Extending the WPVS Visualization and Interaction Capabilities

Benjamin Hagedorn
Benjamin.Hagedorn@hpi.uni-potsdam.de

A Web Perspective View Service (WPVS) provides images of perspective views of 3D geovirtual environments (3DGeoVE) which can be displayed by the service consumer without client-based 3D rendering. Such visualizations can be easily accessed by simple clients such as mobile devices and can be integrated into processes, e.g., for city planning or ad-hoc threat response applications. So far, the WPVS does not provide any interaction or navigation capabilities, which restricts its degree of usability. To increase the spectrum of the WPVS functionality and, thus, its usability and applicability, we present the concept of an extended, smart WPVS. The proposed extensions provide meta information for generated views and more effective 3D interaction and 3D navigation for service-based complex 3D geovirtual environments.

1 Introduction

The amount of collected geodata, it's complexity, and it's usages are constantly growing. Geodata comprises spatial, thematic, and temporal information and can be applied in various domains, applications, and systems. For these systems and for the sustainability of the collected geodata, interoperability is a crucial issue. This includes aspects such as a common understanding of geoinformation content and quality, geodata description, and geodata access. The Open Geospatial Consortium represents a jointly international effort targeting at geoinformation interoperability. In varous initiatives, the members of the OGC reached consensus on the format of data and several web services for accessing, processing, and visualizing geodata.

Geovisualization plays an important role in the chain of geoinformation usage. In the field of two-dimensional geoinformation, visualization is mainly provided by the *Web Map Service (WMS)* [13]. It allows for retrieving map-like views of various geodata. By the help of *Styled Layer Descriptors (SLD)* and *Symbology Encoding (SE)* [14] this visualization can be styled and adjusted according to the service consumers' requirements. So, from the same data basis, e.g., a road map and a map of trails can be generated, which contain and emphasize different elements and are specific for different user groups and usage scenarios.

The growing importance of three-dimensional geoinformation has been reflected by the revision of geodata description standards (GML3), but also by the development of 3D portrayal services. The key 3D portrayal services in the OGC's geoservice family are the *Web 3D Service (W3DS)* and the *Web Perspective View Service (WPVS)* [10,

Figure 1: Web Perspective View service visualizing city planning alternatives in Potsdam.

12]. Both services have not become OGC standards yet. The W3DS has the status of an OGC discussion paper and the WPVS is still an internal draft. The current OGC web services initiative (OWS-6) brings these 3D portrayal services back into focus.

We are participating in a 3D portrayal initiative within the OGC which resumes the work at these services, reviews the existing specification efforts and aims at creating a 3D portrayal services family. As part of this initiative, we want to extend the WPVS by visualization and interaction functionality based on state-of-the-art computer graphics architectures. This report describes the conceptual foundations for extending the WPVS and derives several new functionality from investigating typical application scenarios for 3D portrayal.

2 3D Portrayal Services

2.1 Relevance of 3D Portrayal

For 2D portrayal, the WMS represents the ”work horse” for interoperable visualization of 2D maps. The service consumer chooses the information layers to include in the map-like visualization and may adjust the visual appearance of the 2D features. Additionally, the WMS allows for requesting type descriptions of the represented features and for retrieving additional information of a feature at a specific image position.

Several activities within the OGC aim at the interoperable description of 3D geoinformation. Those are, e.g., GML3 (which includes three-dimensional features) and CityGML (which is a GML3 profile for describing regional landscape models and city models). For the portrayal of this 3D geoinformation, W3DS and WTS (which will be replaced by the WPVS) represent primary specifications. Complementing the interoperable 2D map generation and access by WMS, 3D portrayal becomes more and more important. Compared to 2D maps, perspective views can improve the perception and interpretation of complex spatial information: They show the height of geoobjects, included facades hint on the usage of buildings, etc. Perspective views become a generally known and accepted medium for spatial information. Nevertheless, there are no standard approaches widely used for 3D geovisualization.

2.2 The OGC Portrayal Model

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 [11]. Application services may be either application servers, or application clients. 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), i.e., between server and clients.

