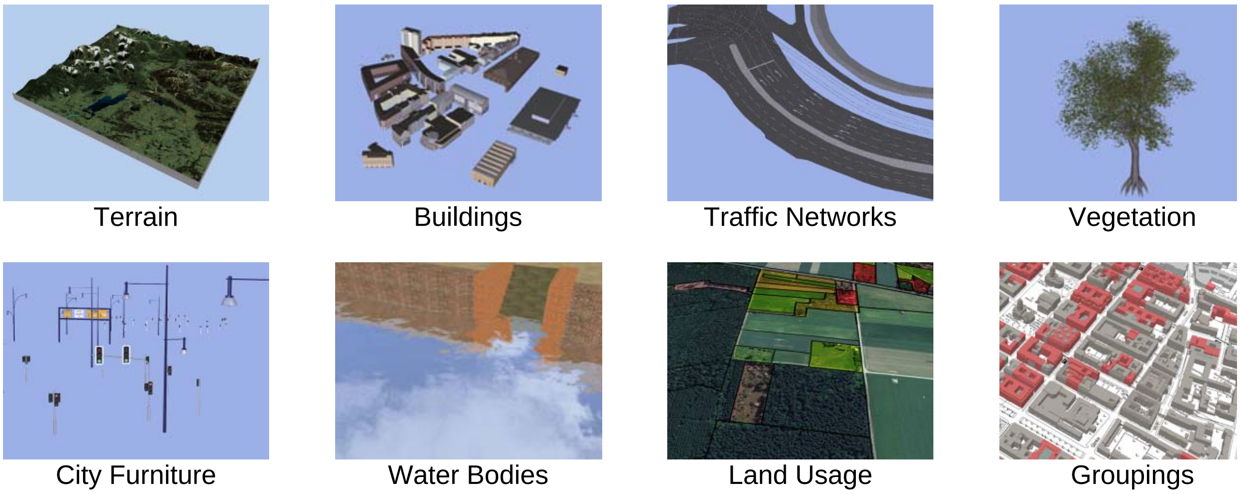

Figure 1: Aspects of complex geoinformation considering 3D GeoVEs.

approach for 3D portrayal, is currently under discussion to become an OGC standard.
The OGC web services such as Web Feature Service (WFS), Web Coverage Service, and Web Map Service (WMS) provide means to communicate geodata and can be considered generic, low-level geoinformation services. However, current geodata infrastructures need to evolve towards integrated systems for the provision of customized information and services (Morales and Radwan, 2004). High-level geoinformation services are generally characterized by the following capabilities and functionalities:

Enhancing geoinformation: Include services that enhance geodata by adding, manipulating, correcting, or transforming geodata, e.g., a specialized mass coordinate transformation.

Provision of specific business functionality: The usage of (value added) geoinformation for special purposes in a variety of business processes will be a main issue in the future development of service-based geoinformation provision. An example of such specific business functionality is a plausibility check for edited and updated geoinformation. This check includes domain-specific knowledge about the information structure, semantics, and rules for consistency.

Integration of complex geoinformation: 3D geovirtual environments (3D GeoVE) provide a conceptual and technical framework for the seamless integration of geoinformation that is different in format, scale, and amount of details. They provide mechanisms to enable the composition, management, editing, analysis, and visualization of this integrated geoinformation. 3D GeoVEs include complex geoinformation such as illustrated in Figure 1. For the integration of complex geoinformation there are two principal ways, "integration at data level" and "integration at visualization level". (Döllner and Hagedorn 2007a)

Integration at data level means the unification of geoinformation by transformations into common data formats or data models. While data format integration is at the syntactical level, data model integration works on a semantical level and introduces a higher added value to the integrated data itself.
Integration at visualization level means the provision of imagery and therefore inherently includes the issues of data selection, data mapping, image synthesis, image transfer, and user interaction.

Provision of high-quality visualizations: About 80 percent of all information has a spatial reference which can be used as a basis for the integration and the effective and consistent visualization of such information. Geovisualization can support a user in analysis tasks and in gaining new insights into geodata. In common (two dimensional) geoinformation systems visualization is an essential part. And so it is in distributed geoinformation systems which implies that visualization is a main issue in geoinformation services.

Support of user interaction: Especially for visualization services, the support of user interaction can be an essential capability. Additionally, high-level user interaction services are imaginable, which are set up on the top of other geovisualization services.
In this context user interaction means to explore and analyze the information space. For fulfilling these tasks, navigation is an important interaction technique as it allows the user to move around and perceive the information of interest.

Support of context awareness: Dey and Abowd (1999) define a system to be context-aware "if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's tasks". Thereby context "is any information that can be used to characterize the situation of an entity. An entity is a person, place or object that is considered relevant to the interaction of a user and an application, including the user and applications themselves."
In the field of service-based provision of geoinformation, context-awareness refers to identifying and providing information about the tasks the user fulfills and the devices that the users deploys.

Besides high-quality visualization itself, geovisualization plays a role for the implementation of other high-level functionalities, too:

- The integration of complex geoinformation can be performed at the visualization level.
- User interaction is closely linked to visualization as user input by devices such as keyboard, mouse, and stylus lead to updates of the visualization that itself can support interaction by presenting items to interact with.
- Context awareness can be supported by the appropriate visualization for a specific user with a specific task.

1.2 Separation and Distribution of Geovisualization Concerns

The visualization pipeline (Spence, 2001) of 3D GeoVEs includes accessing and selecting geodata, mapping them to computer graphical representations, and rendering of depictions, which can be perceived by humans. Using this visualization pipeline as a basis for portrayal raises the question about the exchanged information and the separation of rendering concerns between the portrayal service provider and consumer. The following types of exchanged information can be distinguished:

- Raw data, e.g., a terrain model in raster format.
- Geographic model, e.g., a CityGML city model.
- Computer graphic model, e.g., a VRML scene graph.
- Generated images, e.g., a two-dimensional map or a three-dimensional perspective view.
- Sequences of images, e.g., an MPEG video.

The different types of transferred information also mean different separations of visualization tasks.

In the case of raw data and of geographic models the service consumer has to implement the whole visualization process, i.e., data selection, information mapping, and rendering, which are intensive in hardware, processing, and storage requirements. When exchanging computer graphic models, the service consumer does not need any geographical knowledge for mapping geodata to computer graphic objects. But as a drawback the semantics of this geodata is not available for the rendering process or for supporting interaction. When the portrayal service provides already synthesized images, the service consumer is freed from any computer graphical processing. By this way geovisualization also gets applicable on small devices. Additionally, the protection of the underlying geoinformation against unauthorized usage is inherent in images as transfer formats. For raw data additional effort is necessary for digital rights management. Image sequences are a kind of image provision which especially can improve the usability of portrayal services.

