

Implementing 3D Geovisualization in Spatial Data Infrastructures: The Pros and Cons of 3D Portrayal Services

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Abstract

Visual representations of geospatial information proved to be valuable means to facilitate thinking, understanding, and knowledge construction about human and physical environments, at geographic scales of measurement. Massive amounts of distributed and heterogeneous geospatial information and geospatial computing functionality are increasingly available as distributed resources that can be accessed through the Internet. This increased availability has created the demand and feasibility to build distributed systems that leverage these resources for visualizing and interacting with geospatial information. For the implementation of such distributed systems, the application of the architectural concept *service-oriented architecture* (SOA) and OGC standards are commonly proposed. The primary potential of the application of the SOA paradigm in the geospatial domain is that it supports the uniform access, exploitation, integration, and reuse of distributed geodata and geospatial functionality. The application of the SOA paradigm for designing geovisualization systems implies the functional decomposition of the geovisualization process into reusable services accessible through a network. The OGC has approved various standards for service interfaces, data models, and data encodings in the geospatial domain. For the presentation of information to humans, the OGC proposes portrayal services. For 2D portrayal the web map service (WMS) is proposed as an approved standard, whereas for 3D portrayal the web 3D service (W3DS) and the web perspective view service (WPVS) are proposed as different approaches that are both still in the early stages of the standardization process.

In this paper, we characterize, discuss, and compare the WMS, W3DS, and WPVS portrayal services as proposed by the OGC with a particular focus on 3D portrayal. We discuss the potentials and limitations of the different approaches and the conditions under which they can be applied in an effective and value adding way. With this contribution, we aim at supporting decision makers in choosing portrayal services meeting their requirements for spatial data infrastructures (SDI), the present process of standardizing 3D portrayal services and related research.

First, we investigate characteristics of geodata as input for the geovisualization process using the example of virtual 3D city models. Models of this class are digital, georeferenced representations of spatial objects, structures, and phenomena of urban areas, which are increasingly built and leveraged in various application areas such as urban planning, environmental management, and tourism. Visualizing virtual 3D city models is a highly relevant functionality of respective SDIs, which poses high requirements on the involved computer systems. We illustrate the inherent complexity of virtual 3D city models by calculating the storage requirements for a city model of Berlin consisting of aerial images, digital terrain models, building models in different levels of detail including facade textures, city furniture objects, and vegetation models.

Second, we present the fundamental possibilities to decompose functionally the geovisualization process in a SOA that are eventually reflected in the designs of the portrayal services of the OGC. In order to combine SOA concepts, geovisualization concepts, and OGC standards in a common conceptual frame of reference, we present an architectural framework that organizes and relates the aforementioned concepts. In this framework, we relate the software layers of the SOA reference architecture to the selection, mapping, and rendering stages of the visualization pipeline and relate OGC standards to the layers and stages. Concrete portrayal services differ in which visualization stages they

implement to what extend and if they either contain the geodata that is to be visualized or accept it as separate input. For example, the WPVS implements all stages of the visualization pipeline and is capable of generating an image of a 3D scene from a subset of its locally contained geodata as requested by a client. On the other hand, the W3DS implements only the selection and mapping stages and is capable of generating a scene graph subset of its contained geodata as requested by a client. This scene graph represents a computer graphical description of a scene and has to be rendered by the client. Moreover, we introduce the WPVS-SLD and W3DS-SLD services as variations of the respective services by adopting corresponding concepts from the WMS. These services implement at most one respective stage and do not contain geodata.

In the main part of the paper, we systematically discuss and compare the 3D portrayal services WPVS, WPVS-SLD, W3DS, and W3DS-SLD. The absence of dedicated portrayal services would imply that a client would have to implement all stages of the visualization pipeline itself. However, this would hinder the exploitation of the full potential of service-oriented geovisualization, in particular reusing, composing, and uniformly accessing services as the fundamental building blocks of a SOA. Similarly, applying WPVS-SLD or W3DS-SLD instead of WPVS or W3DS does not exploit the full potential because these services can still be decomposed into reusable functional services that are composable on the service level. Nevertheless, applying these services can be adequate, e.g., when migrating existent systems and making their functionality available as services or when the additional network communication overhead incurred by the decomposition into a larger number of services is not acceptable.

We analyze and compare the 3D portrayal services in detail along the dimensions visual quality, client-side characteristics, network communication, server-side characteristics, and geodata and content aspects and summarize some of the results in the following. WPVS-based portrayal offers the potential of generating visual representations of higher general quality since W3DS-based portrayal is restricted by the limiting capabilities of the rendering client and the scene graph description employed by the W3DS (e.g., VRML). When employing WPVS-based portrayal, the complexity of integrating the visualization into existing processes is low, the degree of interaction is low, the requirements on software development, software installation, hardware resources, and administration and maintenance are low. On the other hand, when employing W3DS-based portrayal, the complexity of process integration and the demand on required hardware resources are medium, the degree of interaction is high and the efforts on software development, software installation, and administration and maintenance are high. The transmission load between the portrayal service and the client is low when employing WPVS-based portrayal and high when employing W3DS-based portrayal. On the server-side, demands on software development and required hardware resources are worse when using a WPVS than when using a W3DS. Regarding geodata and content aspects, the potential for geodata integration is high when employing W3DS-SLD or WPVS-SLD, medium when employing W3DS and low when employing WPVS. Support for updating geodata is high when using W3DS-SLD or WPVS-SLD and low when using W3DS or WPVS. We rate access control and accounting possibilities equally high for all service types whereas we rate licensing and privacy potential low for W3DS and W3DS-SLD and high for WPVS and WPVS-SLD.

Finally, we summarize the strengths and weaknesses of the discussed services. We illustrate the utility of each portrayal service for different application scenarios, using the already introduced hypothetical virtual 3D city model of Berlin to estimate performance and usability. Moreover, we briefly discuss a selection of current limitations and issues of the portrayal services that should be covered by future research and within the standardization process.