The OGC portrayal model (Fig. 2) can also be applied to 3D portrayal. Components of a 3D portrayal services family are arranged along that pipeline. Major aspects of these services and specifications aim at the generation of display elements (e.g., a scene graph), rendering images, and giving the possibility to influence the visual appearance of features by styling. While generating and serving display elements leads to client-site rendering, generating images represents fully server-side rendering. The OGC Portrayal model allows for three segmentations which are described in [2]:

- *Thick Client / Thin Server:* The client request selects 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 scene graph) 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.

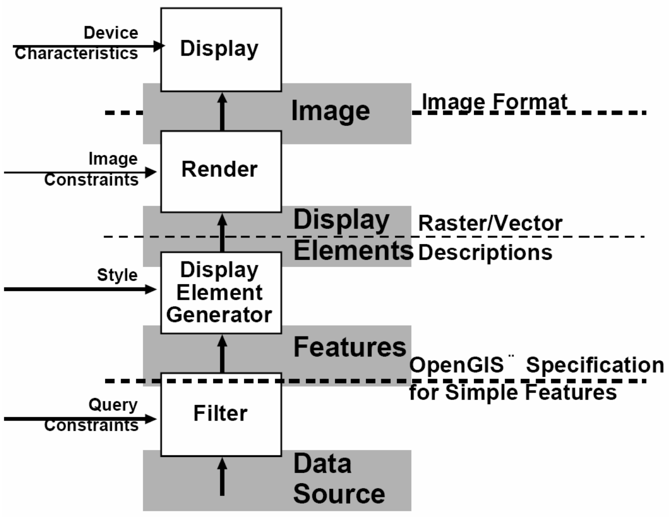

Figure 2: The OGC portrayal model. [11]

2.3 The Web 3D Service

The W3DS [12] generates computer graphical representations of 3D landscape and city models, which are streamed to the service consumer in 3D graphics formats (e.g., VRML, X3D, COLLADA). This graphics data can include appearance information but is mostly not capable of transferring thematic information. The computer graphical representations, which could be arranged in a 3D scene graph, have to be processed and rendered by a W3DS client using the rendering techniques of its choice. The W3DS client is a rich client allowing for an interactive 3DGeoVE including real-time navigation.

A full W3DS and a web-based client have been implemented at the University of Bonn. [1] It provides exploration capabilities for the city of Heidelberg. The client is implemented as a Java Webstart application which installs and retrieves the computer graphical representations from the server. For rendering high detailed and high-quality visualizations of the presented 3DGeoVE, modern 3D graphics acceleration hardware and high bandwidth are required.

2.4 The Web Perspective View Service

The WPVS aims generates images of perspective view of a 3D scene and sends this to the service consumer. With this approach, we can set up a dedicated server with appropriate 3D hardware, i.e., we don't have to deal with incompatible, diverse 3D hardware configurations on the client-side. Users get access to arbitrary complex geovirtual environments with high-quality graphics output and without having to install specialized 3D applications or streaming complex 3D data – only images are transferred. This a) omits incompatibility problems of 3D renderer systems and hardware, b) reduces administration and maintenance costs, and c) allows for a simple integration of 3D geovisualizations into complex workflows. The WPVS defines four operations (see Ta-

Table 1: WPVS operations (from [10]).

Operation	Description
GetCapabilities	The mandatory GetCapabilities operation allows clients to retrieve service metadata from a server. The response to a GetCapabilities request is an XML document containing service metadata about the server, including metadata about the data available from that server.
GetView	The WPVS GetView operation allows clients to obtain a specified subset of identified layers from a WPVS server. In addition, the GetView operation allows the client to select the perspective view of the retrieved layers and the format.
GetDescription *(optional)*	The GetDescription operation allows clients to retrieve the descriptions of one or more identified datasets or styles.
GetLegendGraphic *(optional)*	The GetLegendGraphic operation allows a client to retrieve a graphic containing a map legend for an identified dataset and style. Implementation of this operation is optional by WPVS servers.

ble 1); the GetView and GetCapabilities options are mandatory. Fig. 3 contains an example of a WPVS GetView request.

