Service-Driven 3D Atlas Cartography

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Abstract. The field of web cartography, and thus of web atlases, has been growing and changing fast due to the democratization of the digital media, the world wide web and finally the 3D technologies. In this article, we will discuss the advantages and challenges that arise with the use of service-oriented architectures and 3D visualization for web atlases. A literature and technology review will allow to define requirements for service-driven 3D atlases. Then, we will test a prototype against these requirements to assess strengths and weaknesses of available solutions. Finally, we will offer concluding remarks and further directions of development.

Keywords: Atlas, 3D Visualization, Service-Oriented Architecture

1. Introduction

Digital atlases are powerful tools to display and explore geospatial data in interactive and dynamic ways and thus they should take advantages of the newest development in the fields of online visualization and web services. Because the general public has now also access to 3D technologies and portrayal techniques, 3D geovisualization solutions for atlas should also be developed. The availability of 3D web atlases could allow interaction with spatial data like never before, but developments are still needed to reach a fully interactive 3D web atlas. However, the belief that 3D visualization of landscape and other spatial information may be more intuitive and simpler to understand for non-experts (Bleisch & Dykes 2006, Meng 2003, Rase 2003, St. John et al. 2001) and the possibility of delivering spatial information over the internet to a greater number of users are strong incentives to go towards service-driven 3D atlases.

2. Core Concepts

2.1. Atlases

The definition of atlases has been evolving with time and available technologies. The earlier and general definition of the 18th century stated that atlases were collections of maps with a specific purpose and organized in the form of a book with tables, graphs and text (Ramos & Cartwright 2006). That definition reached its limits with the emergence of digital atlases and computer science and the modern definition became more flexible regarding the organization, the spatial extent and the content of atlases. However, atlases should not only be a mere collection of geoinformation, but they should present cartographically well-designed maps that underline the features displayed and offer exploration possibilities (Sieber et al. 2011).

2.2. 3D Visualization

In the framework of this article, 3D visualization is understood as 3D perspective views on a 2D surface (e.g. a computer screen), but that the viewers perceive as 3D. The main characteristics of 3D atlases are the changing spatial viewpoint (3D navigation) and the three-dimensional topographic view or statistical representation (Persson et al. 2006).

The general discussion about the advantages of 3D visualization over 2D visualization is still under debate. Nonetheless, a consensus emerged about the fact that the advantages brought by 3D visualization mostly depend on the task at hand.

The naturalistic display of 3D representations supposedly help the non-experts to better understand 3D views because of its similarity to the real world (Beard et al. 2005, Bleisch & Dykes 2006, Rase 2003). The cognitive process is simplified because the third dimension does not need to be interpreted from 2D representations (e.g. isolines) and thus “the cognitive distance” is smaller (Meng 2003, Rase 2003). It is also stated that 3D visualization may have an upper hand regarding shape understanding and orientation tasks. It seems to be especially useful for the qualitative understanding and surveying of space, as well as for approximate navigation (Bleisch & Dykes 2006, Bleisch & Nebiker 2008, St. John et al. 2001, Tory et al. 2006). However, it appeared that users have difficulties to accurately interpret variations in the landscape, for instance slope or exposition, partially due to the fact the 3D space is not linearly distorted. Thus, it renders tasks requiring relative positioning and location of several objects more complicated (Bleisch & Nebiker 2008, St. John et al. 2001).

2.3. Service-Oriented Architecture

A Service-Oriented Architecture (SOA) combines loosely interacting software components delivering services. Those are modular and interoperable units that allow to access, manage, process, combine and visualize heterogeneous, complex, and vast geoinformation sources (Hildebrandt 2008). These components are also called web services and use the concept of request-response between a client and a server. SOA allows to use a thin client that only has to display the image, while the three other stages of the visualization pipeline (data selection, elements generation, image rendering) are carried out on the server side (Hagedorn 2010). A thin client enables an easy access to 3D geodata by bypassing issues about interoperability, computing resources for rendering or memory for storage that could arise on the client side. These web services can be either chained (different tasks are needed to provide the end result) or combined (integration of geodata from different sources).

3. Technology Review

3.1. Graphic Formats

There exist different formats for online graphic data, and specifically for 3D geodata. This section assesses some of their strengths and weaknesses.

X3D (successor of VRML and ISO standard) developed by the Web 3D Consortium can be parsed by many open source platforms, which makes X3D a good candidate for interoperable solution, however a plugin is necessary.