Mixed forms of geographical portrayal services are possible, which provide information from different sources and thereby can reduce the named constraints. As an example a WMS can provide the operation GetFeatureInfo and thereby support additional semantical information about a graphical object at a specific pixel position of the previously provided 2D map.

A core concept of service-based systems represents the composition of distributed functionality in a standardized manner. This enables the construction and flexible adaptation of complex and value-added systems and applications. In the geoinformation domain, service composition is often referred to as *geoinformation service chaining*. Alameh (2003) distinguishes three service composition patterns: Client-based chaining, aggregate services, and workflow service-based chaining.

1.3 Styling 3D-Geovisualizations

For controlling the steps of the geovisualization pipeline and so the final outcome, different visualization aspects are important. These are especially views, styles, and rendering and interaction constraints. In Figure 2, they are illustrated in the context of creating geovisualizations by a high-level geoservice and their provision to human users or integration into business processes.

Views: Views represent different selections of the information which can be provided by a concrete portrayal service. Views allow customizing the visualization to concrete user groups and user tasks. The views supported by a service correspond with the abstraction level of the service, i.e. its granularity. E.g., a portrayal service for urban management visualization could provide a city planning view, an emergency response view, etc. Views correspond to the filtering stage of the rendering pipeline, as they may define the data which is integrated (e.g., imported from other geoinformation services).

Styles: Styles address the mapping of the geographic model on the computer graphic model. Styles influence the graphical character of the synthesized image. For example, they can define:

- Elements to hide or unhide.
- Opacity of objects.
- Graphical character of objects (sketchiness, cartoon style, etc.).

The distinction between view and style is not a strict one. Especially in higher level visualization services, views might include style issues. E.g., in an emergence response view the coloring of buildings of interest might be predefined by the view and is not changeable by user-defined styles.
Both, possible views and possible styles must be represented in the service description and must be considered in the service interface.

Rendering constraints: Rendering constraints address aspects such as requirements on image size, image resolution, color modes or transfer formats to use. E.g., imagery can be provided by a static image showing the situation at one point in time or by video which can be used for showing spatial changes of the

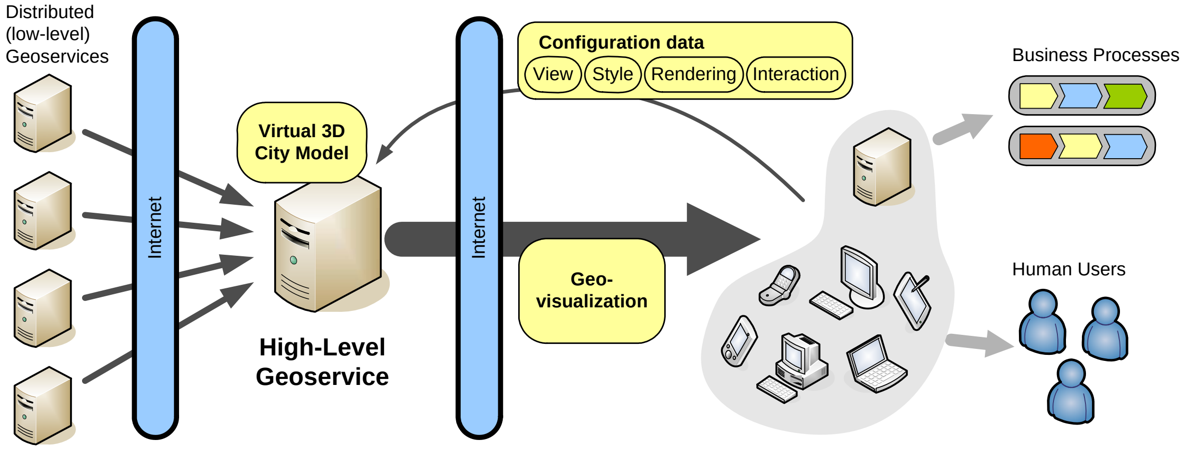

Figure 2: Geovisualization within the context of high-level geoservices.

camera position or for representing changes in time, e.g., for flood visualizations, or for showing historic scenes and their development over time.

User interaction aspects: User interaction may be restricted by different constraints, as devices (keyboard, mouse, stylus, etc.), user constraints (age, handicaps, handkerchiefs, etc.), or environmental circumstances (little light, noise, etc.).

2 Styling for BIM Visualization

This section describes the implementation of a high-level geoservice for the visualization of building information models (BIM) within its geospatial context. This geovisualization service is designed to integrate complex geoinformation, and provide high-quality geovisualizations for the specific domain of building information. This work has been published by Hagedorn and Döllner (2007). Here, the question of styling is addressed especially by providing different views and visualization styles to the service consumer.

2.1 Visualization of BIM by Virtual 3D City Models

While a growing number of manifold geoinformation sources become available, detailed information about individual buildings is typically not managed nor represented by GIS data. To enhance and complement virtual 3D city models in this respect, information provided by CAD models and other building-management tools needs to be integrated and helps to bridge the gap between the BIM, CAD, and GIS domains (Figure 3).

We describe an approach to visualize and analyze CAD-based 3D building information models (BIM) within 3D virtual city models. This way, detailed georeferenced building information about usage, structure, properties, and associated workflows becomes available embedded into their spatial context. Without such integration, we would not be able to see the spatial context of BIM. Furthermore, the approach represents a general strategy to seamlessly integrate georeferenced data from the domain of CAD with GIS data at the visualization level.

For the visualization of building information we identify two challenging tasks:

- The visualization of internals of composite structures (e.g., enabling an inside-view for a building).
- The visualization of intangible information (e.g., the usage of a room or groupings such as stories)

Both are regarded by the building visualization techniques that are described in this section. We present two techniques for the automated ad-hoc visualization of BIM and GIS information. This high-level functionality can be provided in a service-based manner and so can be included into ad-hoc rescue-processes for enabling, e.g., high-quality visualization.

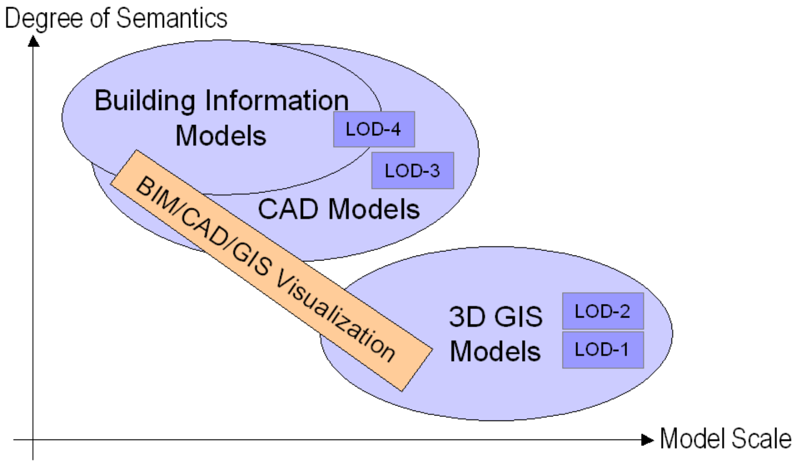

Figure 3: Scales and degree of semantics found in 3D building models with corresponding CityGML level-of-detail categories; the proposed visualization bridges the gap between BIM, CAD, and GIS model use.