2.5 Comparison of WPVS and W3DS

Table 2 briefly compares the W3DS and WPVS. From these characteristics different usages of both services follow. Using the W3DS together with a powerful rendering client allows for real-time navigation and interaction in the 3D scene. For the provision of complex scenes by W3DS a high bandwidth is needed.

The WPVS can be used by more simple clients and in situations where available bandwidth is low. Navigation in a base WPVS is step-by-step and far from real-time interaction. We believe that this drawback can be attenuated by intelligent loading and display strategies (e.g., image preloading or cube map generation).

The WPVS encapsulates the hole rendering process and provides simple portrayal functionality by generating and delivering images; the W3DS provides 3D scene graphs dedicated for consumer-side rendering. Thus, in a spatial data infrastructure providing

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http://myserver.org/wpvs?SERVICE=WPVS&VERSION=1.0&REQUEST=GetView&
CRS=EPSG:26912&POI=424994.4,4513359.9,1550.0&PITCH=30&YAW=30&ROLL=0&
DISTANCE=1000&AOV=60&BOUNDINGBOX=424585.3,4512973.8,425403.5,4513746.0&
ELEVATIONMODEL=Default&WIDTH=640&HEIGHT=480&OUTPUTFORMAT=image/jpeg&
LAYERS=City,River&STYLES=default&EXCEPTIONFORMAT=INIMAGE
```

Figure 3: Example of a WPVS v.1.0.0 URL-encoded GetView request.

Table 2: Comparison of the WPVS and W3DS.

	WPVS	W3DS
Transferred data	Imagery	General scene graph
Transmission load	Depends on type, quality, and size of imagery	Depends on the size of the 3D scene
Server-side complexity	High	High
Client-side complexity	Low	High
Resulting visual quality	Determined by the service provider	Depends on the service consumer rendering capabilities

3D portrayal, the WPVS could act as a consumer of the W3DS. Acclaiming that, there should be a large overlapping in the WPVS and W3DS service interfaces.

A major difference between WPVS and W3DS is in the application of optimization strategies for rendering. The W3DS rendering client can implement strategies such as culling, caching, and level-of-detail mechanisms and can take advantage of the navigation and interaction state. In contrast, the WPVS is stateless and does not provide any session management functionality. Thus, the WPVS rendering system can not make any assumptions about the data to load and render. In worst case, an underlying (naive) rendering system would have to load and render different data for each single WPVS GetView request.

3 WPVS Extension Requirements

3.1 Relevant 3D Portrayal Functionalities

The functionalities of a 3D portrayal system (WPVS, W3DS) can be grouped according to the following functional dimensions:

- *Information*, which is included within and represented by the generated visualization. An essential part of this information are, e.g., images of the 3DGeoVE. The WPVS arranges information content by layers, which must be chosen by the WPVS consumer for being included in the finally rendered image. Beyond the portrayal of real world geometry, additional spatial and non-spatial (but georeferenced) geodata could be included in the visualization. Fig. 1 shows an example of a 3DGeoVE including plat information. Even non-visual visualizations could be integrated, e.g., sounds emphasizing the characteristics of a scene.

- *Styling* comprises the information aiming at influencing the visual appearance of the rendered images. On a technical level, it describes the mapping of geoinformation to computer graphical elements, regarding visual variables such as shape, size, orientation, color, and texture. For example, the OGC defines the SE styling specification, which can be applied, e.g., with a WMS request. For 3D portrayal

Table 3: WPVS operations grouped by their main type of 3D portrayal functionality.

Type	Functionality	Scenarios[a]
Information	Show the surrounding of a site	2.1
	Visualize underground geodata	1.6
	Generate a video tour passing specific locations	5.4
	Create a set of views along a path	6.1
	Retrieve additional information for a scene object.	1.1, 1.4
	Enrich the scene by further scene objects	4.2, 4.3
	Calculate and display the visibility of objects	3.5
	Inspect the inside of objects	3.4, 4.3
	Measure distances and size	2.3
Styling	Color scene objects according to attribute values	2.2, 3.2
	Use a styling tool for defining the scene appearance	5.2
Interaction	Select a scene object by picking	1.1, 1.2, 1.4, 1.5
	Annotate scene objects by text or sketch	1.2, 1.5
	Use specific interactions for information retrieval	3.3
	Use 3D portrayal on mobile devices	4.1
	Use 3D portrayal in a web browser	5.1

[a]Numbering according to the scenarios in appendix A.