WebGL[1] (open standard), which is the equivalent of OpenGL ES for browser, allows for interactive 3D graphics using the HTML5 canvas element. Due to the limitation of vertices number, only small models can be displayed at high resolution. Thus, it makes WebGL ideal for block diagrams, as they have limited extent.

KML[2] (OGC standard) supports georeferenced annotations and visualization for mobile maps and virtual globes. Many open source virtual globes can accept KML as input.

GML[3] (OGC and ISO standard) and *CityGML* (OGC standard) provide an XML-based modeling language for geographic features. They can be used to retrieve features through web services, as they can be transferred as text.

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[1] Web Graphics Library

[2] Keyhole Markup Language

Flash (proprietary format) is widely used, but restricted to 2D content and might require a plugin.

SVG[4] (open format) is an XML-based format for 2D and pseudo-3D graphics and supports foreign objects such as raster image and html. It is accessible by DOM, allows for interactivity with JavaScript and is WMS compliant. It is a good candidate for a Graphic User Interface.

X3DOM (framework under discussion) aims at integrating X3D within HTML5 by rendering a 3D model within an HTML5 page using WebGL and without any plugin.

Collada (open standard) is an XML-schema used to transfer 3D objects between applications with incompatible proprietary formats. Many 3D programs can read and write as well as render Collada objects.

3.2. Web Services

Web services are the base components used to build SOA and thus there exist many various services providing different tasks. This section will focus on the Web Services oriented towards visualization and less towards data recovery.

One of the most widely used is the *Web Map Service* (WMS), which dynamically provides the client with 2D maps in an image format from geographic information, both raster and vector (Open Geospatial Consortium 2006). All browsers can read .jpeg and .png format and image files usually have reasonable size. However this service provides only a view of the data and not the data themselves.

Regarding 3D data and visualization, there has been a succession of web services trying to provide something similar to what is available for 2D with the OGC web services. First, the *Web Terrain Service (WTS)* aimed at offering a standard for 3D scenes, when it appears the WMS could not just be modified for 3D. It never reached the standard level, but was the base on which the *Web Perspective View Service (WPVS)* was developed. The WPVS only transfers image, as the WMS, and thus requires little data transfer too. However, the OGC decided that its drawbacks regarding navigation and feature information query were too important and they started to develop a more comprehensive standard for 3D portrayal under the name of *Web View Service (WVS)*. It became an OGC Discussion Paper in 2010 and is the latest candidate for an OGC 3D web service. It provides with a por-

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[3] Geographic Markup Language

[4] Scalable Vector Graphics

trayal service for 3D geodata, mainly by delivering 2D images displaying 3D scenes (Hagedorn 2010). The servers render the scenes from 3D geodata on the fly. Additionally to this image-based approach, it now also supports analysis, navigation and information retrieval while still allowing for a thin client – thick sever architecture. In parallel a *WVPS++* was develop by the Hasso Plattner Institute, where the thematic information were as well encoded in an image format. Parameters were added to enable more complex handling of projection and navigation (Hagedorn et al. 2010).

In parallel, a *Web 3D Service (W3DS)* standard is being developed for the retrieval of 3D geodata as scenes. Because the rendering happens on the client side, it requires a medium client scenario as well as a plugin and additional bandwidth compare to a WVS (Schilling & Kolbe 2010).

4. Requirements for Service-Driven 3D Atlases

The following requirements regarding service-driven 3D atlases are based on previous work and literature, as well as on existing digital or web atlas products. There have been two trends of requirements that emerged with the possibility to share geodata on the Internet. First, users ask for the ability to access large amounts of spatial data. Second, they want a decentralized access method so that different users can access the data from different places. Additionally, requirements for the visualization and interactivity within the atlas are crucial.

4.1. System Requirements

Although system requirements are not specific to 3D geovisualization, they are highly pertinent to it. First and foremost, the atlas is based on a *service-oriented architecture (R1*) to allow the visualization of geodata independently from the processing software or capabilities of the client. Additionally, a *thin client* is sufficient and *no plugin (R2)* is required: the visualization happens directly in the browser. The goal is to avoid any compatibility issues between a plugin and a browser or platform. The system should work *independently from the software and platforms of the client (R3)*, allowing to optimize dissemination of the products and to pre-empt compatibility issues (Hildebrandt & Döllner 2010, Hildebrandt et al. 2011).