As a use case we defined a fire and rescue scenario, which represents an application domain where the availability of building information is of high interest for saving people and assets. The following geo-referenced building information can be considered relevant for such fire and rescue scenarios:

- Fire extinguishers;
- Sensors such as smoke detectors, temperature sensors, or motion detectors for estimating the source of fire and the overall condition;
- Sprinklers, hydrants, hose reels, rising mains;
- Statics and material of building structures, e.g. windows;
- Cables, ducts, and funnels spreading heat, fire, and smoke;
- Information about locking of windows and doors (e.g., lattices) and key owners;
- Storage locations of dangerous substances (e.g., gas, oil, cleaning supplies, and chemicals);
- Expected overall number of people, number of people who need assistance (e.g., young and older ones);
- Navigation hints (e.g., room numbers) for supporting the orientation of helpers;
- Tracking information of people and objects.

2.2 Mapping BIM to Geometry

For each BIM data to be mapped onto the city model there must be an existing or derived geometry whose appearance can be adjusted according to the type and value of the building information.

If the original building information is of type geometry, this geometry is reused for the city model object. If no such inherent geometry exists, either another BIM object can be used for representing the building information or a corresponding geometry has to be generated. For example, derived geometry is required for visualizing relationships such as room's connectivity, escape routes (topology) or stories (grouping of rooms). The geometry can be composed from surfaces, e.g., for extracting the story geometry from all associated walls, windows, etc.

Non-geometric building information can be mapped to attributes of geometry. For example, the energy consumption of buildings could be mapped to the height of the building's block model. Alternatively, non-geometric building information can be represented by annotations of the 3D scene, for example, to visualize the presence of extinguishers, HVAC installations, or first-aid kits. 3D annotations can be visualized by texts, symbols, or 3D objects (e.g. an extinguisher model) and are integrated into the 3D scene or positioned within the view plane as described by Maass and Döllner (2006a, 2006b).

2.3 Enabling Insight for BIM Visualization

One approach for visualizing BIM information hides and emphasizes building structures: Important objects are highlighted and less important objects are reduced in perceptibility or even removed from the visualization. Apart from removal case, this technique leaves geometry unaltered, which enables to perceive and judge the real-world spatial configuration and relationships.

- A *BIM-view* configuration describes the objects that are included or excluded from the visualization and which BIM-style to apply.
- A *BIM-style* controls the visual variables and defines the appearance of city model objects and building objects.

For the visualization of values, a BIM style offers the possibility to define one of the

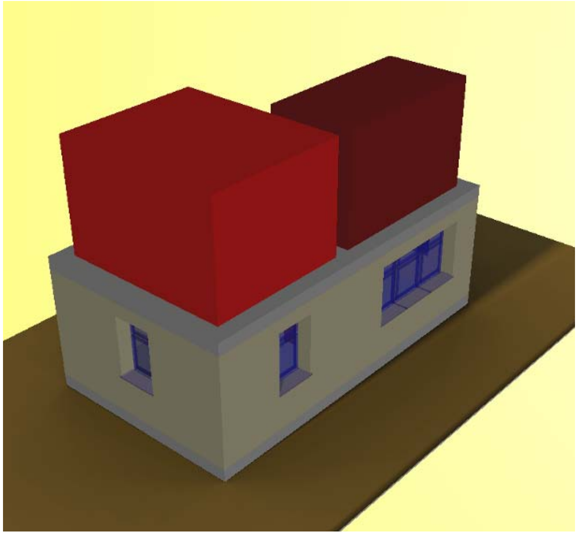

Figure 4: View showing the relative temperature on the second floor.

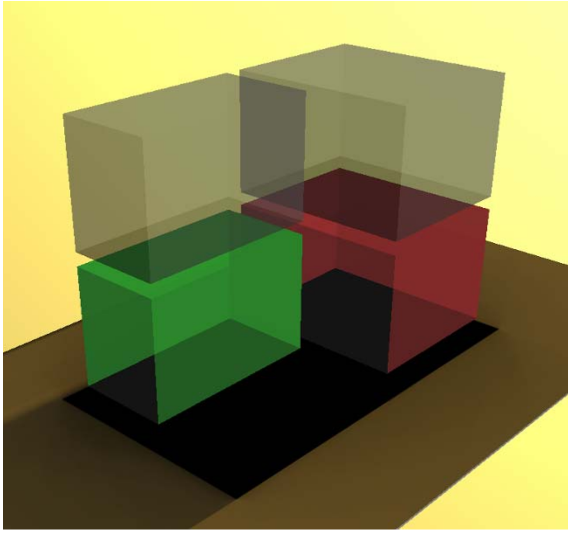

Figure 5: View showing the rooms with hazardous materials.

object attributes whose values modify the original object color. Furthermore, a base color hue (whose value is modified) and a normal range for the attribute's values are defined.
According to the rendering, we are using only color, transparency, and outlines for this visualization technique.
Figure 4 shows a 3D building. Only its second floor is inspected in detail. The view contains all elements of the first floor in normal style. For the second floor only room objects are included. For the story separation CityObjectGroups have been evaluated. The rooms on second floor are colored according to their temperature value from light red to dark red. In the sense of the fire scenario this can indicate the fire source.
Figure 5 shows another view for identifying any rooms in the building that include any hazardous materials, e.g., oil, gas, or chemicals. Therefore, only rooms of the building are displayed in transparent mode and only those rooms are colored which contain such materials.

2.4 Deforming Building Structures for BIM Visualization

As another approach to visualizing BIM we distort the geometry of building elements on the basis of their semantics. In detail CityGMLGroupings are evaluated for identifying the stories of a building and all story elements. Those are used for exploding the building model vertically and for popping open the building model vertically, respectively.
For explosion views, a geometrically translation is applied to the building stories and roof. Thereby insight into every story is enabled and indoors elements such as furniture can be perceived without modifying the building objects' appearance, e.g., by using transparency. Such visualization is essential when dynamic data such as

Figure 6: Tilting up of the building for gaining insight.