no styling specifications exist, yet. Recently, Neubauer and Zipf [9] developed a 3D extension for SLD and introduced this to the OGC specification process.

- *Interaction* is the user-centered process of operating the information system, e.g., changing the general information content, investigating the scene by navigation, and investing scene objects by retrieving specific information.

A specific portrayal functionality may not only regard a single dimension, but is positioned in the functional space set up by these dimensions. E.g., retrieving information about a specific building means to interact with the scene (or it's image, e.g., by picking a building and choosing the interesting information) and to visualize the retrieved information according to a specified styling description.

3D portrayal plays a role in various application domains and within those in various application scenarios. As a basis for specifying 3D portrayal capabilities within the OGC standardization process, [8] lists selected scenarios in several application domains, e.g., in the field of civil service, business development, and tourism. Appendix A lists these application scenarios in more detail. The list is not complete but gives an idea of what might be possible by the help of 3D portrayal services.

Table 3 groups the functionalities, which can be derived from these application scenarios. The functionalities are often relevant in more than one application domain and slightly overlap.

3.2 General Requirements for WPVS-Based Portrayal

According to the 3D portrayal model, the separation of concerns is important when extending the WPVS. The following general requirements for 3D portrayal basing on server-side rendering could be formulated.

- *Support simple clients:* The main benefit of server-side rendering is to omit client-side rendering capabilities, e.g., high-end graphics hardware. The client must be able to easily request a 3D portrayal service and to use the generated visualization.

- *Provide high quality visualizations:* Even with simple clients, the visualizations should be of high quality. This could mean to retrieve aesthetic images of appropriate resolution from the portrayal service and to interact in a smart and effective manner for exploring the 3DGeoVE.

- *Keep service interface simple:* For allowing for the easy use of the portrayal service, the service interface should be kept simple. So it should contain a little number of parameters or, at least, provide default values. This would lead to an easy integration within applications and systems for supporting workflows.

- *Keep transmission load low:* For retrieving a specific functionality, the number of service requests should be small. Additionally, the used bandwidth should be kept low. E.g., rendered images should be provided in appropriate resolutions and size.

- *Support user assistance:* Smart user interfaces allow for easy use of the 3D portrayal. User interface functionality should be simple, obvious, familiar, safe. Intelligent clients and smart client-server interaction strategies could reduce the time needed for achieving a specific goal, and also reduce rendering load and bandwidth usage.

3.3 Limitations of the WPVS

The interaction capabilities of the WPVS are restricted to the generation of perspective views. In particular, it does not provide advanced interaction capabilities or information retrieval beyond RGB images.

Further on, the WPVS does not address efficient and goal-oriented navigation (including wayfinding and motion) and supports only a point of interest (POI)-based camera specification: the camera position is described by polar coordinates relative to a geospatial position, the POI. Consumer-side service proxies (e.g., the WPVS application client) are in charge of providing appropriate navigation functionalities and map those to the camera configuration.

The WPVS GetView request defines a SLD parameter which is intended to reference or contain a styled layer description. As far as we know, there is no WPVS implementation which takes advantage of this parameter. Furthermore, the current SLD/SE specification does not allow for styling three-dimensional features.

4 Suggestions for Extending the WPVS

4.1 Enhanced Styling for 3D Portrayal and WPVS

A specific visual appearance of the portrayal output is achieved by styling functionality. As described above, the OGC styling specifications, SLD and SE, do not consider the styling of three-dimensional features. Neubauer et al. [9] extended the SE for 3D styling and implemented it for a W3DS. These additions extend the existing SE symbolizers (point, line, polygon), add symbolizers for solids and surfaces, include external 3D objects, support billboards, lines as cylinders, introduce material descriptions and different local shading models, and support rotations. A W3DS user can edit a styling description and use this with requesting a scene from the W3DS. This styling information is used for generating the scene graph representation which is returned to the requester (e.g., as VRML or X3D structure). The complex rendering client uses this information for synthesizing the images.