Interoperability (R4) is an important requirement mentioned in the literature along with *integration*. They are needed to connect computers in an efficient and effective manner on more than one level of abstraction (Brodlie et al. 2007, Hildebrandt & Döllner 2010, Hildebrandt et al. 2011). Interoperability has many advantages, including allowing to build flexible and adapting systems, that can fulfill various objectives (Andrienko et al.

2005) and offering access to different geodata sources in a homogenous way with a single set of processing tools (Altmaier & Kolbe 2003).

Non-functional features are also part of the requirements, especially the support for straightforward *updating, scale-up and extensibility (R5)* on one hand and *reuse and robustness (R6)* on the other. *R5* and *R6* participate to the life span of the product and to the optimization of its use (Hildebrandt & Döllner 2010, Hildebrandt et al. 2011). Furthermore, for flexibility and extensibility reasons, *open sources solutions (R7)* should be favored.

Finally, 3D geovisualization does ask for two more specific requirements: with 3D geodata, it is even more important to be able to support *massive amount of geodata (R8)* as well as *dynamic geodata (R9)*. 3D data are more voluminous and thus the speed of data display and access plays an important role in the ease of use and usefulness of 3D geovisualization applications (Andrienko et al. 2005).

4.2. Visualization Requirements

The *level of abstraction (R10)* at which the systems are built is becoming a relevant requirement, especially regarding productivity (Döllner 2005, Hildebrandt & Döllner 2010). The higher the level, the less details have to be handled and the code becomes thus lighter.

A key requirement for 3D web atlases regards the *quality and effectiveness of the visual representation (R11)*: web services ought to be able to provide visual representations that reach the quality and effectiveness of traditional cartographic products (Hildebrandt et al. 2011, Iosifescu-Enescu 2011). Web services for 2D maps are already able to deliver web maps that are visually as satisfactory and effective as classical map (Ortner 2011), now the same has to be shown for 3D views and 3D objects. Desktop applications can be used as benchmark to test new 3D web cartographic products. Next, in order to allow users to explore not only the landscape but also thematic data, *support for user-defined styling (R12)* should be introduced. It enables the generation of different views from a same dataset, for example by providing color schemes or landscape and atmosphere options to match different weather and time situations. Finally, because 3D geovisualization is more complex to explore, *multiple and coordinated views (R13)* are an important features to help the users break down the complexity of the 3D information and compare different views (Hildebrandt & Döllner 2010).

4.3. Interactivity Requirements

Digital atlases allow getting the most out of geodata by placing a high emphasis on *interactivity and dynamic display (R14)*. Interactive functions can be implemented progressively with the project development. However, some interactive functions are minimum requirements for an atlas to be functional and usable. First, general functions should always be present (Ormeling 1997). Although they can be implemented in different ways, icons and status bars are the most used (Cron 2006). They provide the users with information about the state of the atlas (zoom mode or information mode for instance) and offer access to functions such as quit, print and forward/backward. Second, navigation is essential not only spatially but also thematically: without proper navigation functions to interact with their content, web atlases offer only few advantages.

Because of the 3D nature of the representation and data, an *intuitive and appropriate spatial navigation (R15)* is indispensable. The users expect to be able to manipulate the 3D representation as an object in the real world. The navigation should not require any training and thus be very intuitive. Further, as the atlas grows in complexity, *querying and simple processing (R16)* should be available, for instance data histogram and searching tools.