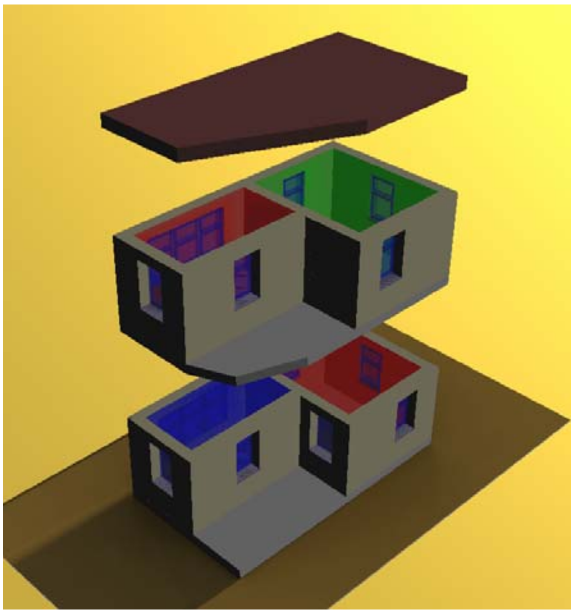

Figure 7: Explosion view for gaining insight; room usage is color coded.

tracking data of firefighters shall be integrated with this building model and all their positions shall be visible at the same time.
A second deforming technique just tilts up the building structures above a defined storey, see Figure 6. On the one side this tilting provides less information than the explosion view, on the other side it needs less image space and still contains more information than just removing the upper building parts from the visualization.
As shown in Figure 7 this deforming visualization technique can be combined with the mapping technique described above. The view includes all building information; only for the second floor the room usage is color-coded.

2.5 Web Perspective View Service for BIM (BIM-WPVS)

In general, the BIM-related high-level geoinformation service could be implemented on top of the following OGC web services:

- **Data-oriented:** A Web Feature Service (WFS) would deliver and modify feature objects and their attributes;
- **Scenegraph-oriented:** A Web 3D Service (W3DS) would deliver a scene graph, i.e., a specification of a virtual 3D world including 3D objects, their attributes und hierarchical structure; this data is processed by 3D rendering engines for visualization.
- **Visualization-oriented:** A Web Perspective View Service (WPVS) would provide perspective views of a static 3D scene as image, i.e., a rendering of a 3D GeoVE.

The BIM-WPVS is implemented in a visualization-oriented way. Using a WPVS has the key advantage that there is no need for consumer-side 3D rendering because image synthesis is performed at the server side; the server can be equipped with appropriate 3D computer graphics hardware. In particular, we can deploy high-quality 3D rendering without having to consider the diverse client 3D rendering capabilities since BIM visualization results need only to be transferred to and displayed by light-weight client applications (Singh, 2001). This separation allows us to implement specialized 3D visualization techniques such as for natural phenomena (e.g., including water or sky), to apply processing-intensive techniques (e.g., non-photorealistic rendering, vegetation rendering, or ambient occlusion for simulating global illumination in 3D GeoVEs).
As a disadvantage, WPVS (as well as W3DS) do not transfer any further semantics to the client than the information contained in the synthesized image (or scene graph, respectively). Semantical information is currently only provided by data services, such as the OGC WFS, which, e.g., could deliver a semantical model of a geospatial scene in the CityGML format. This approach would require additional knowledge about the format and processing of CityGML at the service consumer side.

Compared to the OGC WPVS, our BIM-WPVS is extended as follows:

- BIM-WPVS includes integration capabilities for different geoinformation, i.e., terrain data, vegetation, several building data, and additional building information.

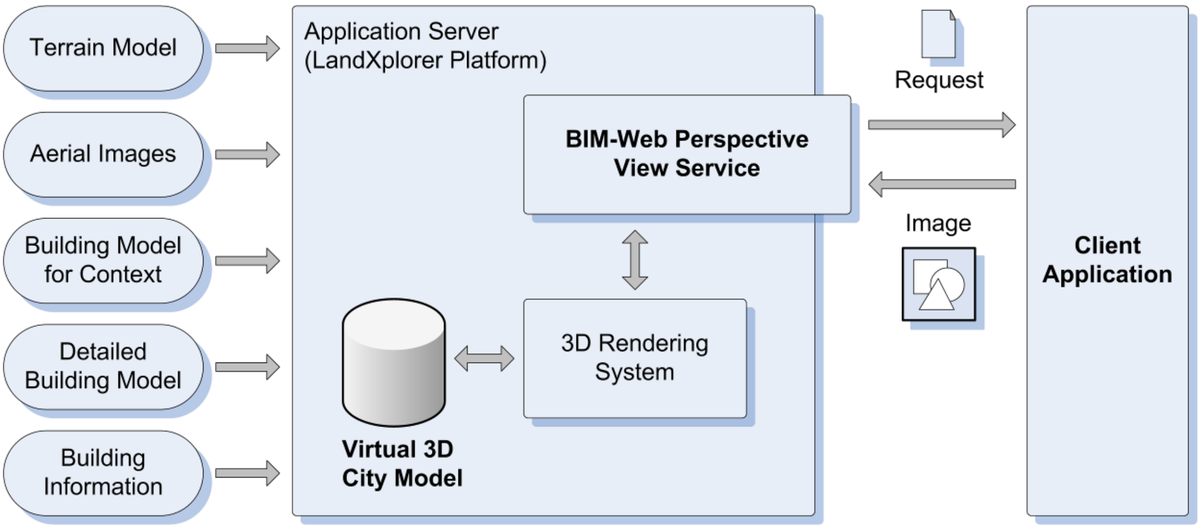

Figure 8: System architecture of the BIM-WPVS.

- BIM-WPVS provides different views that are configurable with respect to visualized data and visualization style.

The perspective view provided by the BIM-WPVS can be integrated into different processes for giving users insight into the geoinformation in an effective way. The application of the BIM-WPVS can be further enhanced by the combination with other services which could enable the access to further complex geoinformation (e.g., to ad-hoc sensor network data), provide functionality for further improving the visual representation of the virtual 3D environment (e.g., by adding annotations to the view), or supply interaction capabilities (e.g., for navigation and editing). Security is another important issue that can be addressed with service composition. In the context of a BIM-WPVS this includes user authentication and authorizing the access to the underlying data which has to be appointed with user restrictions, accordingly.

2.5.1 Service Architecture

Figure 8 illustrates the system architecture of the BIM-WPVS. Various sources and formats of geoinformation are accessed, integrated and composed by the central LandXplorer-based server component. It is capable of integrating terrain data, aerial images, LOD-4 building models, additional detailed building information, and further context buildings for the geospatial surrounding on the basis of a virtual 3D city model.

In our case the different geoinformation is accessed from a central database, but it might be distributed and could be accessed by using WFS and WMS web service adaptors that we have added to the LandXplorer CityGML viewer as a contribution to the CAD/GIS/BIM thread within OGC's web services initiative, phase 4 (OGC, 2007). In contrast to that work, the BIM-WPVS deploys a fat-server/thin-client approach.