Beyond these extended SE styling capabilities, it is up to the rendering client to implement and provide additional rendering techniques and effects. Table 4 lists several rendering techniques, which are relevant for 3DGeoVEs and would have to be implemented and provided by the WPVS. For requesting these appearances, additional and more abstract styling definitions than those in the planned SE extension are required (e.g., for describing solar altitude or cloudiness).

4.2 Cartographic Geovisualizations

Cartography deals with the mapping of real world features onto graphical representations considering specific users, specific purposes, a required map scale, or limited space of the presentation media. It mainly aims at the production of highly legible and effective maps.

Generalization represent the main cartographic method for reaching this aim. It comprises several generalization operations such as selection, simplification, combination, enhancement. Graphically, these techniques, e.g., influence the shape and geometric complexity of a geographic feature representation, its position, its size, as

Figure 4: Examples for rendering styles and effects relevant for 3DGeoVE: ambient occlusion simulating daylight (left) and sun, clouds, atmospheric effects, and water shading (right).

Table 4: Advanced rendering techniques for 3D geovirtual environments.

Rendering Styles & Techniques	Description
Global illumination	Rendering techniques which produce a more natural lighting regarding scene objects interferences. Additionally, it helps to interpret and understand the image.
Water rendering	Using environment mapping, water surfaces mirror the surrounding features or sky. Waves on the water can make the image more authentic.
Sun and cloud rendering	Sun and cloud do not only support the authenticity of a generated image but can also transfer additional relevant information such as weather conditions or day time.
Depth of field	Before and behind a specific depth range, the scene objects get blurred. The sharp scene objects get more focused.
Focus & context lenses	Within a virtual lense area (the focus area), specific information are displayed, e.g., geo-referenced thematic information such as geological data.
NPR rendering	Non-photorealistic rendering is the stylization of the appearance of scene objects within the 3DGeoVE. It can include, e.g., color quantization and edge enhancement. So, NPR can provide facade generalization and can support information communication.

well as it color or texture.

In general, cartographic principles and methods also apply for 3D perspective visualizations. In particular, 3D visualizations mostly contain different scale levels, which is different from 2D maps: in a perspective view, scene part close to the virtual camera have a larger scale than those that are far away. Without an appropriate generalization techniques, these far away scene parts appear as pixel mush and, thus, lack legibility.

Further on, in 3D perspective views, vertical surfaces become visible and provide essential information, which is not the case in 2D maps. For example, a building facade could hint on the type, usage, age, or state of the building; windows and doors could serve as scale defining elements indicating the building size. In 3D virtual environments, these surface information are often given by textures, recorded, e.g., by aerial photography. Non-photorealistic rendering could be applied for the generalization of these textures, as it could reduce the overall texture information, but emphasize the relevant features of a texture, and improve the legibility. Fig. 5 illustrates the examples of geometric generalization and texture simplification for 3D city models.

For the WPVS the consideration of cartographic visualization would mean to allow the service requester to directly specify the visual appearance of the generated image of the perspective view or to indirectly specify the appearance by describing the re-

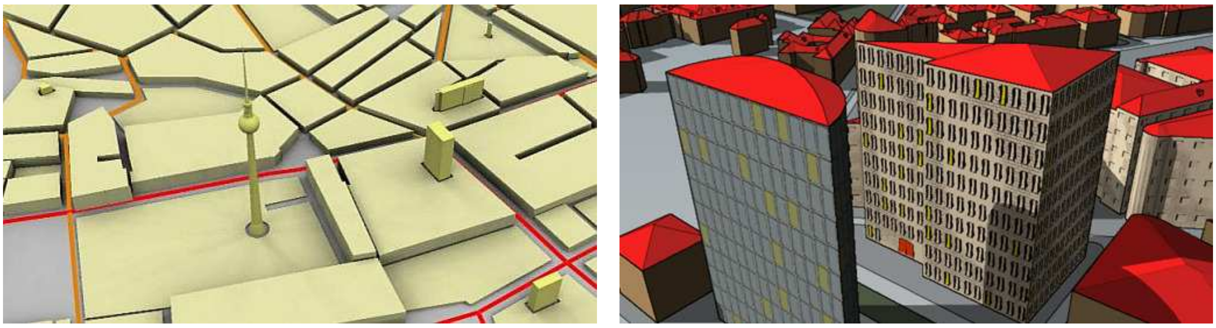

Figure 5: Geometrical generalization (left [4]) and texture generalization (right [3]) for a virtual 3D city model.

quirements of the generated map, which then has to be evaluated by the WPVS for deriving appropriate scale levels and accessing or generating appropriate generalized data.

4.3 3D Annotations