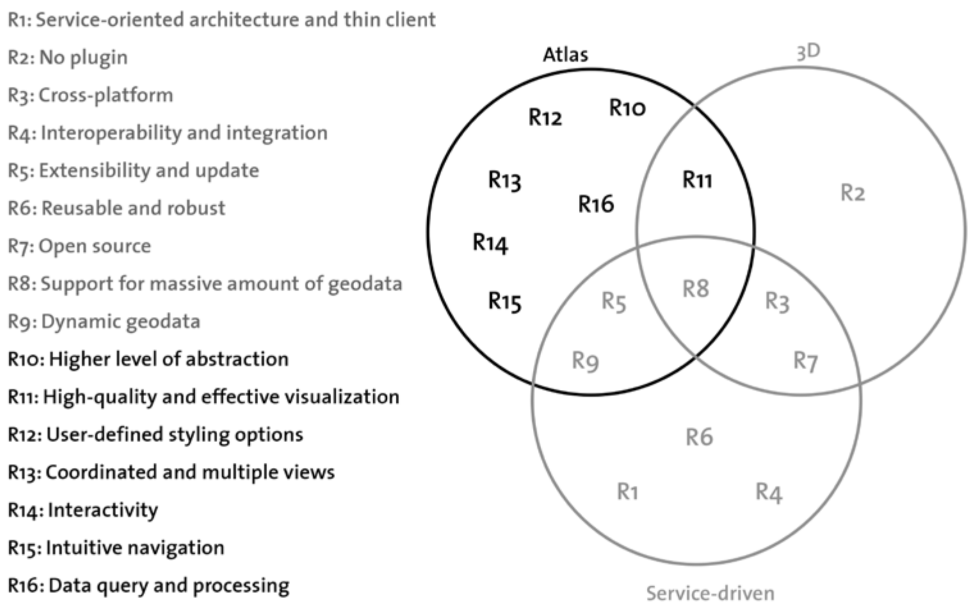

Figure 1. Requirements for service-driven 3D atlases in their field of influence, modified from (Panchaud 2012).

5. Implementation

A prototype offering panorama views and block diagrams based on a SOA has been developed to prove the feasibility of service-driven 3D atlases.

5.1. Architecture

The prototype uses a three-tier architecture to take advantages of web services communicating between a thin client and thick server system.

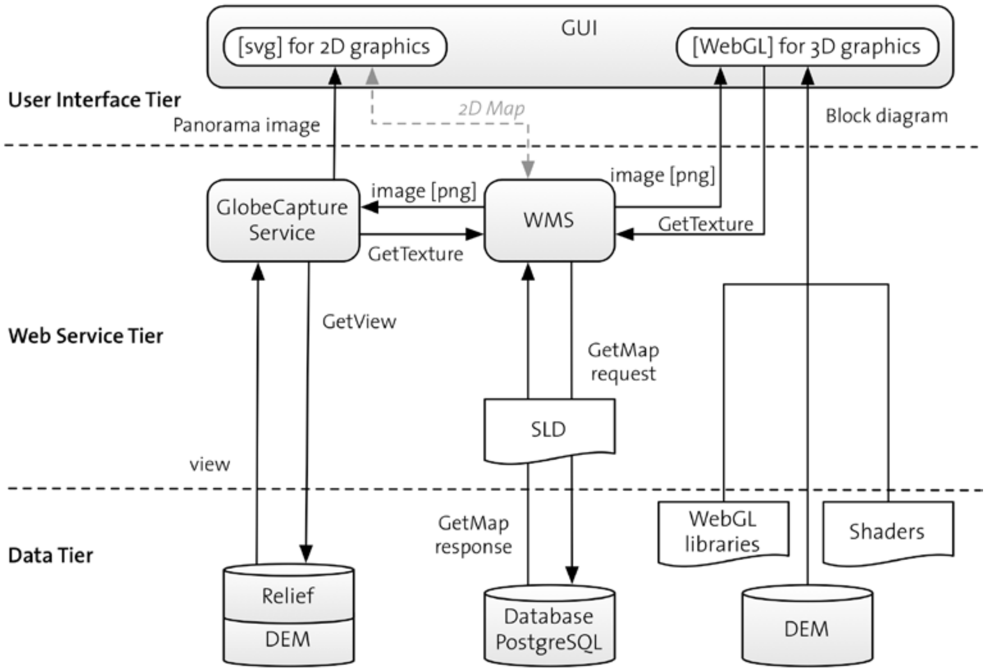

Figure 2. Architecture of the prototype (Panchaud 2012).

The Data Tier comprises the data organized in databases and files. The thematic data and geometries for the WMS are held in a PostGIS database and come from a previous work (Ortner 2011). Another repository contains the shaded-relief files and the DEM that are used for the panorama views. A third server holds the DEM and the WebGL libraries for the block diagram generation. The Web Service Tier regroups two web services. First, the QGIS Server, which is a cartographic WMS, provides the texture for both the panorama views and the block diagrams. It additionally supports cartographic extensions, such as pattern, diagrams and custom SVG symbols (Iosifescu-Enescu 2011, Iosifescu-Enescu et al. 2013).

Second, the Globe Capture Service (GCS), which is a custom 3D web service developed at the IKG[5] for the online version of the Atlas of Switzerland (under development), allows to request perspective views of any point in Switzerland. It requires a DEM to generate the perspective view and then textures to be draped over it. The textures can be predefined images (e.g. grayscale relief as default) or requested from a WMS (e.g. for additional thematic data).