2.5.2 Service Interface

Similar to the OGC WPVS, the BIM-WPVS provides two operations, GetCapabilities, which provides information about the service and its capabilities, and GetView, which provides the synthesized image.

GetCapabilities: Describes the geoinformation layers that are available through the service and can be selected by the service consumer for visualization. Building information is modeled as one layer of the BIM-WPVS. The GetCapabilities response further describes different general analysis views, which can be chosen for the server-side image rendering process. These views define the in-scope building information and how they are visualized.

GetView: Provides the capabilities of the BIM-WPVS to the service consumer, i.e., the rendering of an image that emphasizes specific building information. For its configuration, the service provides several parameters which a) define the geoinformation layers to include, b) define the position of the virtual camera or leave this to the server for automated calculation, c) define the requested image size, d) define the general analysis view to apply, or e) define a task- and domain-specific view with explicitly setting the relevant entities and the visualization style.
Figure 9 shows the results for two GetView requests which integrate detailed building information for a large campus building within its geospatial context (e.g., terrain data, aerial image, and surrounding buildings). They use the explosion view to allow the service consumer to gain insight into the building structure and properties. The examples use color-coding highlighting a single room and for showing the room temperatures within the building.

2.6 Results

We have outlined design and implementation of a high-level geoinformation service that helps to close the gap between spatial information at the building level and spatial information at the city model level. We have explained how to map BIM data to components of virtual 3D city models, and exemplified the approach by two BIM-

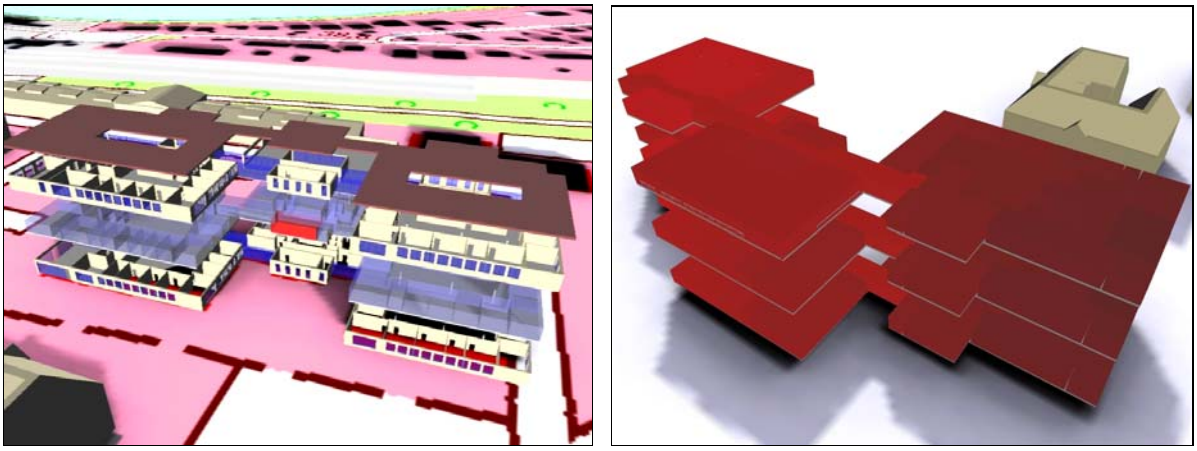

Figure 9: Explosion views of a large campus building within its geospatial context for finding a single room (left) and for showing room temperatures.

specific visualization techniques. We demonstrated the applicability of the approach by our implementation of a BIM-WPVS, which successfully utilizes virtual 3D city models for seamlessly integrating and visualizing GIS and BIM data; rendering styles can be configured by the service operation parameters and different views for analysis purposes can be obtained.

As a general insight, we consider the BIM-WPVS as an example of a high-level geoinformation service that synthesizes complex data and applies advanced 3D visualization techniques while offering a high degree of interoperability due to the server-side 3D rendering.

3 Styling with Distributed 3D Geovisualizations

This section describes an approach for the textual annotation of a perspective view generated by a WPVS. This functionality corresponds to the TextSymbolizer offered by the SLD specification but is extended to 3D geovisualization and is additionally implemented by distributed portrayal and processing services. A composition client uses and combines the functionality of these independent services. This work has been published by Hagedorn et al. (2007).

3.1 Annotation of 3D Geovirtual Environments

Annotations are essential elements to communicate textual and symbolic information for cartographic maps and within 3D GeoVEs. Traditionally, they name point, line, or area features, such as locations, streets, rivers, districts, or lakes. A number of criteria, e.g., a clear correlation with the feature, the legibility of the annotation, and the occlusion of other annotations or important image parts have to be considered to optimize the information transfer to the user and to achieve an aesthetical appearance of the annotated depiction. The use of electronic media for map creation and presentation raises the need for automated annotation techniques. This need has been strengthened by the increased use of interactivity in today's geovisualization applications and systems, which allows users the real-time exploration, analysis, and modification of geospatial data.

A first approach for the automated labeling of interactive 3D GeoVEs was presented by Bell et al. (2001). They developed a view management data structure that efficiently supports the registration and query of rectangles on the view plane. This is used to mark such regions as occupied that show important scene elements or formerly placed labels. Maass and Döllner (2006b) present another view management strategy that is optimized for point feature labeling of terrains. Furthermore, they develop a technique that directly embeds annotations as 3D elements into the 3D scene instead of presenting them as screen overlays (Maass and Döllner 2006a, 2007).

3.2 Composition Concept

Our approach to annotated 3D views of GeoVEs combines two main services, an extended Web Perspective View Service (WPVS) and the Web View Annotation Service (WVAS). The service chain is implemented as client-based service composition. Complementary to the thick geovisualization service, this client is constructed as a thin client. It knows about the component services and completely