The annotation of a 3DGeoVE by text or symbols is an important aspect. It allows, e.g., for the integration of meta information or comments. To ensure high legibility, annotations have to be embedded such that they avoid occlusions among themselves and with geospatial objects of the scene. As described in [7] annotations can be integrated within the rendering process by providing a so-called depth image by WPVS additionally to the RGB image. Together with the camera information it serves as input for a processing service producing annotated images by synthesizing an annotation image and blending this with the WPVS produced RGB image.

4.4 Object Information

The WPVS could also support emphasizing and accessing object information that can not be directly descried from the common object visualization (in photorealistic or non-photorealistic style). This additional information could include general information (e.g., object categories, identifiers, or names) as well as domain-specific information (e.g., building height, floor space ration, or other BIM-related data). The representation of this information could be either dedicated to the user or could be evaluated and facilitated by a client application. This functionality corresponds to the *GetGeature* operation of the WMS, which allows for retrieving additional object information of features visible in a 2D map.

4.5 Analysis Functionality

The WPVS could provide simple *measuring functionalities*, which could be, e.g., measuring an area or measuring distances of a point to camera or between several points in the image. This requires interaction capabilities of the WPVS, which had to process

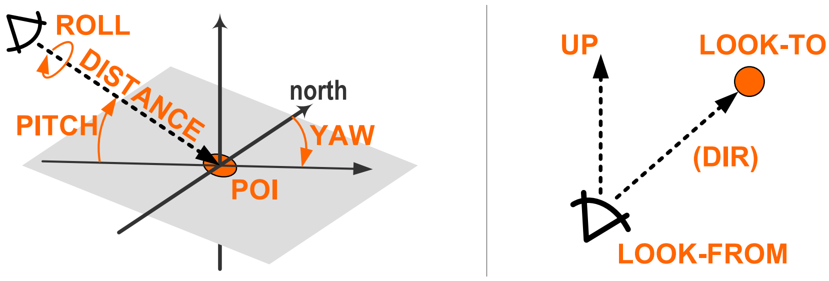

Figure 6: WPVS camera definition. Current POI-based description (left) and convenient camera-centered version (right).

picked points or sketched paths by projecting them into the 3D scene ans use this as input for analysis functionalities. *Information lenses* represent an other category of analysis functionality which permits the integration and combination of different information layers; the user would, e.g., move the mouse and retrieve thematic data for a specified region within the image. Information lenses could be implemented by client-side blending of different information layers; considering depth information would allow for perspective lenses.

4.6 Convenient Camera Specifications

Positioning the virtual camera is an essential part of the WPVS GetView operation. A WPVS implementation has to transform this information into the internally used camera specification and derive orientation and projection matrices for synthesizing the images. The WPVS supports a POI-based camera definition: a POI defines the camera look-to and the camera position is given relative to the POI by polar coordinates, distance of the camera, role angle, and angle of view (AOV) centered at the POI – see Fig. 6 left. The POI is defined in a specific coordinate reference system. This POI-based camera definition is useful for a POI-based navigation, i.e., to look to some specific locations.

Several use cases conceptually deal with a camera-based view definition. They require, e.g., to define the camera position, the gaze direction or look-to position, and the camera up vector – see Fig. 6 right. Complementing the camera definition by a camera-oriented variant would make the WPVS usage more convenient for ad hoc usage and integration: E.g., a user retrieved geocoordinates of two specific addresses and could use them as input for a WPVS request without additional calculation. On the one side, this conversion could be encapsulated by the WPVS client, on the other side, the WPVS itself could provide an additional camera definition method.

4.7 Smart Navigation

The general navigation capabilities of the WPVS allow consumers to explore the 3DGeoVE and to retrieve the contained information. So far the WPVS does not explicitly address navigation support. The only way to explore the 3DGeoVE is the modification of the camera parameters. On top of this, a client has to install more high-level navigation functionalities, e.g., moving forward, backward, up down, etc.

Including smart navigation techniques as described in [6] could be a promising approach for using the image itself as a navigation interface. Curves and points sketched on the image are sent to the WPVS, which projects these sketches into the 3D scene for determining navigation intentions and either generates a video or a set of images representing the navigation. This navigation technique is user-oriented and is applicable to all touch-sensitive devices, such as PDAs or smartboards. For the integration of sketch-based navigation, the WPVS would have to be extended by a navigation subsystem and operations for requesting a sequence of views are required.