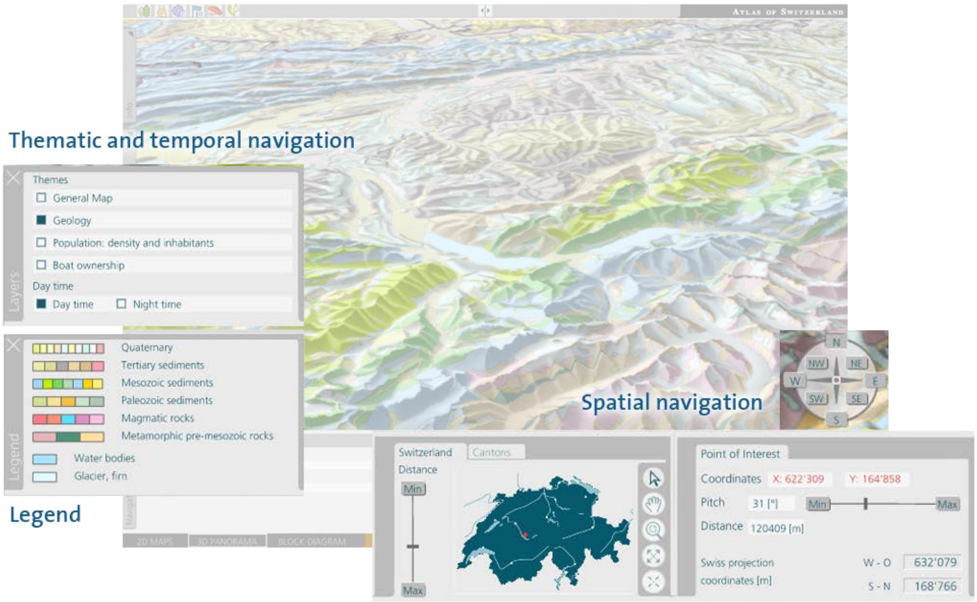

Figure 3. Design of the GUI for the panorama view and its navigational functions (Panchaud 2012).

The User Interface Tier, or Graphic User Interface (GUI), uses SVG and more specifically WebGL for the generation of the block diagrams. A block diagram represents a certain portion of the landscape as a cube that can be rotated. WebGL can request a texture from the WMS using JavaScript. The GUI is based on a previous work (Cron 2006) and its flexibility allows adapting it easily for 3D geovisualization.

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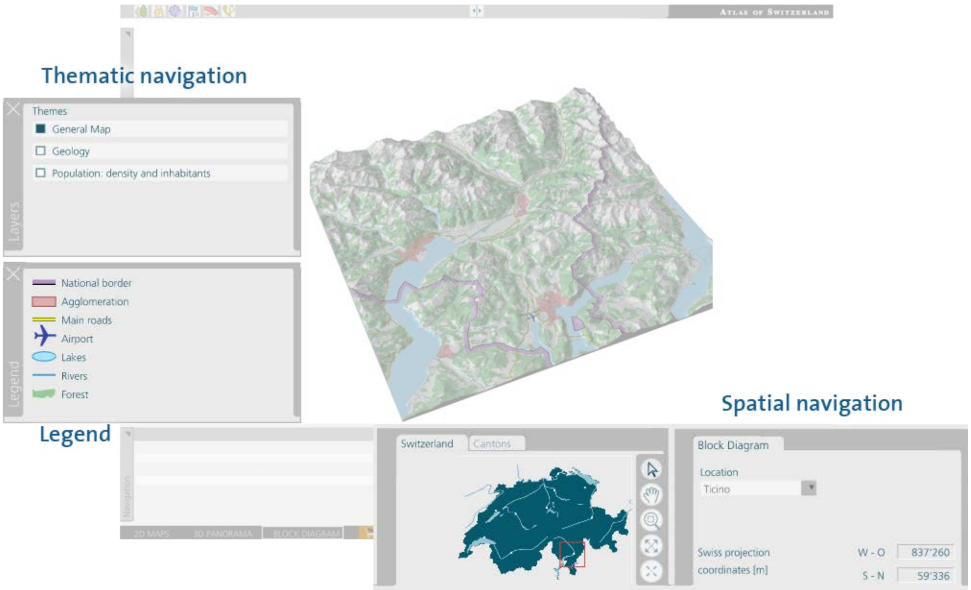

Figure 4. Design of the GUI for the block diagram mode and its navigational functions (Panchaud 2012).