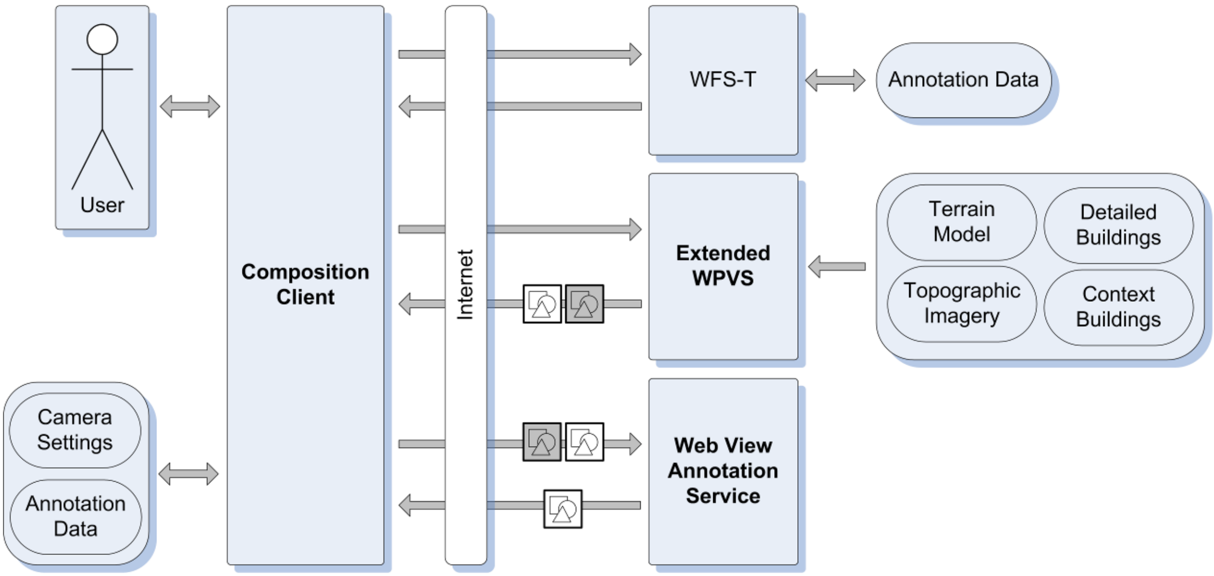

Figure 10: Architecture of the service chain for annotated views of GeoVEs.

controls the service-based geovisualization process. Figure 10 illustrates the overall architecture of our implementation and the main message transfer between the involved components.

Our approach to an extended WPVS encapsulates the access to and the integration of geoinformation in one 3D GeoVE comprising large terrain models, large aerial images, and building data in different formats (e.g., CityGML, 3DS). It is capable of synthesizing high-quality images using rendering techniques for ambient occlusion and atmospheric effects such as sun and clouds. In our case study, the service provides access to the integrated GeoVE of a 3D campus model composed of a terrain model, topographic imagery, and several building models such as main building, auditorium, library, cafeteria, and nearby train station. The composition client receives a perspective view and a depth image from the extended WPVS and forwards them to the WVAS along with a set of annotation descriptions and configurations. Finally, the WVAS calculates and overlays the embedded textual annotations. Figure 11 shows a screenshot of the composition client.

For adding user-defined annotation to the 3D GeoVE, we have integrated a transactional WFS in our WPVS. This data can be requested by other users and can be utilized for creating the WVAS request.
Functionality and interface of the WPVS have been extended to enable their composition with the WVAS. Both services are described in Section 3 and Section 4.

3.3 The Web View Annotation Service

The WVAS provides the single operation GetAnnotatedView. Service request and response are encoded as SOAP messages sent over Http. For both, input and output, images can be transferred in different ways. First, a URL pointing to the image on a web server or representing a URL-encoded service request, e.g., to a WPVS, can be used. Second, the images can be submitted within or attached to the

SOAP message as described by Powell (2004), e.g., using the SOAP extension DIME (Direct Internet Message Encapsulation) for attaching binary data. In our current implementation the color and depth images are encoded as base64 strings and sent within the SOAP messages.

The WVAS is implemented as a stateless service: It does not provide any user or session handling and does not store any camera, canvas, or annotation descriptions. Therefore all input data has to be included in every service request. Some of the data that defined the preceding image rendering process has to be included into the service request as well. In detail the GetAnnotatedView operation use the following input parameters:

- *List of annotations:* An annotation is defined by an annotation text and a 3D position, the annotation's reference point. The annotation can be described as

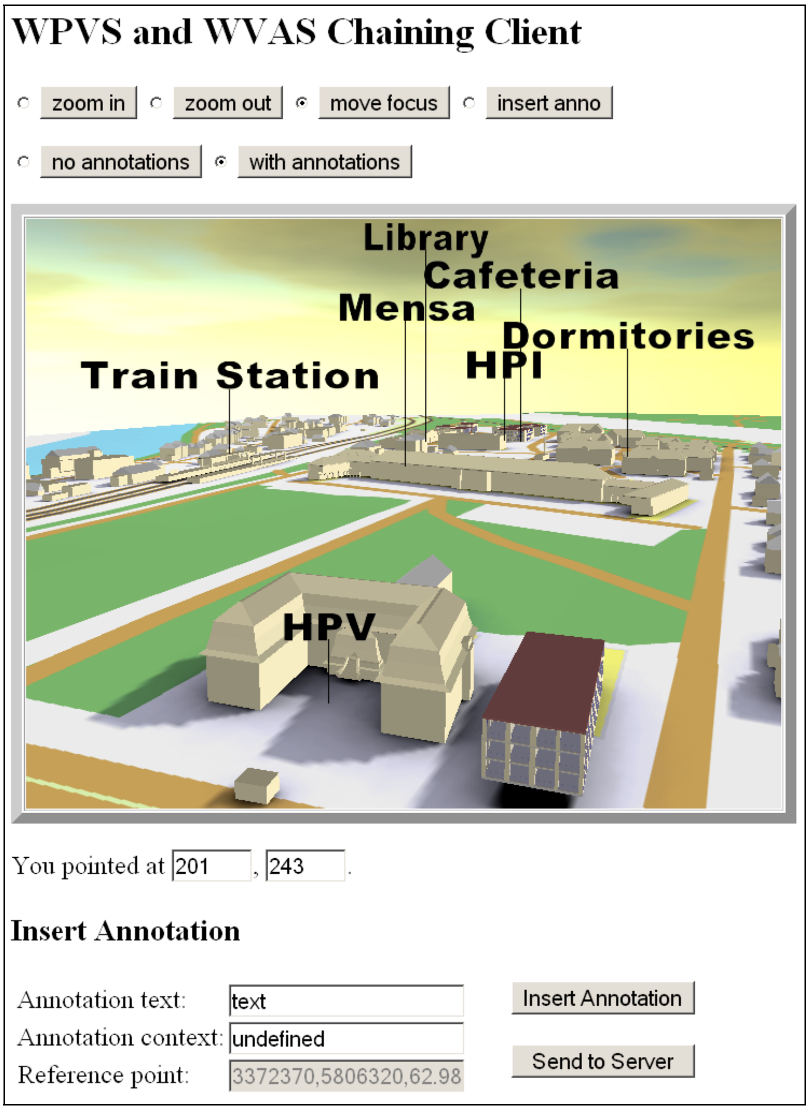

Figure 11: Screenshot from the composition client showing an overview of the campus area.

an abstract GML feature containing a georeferenced gml:Point.