4.8 Single Object Inspection

Besides the visualization of regional 3D landscape and city models, a WPVS profile could facilitate the visualization and inspection of specific features. [5] For example, for building models a specific WPVS instance could integrate the calculation of appealing camera views including filtering and styling capabilities for allowing for gaining insight into the building, e.g., by using techniques such as 3D cut-away-views.

5 Conclusion and Future Work

For enabling interoperable 3D portrayal within 3D spatial data infrastructures, we participate in an OGC initiative for specifying a 3D portrayal standards family. One of the service candidates is the WPVS, which is an OGC draft specification. As a contribution to the OGC 3D portrayal initiative, we revise and suggest additions to the current WPVS specification. The WPVS is limited in visualization, interaction, and navigation capabilities and could be extended in these aspects. This technical report represents a first step towards an extended WPVS. It describes the functional and non-functional context for extending the WPVS and suggests a next version WPVS. These suggestions need to be further formalized; the WPVS service interface must be extended. These extensions could be implemented by introducing new service operations (e.g., for retrieving depth images) or by add parameters to the existing operations(e.g., extending the camera description). Furthermore, for evaluation purposes, a prototypic implementation of the proposed WPVS extensions is planned.

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A Application Scenarios for 3D Portrayal

Table 5: Scenarios for the application of 3D Portrayal Services (from [8]).

1.	**Civil Service**
1.1	**Use a 3D view for processing a building application** A civil service agent can generate a perspective view for a specific address for getting an idea of the current building situation around that address. By picking buildings in the image further building information are displayed.
1.2	**Use perspective views as interface for notifications of claim** A citizen can generate a perspective view for a specific address, can navigate for defining a specific view, can pick a position in that image, and can leave a notification of claim, e.g., about an out-of-order fire hydrant.
1.3	**Show a city planning to the public** For public participation, the municipality of a city can make a city planning available to the public by 3D portrayal services. Via web portal, citizens can view this planning, select and investigate planning alternatives. Either interesting views are offered, or the users can navigate freely.
1.4	**Access city planning data easily** By picking at interesting parts of the perspective view, citizens can request relevant city planning data, e.g., planned size of buildings, planned usage, etc.
1.5	**Allow for commenting a city planning** Citizens can comment a city planning by annotating a specific perspective view by text or even drawing or by selecting and annotating a specific position or object in the view.
1.6	**Inspect underground infrastructure** Engineers and department heads responsible for the maintenance of telecommunication or power cables, sewers, gas pipes, or fresh water pipes can inspect the current situation underground. When a new subways line is planned, the underground infrastructure must be analyzed and checked for conflicts.
2.	**Business Development**
2.1	**Present an urban space to an investor** For attracting an investor, a 3D city model can help to investigate interesting urban spaces. It shows the general surrounding, transportation infrastructure, etc. This reduces the number of on-site inspections and, thus, saves time and money.
2.2	**Color buildings according to their usage** For judging the surrounding of an object of interest, the agent defines to color the buildings in the perspective view according to their usage type, e.g., living space in green, public buildings in blue, and industrial buildings in red.
2.3	**Measure distances and areas** The perspective view can support simple analysis functionality. E.g., distances to nearby building areas or the overall size of a specific area could be calculated and displayed.
3.	**Real Estate Business**
3.1	**Offering interesting buildings to a customer** An estate agent can use the 3D portrayal services for showing buildings to customers. The perspective views show the appearance of the building, including detailed building structures (doors, windows, balconies, etc.) and real facades. Furthermore the agent can show, describe, and investigate the urban surrounding of these buildings to the potential buyer by help of specific navigation techniques supported by the client application.