5.2. Strengths and Weaknesses of the 3D Used Technologies

Combining the GCS and the QGIS Server for perspective views has one straightforward advantage: a simple output as an image in .png format. This standard format allows for transparency, is relatively small (considering most screen resolutions are 72 dpi) and is supported by any browser without any plugin. There is no need for processing nor rendering on the client side and thus this combination can be envisaged for mobile devices too. However, the lack of 3D web service standards brings issues regarding interoperability and integration with other systems. The texture provided by the WMS proved to be satisfactory for surface and line symbolization. Any thematic data in relation with the landscape and the slope can be represented, however no studies have been done on the usefulness of representing thematic data such as percentage and rate on a 2.5D or 3D landscape.

A major weakness of the GCS-WMS combination concerns the point symbolization and labeling, because icons, symbols, diagrams, and labels are flattened onto the landscape relief and often distorted or hidden. Additionally, there is no possibility with this combination to have 3D symbols. The prototype has some issues with the integration of scale-dependent symbolization. It should be resolved when a standard is agreed upon, allowing a fully interoperable combination of WMS and a 3D web service.

The combination of WMS and WebGL raises mostly technical issues. WebGL support in popular browsers is not uniform[6] and the rendering can slightly differ. Its integration with SVG is not optimal, as the canvas element does not rescale automatically with the rest of the GUI. There is also a limitation on the number of vertices that can be drawn at once, which means that for high-resolution DEM only a small extent of the landscape can be rendered. This combination has also the same drawback as the first one regarding point and label symbolization. However, WebGL supports 3D objects and symbols that could be used instead. Interactivity and navigation with WebGL and JavaScript has clearly a high potential, for instance tooltips have been implemented in other projects (Birr 2013, IKG 2013). The WebGL & WMS combination is promising regarding the query and processing requirement, because it already uses attributes, which are accessible via JavaScript. However, this has not been tested.

The following table summarizes the strengths and weaknesses of the two combinations, as well as the expected results with a fully standardized WVS-WMS combination.

	GCS & WMS	WebGL & WMS	WVS & WMS
R1: system-oriented architecture and thin client	++	-	+
R2: no plugin	++	++	+
R3: cross-platform	++	--	+
R4: interoperability and integration	--	-	+
R5: extensibility and update	++	-	+
R6: reusable and robust	-	++	+
R7: open source	++	++	+
R8: support for massive amount of geodata	-	--	?
R9: dynamic geodata	++	++	
R10: higher level of abstraction	++	-	
R11: high-quality and effective visualization	-	++	?
R12: user-defined styling options	+	+	+
R13: coordinated and multiple views	+	+	+
R14: interactivity	-	++	?
R15: intuitive navigation	-	++	?
R16: data query and processing	+	+	+

++	tested and working	- -	significant weakness
+	theoretically possible	-	need improvement
?	will depend on the implementation		

Table 1. Assessment of the different requirements for 3D geovisualization systems (Panchaud 2012).

[6] http://caniuse.com/webgl [Accessed on 28.03.013]

6. Conclusion

The prototype demonstrates that the implementation of a service-driven 3D atlas is possible with existing technologies and that this type of atlases can benefit from SOA. However, the lack of standards for 3D web services is a significant obstacle to fully interoperable and cross-platform solutions, resulting in only partially satisfying solutions. For interoperability and performance issues, 3D web atlases require as soon as possible the definition of standards for 3D web services. It should make the chaining and combining of web services easier, allowing to solve other issues regarding not only system requirements, but also visualization and interactivity requirements. These requirements are a first checklist to guide the development of new service-driven 3D geovisualization tools as they point to specific aspects that have to be considered.

6.1. Outlook

Working on the prototype also opened the road for new ideas about the developments that are needed. First, to solve the shortcoming of WMS with point symbolization and labeling, it can be envisaged to create web services that provide either 3D symbols or billboards to symbolize points and labels. By decoupling the symbolization of the texture from the points and labels rendering, a first drawback could be resolved. Second, the development of a DEM web service as input for the block diagram, instead of predefined area, has also to be examined. It would enable the on-demand generation of block diagrams thus increasing the interactivity. Another direction for further development is the use of a request to access attribute values within the 3D scenes, allowing for tool tips and metadata through web services. Additionally, the field of virtual globes needs to be explored to evaluate how they can be combined with the solutions presented in this paper. Finally, there is a need for studies about the usefulness and advantages of visualization of thematic data on a 3D landscape to further demonstrate the need of 3D geovisualization for web atlases.

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