- *2D color image:* The 2D color image represents a perspective view of a 3D scene for a specific viewpoint and contains RGB values for each pixel.
- *2D depth image:* The 2D depth image is related to the color image. Each pixel stores the distance of the visible scene element to the camera with float precision.
- *Camera definition:* As usual in the 3D computer graphics domain, the camera is defined by the look-from vector, look-to vector, look-up vector, near plane, far plane, and field-of-view angle. This is different from the camera model of the OGC WPVS which is defined by the point of interest (that is the look-to point in our model), the camera distance to that point, angles describing the north direction, pitch, and field-of-view. However, both models can be transformed into each other.
- *Canvas definition:* The canvas definition describes the width and height of the input color and depth images.
- *Annotation configuration:* The appearance of the annotations generated by the technique can be adjusted by parameters such as the placement variant, color, font, and annotation size.

The WVAS is currently implemented as .NET Web Service executed by the Microsoft Internet Information Services (IIS). Its implementation is based on the Virtual Rendering System, "a computer graphics software library for constructing interactive 3D applications. It provides a large collection of 3D rendering components." (VRS 2007, Döllner and Hinrichs 1995)

3.4 Extended WPVS

3.4.1 Extension for Depth Image Provision

The WPVS has been extended by providing additional image-encoded scene information, i.e., the service not only delivers the RGB image of a 3D GeoVE but also an additional image that encodes scene depth. The depth image cannot be created by SLD or SE feature visualization styles, which only influence the mapping of geoinformation to graphical primitives. Instead, the rendering stage in the visualization pipeline has to be modified. We identified at least the following possibilities for integrating such rendering functionality into WPVS:

- *Extending the GetView operation by an additional RenderingStyle parameter:* Depending on this parameter the service decides about the creation of the default color image or the depth image and the format in which they are delivered (e.g., as application/octet-stream for raw binary data).
- *Extending the WPVS service interface by an additional operation GetDepthView:* This operation generates the depth image and only provides appropriate transfer data. The further parameters of the operation are identical to the GetView request.

Both ways provide access to intermediate data of the visualization pipeline, which have not been accessible before to service consumers. This data is not intended for perception by humans but serves as input for new service-based visualization techniques.
Our WPVS implements the additional operation GetDepthView. Nevertheless, the option of explicitly supporting RenderingStyles seems to be very promising as it is a more general concept for enabling additional rendering techniques.

3.4.2 Service-Based User-Interactivity

To support user interaction, we have extended the WPVS by a GetFeatureInfo operation. Corresponding to the WMS GetFeatureInfo operation, it provides additional information about features in the perspective view of the 3D GeoVE that is returned by a previous GetView request. Because of the stateless implementation of the WPVS the GetFeatureInfo request has to specify most of the parameters of the GetView request, i.e., canvas and camera settings, layers to include, and styles to apply. As further parameter the 2D image position of interest is specified.
The server-side implementation of GetFeatureInfo uses a ray intersection test for identifying the selected objects. A 3D ray request is originated at the camera position and shot into the scene. The primarily hit GeoVE object is evaluated and thematic information such as the GeoVE object type (e.g., building, roof, terrain, etc.), object identifier, and geospatial position can be derived and included into the GetFeatureInfo response message.
For the interactive specification of annotations, this position can be used as annotation anchor point. Additionally, object-related information such as the object center, footprint center, or other predefined building-related points of interest (e.g., meeting places, elevators, emergency exits) can be delivered to support the user in specifying annotations.

3.5 Composition Client

The combination of the extended WPVS and the WVAS is performed by the composition client. The client application catches the user input and forwards it to the extended WPVS. This is the same for the user's navigation input, which is mapped to a new camera position and results in a new execution of the service chain. Additionally, session state handling is addressed, including tracking the camera settings and determining the annotations to be added to the perspective view. In our case, the session handling was performed by the composition client itself. Server-side session handling is another approach, which could be implemented with a service-based composition approach. The sequence diagram in Figure 12 illustrates the steps performed by the composition client to process the user input (for annotation definition) and combine the extended WPVS and WVAS (for annotated view creation). This scenario contains the storage of user-defined annotations at the WFS-T.
Currently, the client application is implemented on a JavaScript basis. As with AJAX, this enables asynchronous communication with web services using the XMLHttpRequest object with SOAP messages. The input and output image data is encoded as base64-string and transmitted as part of the SOAP request or response messages, respectively.

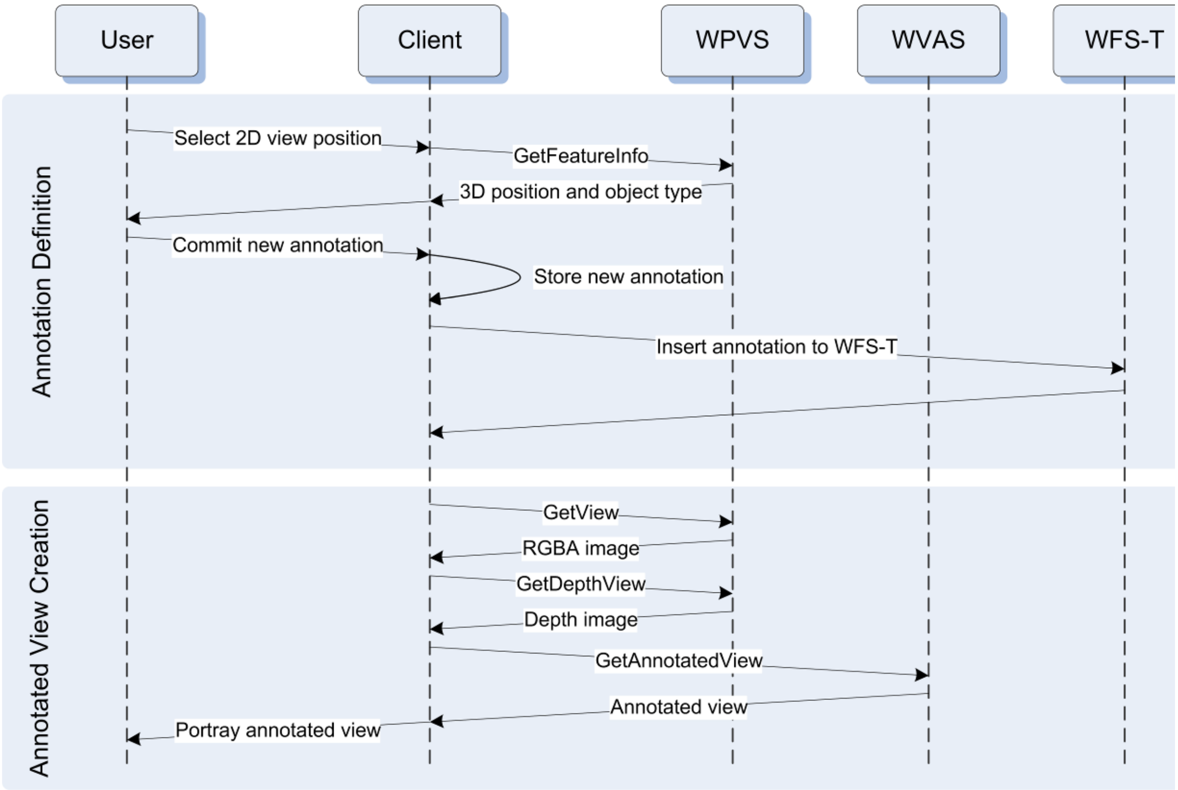

Figure 12: Sequence diagram describing the overall workflow for defining and creating the annotated perspective view.