3.2	**Highlight buildings to sell** Within an interesting building area, the estate agent can influence the visual appearance of buildings that can be rent or bought. He selects some buildings by their address and others by their owner and defines which color to use for their representation. Furthermore he highlights all nearby public buildings in a different color.
3.3	**Access BIM information easily** For all the buildings in the view, the agent can request additional BIM information such as the age of the building, usage, number of rooms, room sizes, its renovation state, land parcel information, etc. This is done by easily picking the object of interest in the image.
3.4	**Allow for looking inside buildings** Within a city model the agent can select a single building of interest and request a building-specific visualization which allows, for looking into the building and, e.g., see the structure of the rooms at each floor.
3.5	**Calculate and display the visibility of objects**

	For installing a hotel, an investor looks for a building with a good view, i.e., from where a set of relevant points of interests (e.g., church, market place, monuments, palace garden, etc.) have a high visibility. The system allows the agent to define the points of interest and the area in which to search for suitable buildings. Then, the system calculates the visibility of these POIs for each building, maps this information to the building faades, and generates new perspective views.
4.	**Security and Safety**
4.1	**Introduce an operational area to a mobile action force** In preparation for safeguarding a demonstration, action forces need to get an overview of the operation area, including size and topology of street, danger spots, etc. The presentation of the city by 3D portrayal can replace on-site inspections, and thereby reduce cost. If necessary, perspective views can be accessed by mobile devices.
4.2	**Generate views containing escape routes** For a mass event, escape routes have to be defined and must be visualized to the security personnel as well as to the visitors. By help of a styling tool, the safety officer can enrich a perspective view of that area by additional path objects representing these escape routes. This styling description is then published and used by end users.
4.3	**Support Fire Fighters** The fire department requests a detailed indoor building model in case of a fire incident. The 3D indoor model is analyzed in the command center before the fire fighters reach the site. Possibly the visibility in the building is limited due to the smoke. Possible access and escape routes are determined to help the fire fighter evacuating the building.
5.	**Tourism**
5.1	**Investigate a vacation spot** A tourist can use web-based 3D portrayal for investigating a vacation spot already from home. For example, this could support the decision for a specific accommodation according to the appearance of the surrounding.
5.2	**Generate a specific touristic 3D city map** For a city tour, a tourist needs specific information such as the location of bus stops, railway stations, hotels, museums, theaters, hotels, bars, restaurants, the tourist information, etc. By an authoring tool, a municipality clerk can create a specific touristic 3D city map containing this information. A styling tool allows him to define how the integrated information shall be represented.
5.3	**Show the current environmental situation** For making a virtual city model more appealing and more realistic, they can include sun and clouds, which could be in accordance with the real weather conditions.
5.4	**Generate a video tour negotiating selected points of interest** For tourists a virtual city tour can give an impression about important points of interest, shopping facilities, etc. By an authoring tool a municipality clerk can define such points of interests, which are used as way points for the virtual tour. The tourist can select some or all of these way points for generating an individual video tour, e.g., a flight or a city walk.
6.	**Car and Pedestrian Navigation**
6.1	**Illustrate a track by sequences of perspective views** For illustrating a path description, perspective views along that path can be generated. Even the individual path can be embedded into the visualization. The path illustrations can be derived automatically from the defined path.
6.2	**Guide vehicles and pedestrians on the road.** Mobile users are supported by providing 3D animations or interactive visualizations of the course of the route, which has been calculated by an OpenLS route Service. 3D Visualizations are especially useful for pedestrians using their PDAs, since they can get a better idea of where to go if the system contains also landmarks.