3.6 Results

We have implemented a client-controlled service-chain supporting the 3D annotation of 3D GeoVEs. Figure 13 shows two annotated views of the 3D GeoVE of our campus and how the automatic annotation supports a high legibility by preventing occlusions with scene objects and other annotations.

The presented concept and prototype show how two complementary 3D visualization techniques can be seamlessly combined by implementing these techniques by two independently designed, implemented, and deployed web services; chained together they form a higher-level web service chain. In particular, separating core scene rendering of 3D GeoVE from specialized 3D visualization techniques, for example annotation rendering, facilitates the systematic, modular composition of complex visualization applications and simplifies their implementation. For example, the annotation service could be reused in other web service chains, or it could be enhanced by a navigation information service.

The presented concept can be applied to all visualization services that basically operate in image space provided that the WPVS offers additional scene information. This way, we can use an optimized 3D rendering engine for the most time-critical part, the rendering of complex 3D GeoVEs, and other aligned web visualization services do not depend on the underlying internal representation – they rely on a clearly defined, image-based interface. This approach also offers a high degree of

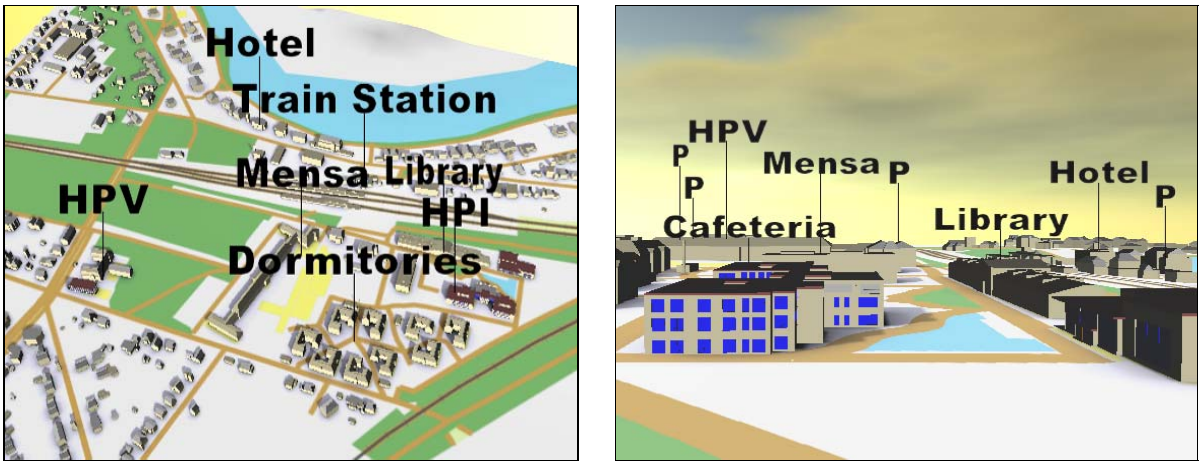

Figure 13: Screenshots of annotated views of the 3D campus model from a bird's eye (left) and close to ground (right) perspective generated by the service chain implementation.

interoperability because the individual web services do not need to exchange contents of 3D GeoVE, for which no commonly accepted standards exist so far.

The extensions to the WPVS can be generalized: In all standard 3D graphics systems (e.g., OpenGL, DirectX), the provision of image-encoded scene information (e.g., depth, surface normals, object identities, etc.) represents a common feature. Therefore, we suggest including these extension into the official WPVS definition. For example, higher-level web services that provide advanced stylized images (e.g., illustrations) could be implemented this way.

4 Related Work

For the specification of visualization styles for 2D maps the OGC supports the Styled Layer Descriptor (SLD) and Symbology Encoding (SE) specifications (Lalonde 2002, Müller 2006). Together with a reference to the input data, a WMS consumer can use predefined styles for the geovisualization or specify own styles to be applied. Annotations can be integrated into the WMS-based geovisualization in two ways: The SLD and SE specifications support textual and graphical annotations by TextSymbolizers (for label placement) and PointSymbolizers (for 2D graphics placement).

Until now, for the styling of 3D GeoVEs, no standards emerged. Neubauer and Zipf (2007) have proposed extensions to the SLD specification for third dimension. E.g., they suggest SolidSymbolizers and SurfaceSymbolizers as new features, 3D legends, billboard integration, 3D placement, and the extension of material definitions for supporting enhanced shading. This extension is leaned against SLD styling mechanism for 2D simple features (such as points, lines and polygons) but does not address the visualization of more complex structured features such as CityGML buildings, which include walls, doors, windows, etc.

Regarding the service composition for geovisualization, the OGC WMS specification together with the SLD specification supports the definition of external geodata sources for being used within the geovisualization process. Neis et al. suggest an

Accessibility Analysis Service (AAS, Neis et al. 2007a) and an Emergency Route Service (Neis et al. 2007b), which employ service composition by aggregate services. For example, they combine street network data from WFS with processing capabilities of their AAS (which generates new geometry described as GML) and WMS mapping capabilities. Weiser et al. (2007) show the possibility of using BPEL engines together with WSDL service descriptions of OGC web services for a workflow-based service orchestration. We do not know about other work about the service-based externalization of intermediate rendering results for beeing used with other geovisualization services.

5 Conclusions and Future Work

This paper introduces two approaches for enabling styling within 3D geovisualization. First, it targets at a domain-specific styling of complex building information and the visualization within its geospatial context. Second, the externalization of intermediate rendering results and combination with additional rendering functionality in a distributed visualization system is shown.

In our future work, we will address the following aspects: First, we will develop advanced BIM visualization techniques that focus on providing insight into complex spatial assemblies using non-photorealistic, illustrative 3D rendering techniques. Second, we will implement the service chain by an aggregate service, which includes the logic for service chaining, currently implemented by the composition client. Third, we will provide web-service adapters to general web services (WMS, WFS), which provide access to geodata (e.g., maps, 3D terrains, and city models), offer lookup services whose results can be visualized by annotations (e.g., taxi stations, restaurants, or parcel tracking information), and use the annotation service for analysis and exploration tasks. Fourth, we want to enhance user interaction implemented by web services. This includes functionality to interactively specify annotations also for line and area features, used to add user comments in urban city planning scenarios, as well as to support network-based multi-user collaboration.

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