Advances in Web Service-Driven Cartography

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Abstract. Service-driven cartography deals with the development of high-quality interactive cartographic online applications based on an interworking of Web services and Web technologies. The main advantages of service-driven cartography are the creation of Web-based cartographic products with content extracted directly from geospatial databases, the rich cartographic output and the up-to-date visualizations.

In this contribution, after a brief review of the core concepts of service-driven cartography we will focus on recent advances in the field performed by our group. These recent advances demonstrate the applicability of service-driven cartography for the implementation of 2D and 3D atlases.

Keywords: Web Cartography, Service-Driven, Web Services, Atlases, Information Architecture

1. Introduction

In recent years, a major requirement for Web cartography became the production of maps directly from spatial data available in geodatabases and distributed repositories. Furthermore, modern Web cartographic applications and atlases are aiming to integrate in the presented maps all the updates and changes that occur in the spatial data as soon as possible.

The history of cartography recorded several advances, taking cartographic products from hand-drawn maps towards *computer-assisted cartography*, *multimedia and Web cartography* and finally to *service-driven cartography*. These advances induced shifts in the cartographic workflow, from electronically produced printed maps (computer-assisted cartography) to multimedia-based mapping products (multimedia and Web cartography) and nowadays to always up-to-date, service-based geospatial portals (service-driven cartography).

The latest trend towards service-driven cartography is a logical continuation of the widespread use of the World Wide Web, since the Web successfully bypassed existing distribution barriers for cartographic products. The Web offers ubiquitous, continual, convenient and concurrent access to cartographic products from all over the world.

This trend is also visible in the latest developments in Multimedia Atlas Information Systems (MAIS), one of the most representative achievements of multimedia cartography. MAIS are defined as state-of-the-art cartographic applications responsible for visualizing and analysing thematic collections of spatial data (Hurni, 2008). Their distinctive features lie in their high cartographic quality, their user-friendliness and their effectiveness as communication platforms, as they evolved from the need to present geographical information in an interactive, multi-scale manner, unachievable in printed atlases. With the widespread use of the Web, the MAIS seized the opportunity to evolve towards modular Web-based architectures and, as a result, notable national atlases such as the Atlas of Switzerland are in the process of creating Web versions (Sieber et al. 2011).

2. Service-driven Cartography

In Web service-driven cartography, the development of high-quality interactive cartographic online applications is based on an interworking of Web services and Web technologies. Moreover, in service-driven cartography the main architectural style is represented by the Service Oriented Architecture (SOA), which combines loosely-coupled interacting software components that provide services (Alonso et al 2004, Erl 2008). Consequently, services are the central elements in developing Web cartographic products and geoportals.

A *service* is defined as a piece of functionality that is made available by a service provider in order to deliver results to a service consumer, based upon the basic concept of request-response (Alonso et al 2004, Iosifescu 2011). For example, the functionality of map rendering is made available by a map server providing the map as an image to be displayed in a Web browser or a Graphical User Interface (GUI). SOA can be applied with many different types of services, but usually it is implemented with Web services that can be uniquely identified by a Uniform Resource Locator (URL) and uses Web standards such the HyperText Transfer Protocol (HTTP)[1] for communication.

[1] http://www.w3.org/Protocols/rfc2616/rfc2616.html, accessed on 25 March 2013

In addition, with the wide acceptance of OGC standards such as the Web Map Service (WMS)[2], the Styled Layer Descriptor (SLD)[3], the Symbology Encoding (SE)[4] and the Filter Encoding (FE)[5], these standards have been incorporated in service-driven cartography in order to enable the interoperability of cartographic products with wider Spatial Data Infrastructures (SDIs).

The above-mentioned standards were the foundation for the development of Cartographic Web Services (CartoWS). These are cartographically enriched and standards-compatible map services that allow, based on a map representation, the precise cartographic visualization of the geospatial data stored in databases. CartoWS are an enabler of service-driven cartography since they use the SE standard for styling map data independently of service interface specifications, while cartographic extensions for the SE standard allow expressing cartographic visualization rules with advanced point symbolization, patterns for all spatial features, gradients, advanced features filtering and thematic mapping (Iosifescu et al. 2009, Iosifescu 2011).

We define the notion of a *map representation* as the description of a map composition with sufficient amount of detail so that a map service is able to generate the corresponding map rendering from the geospatial data (Iosifescu 2011). From the cartographic point of view, the map representation mainly defines the symbology and selection predicates to be applied to every feature in a dataset. A map representation consists of an ordered collection of statements that are independent of the physical model of the data. Consequently, the map representation formally describes all the steps necessary for creating the map content.

In service-driven cartography we enforce the use of the map representation and as consequence, the map services always keep the map content up-to-date. The latest updates for the map content are rendered automatically by the map services, without any human intervention, each and every time a client request a view of the map, since the map representation is applied to the data source but, nevertheless, remains independent of the data source itself.

Furthermore, once the map representation has been defined by a trained cartographer, the existence of the map representation enables not only the documentation of the map-making process, but also the reusability of the effort involved in creating a cartographically correct and expressive map.

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[2] http://www.opengeospatial.org/standards/wms/, accessed on 25 March 2013

[3] http://www.opengeospatial.org/standards/sld/, accessed on 25 March 2013

[4] http://www.opengeospatial.org/standards/se/, accessed on 25 March 2013

[5] http://www.opengeospatial.org/standards/filter/, accessed on 25 March 2013

3. Advances in Service-driven Cartography

Service-driven cartography has been proven to be very effective in the field of environmental management, through the development of several decision support systems and geoportals (Iosifescu et al. 2009, Iosifescu 2011). Among them, we mention the SANY Decision Support System (DSS) (Klopfer et al. 2009) and the GIS Platform for Interdisciplinary Environmental Research of the SwissExperiment project (Iosifescu et al. 2010).

Moreover, service-driven cartography has been designed for implementing any core cartographic product, including national and world atlases. Recent advances were aimed to prove that service-driven cartography has reached a level of maturity that enables them to be used for the implementation of Web atlases. In the following, we will review the results of these recent innovations, in the context of service-driven implementation of 2D maps, 3D visualizations and interactive functions for atlases.

3.1. Service-driven Cartography for 2D Maps

The first step is to investigate the possibility to generate the most frequent types of 2D maps found in atlases in a service-based manner. As target of the investigation we selected the maps from Atlas of Switzerland 3 (Sieber et al. 2009), mainly due to the in-house availability of the necessary data.

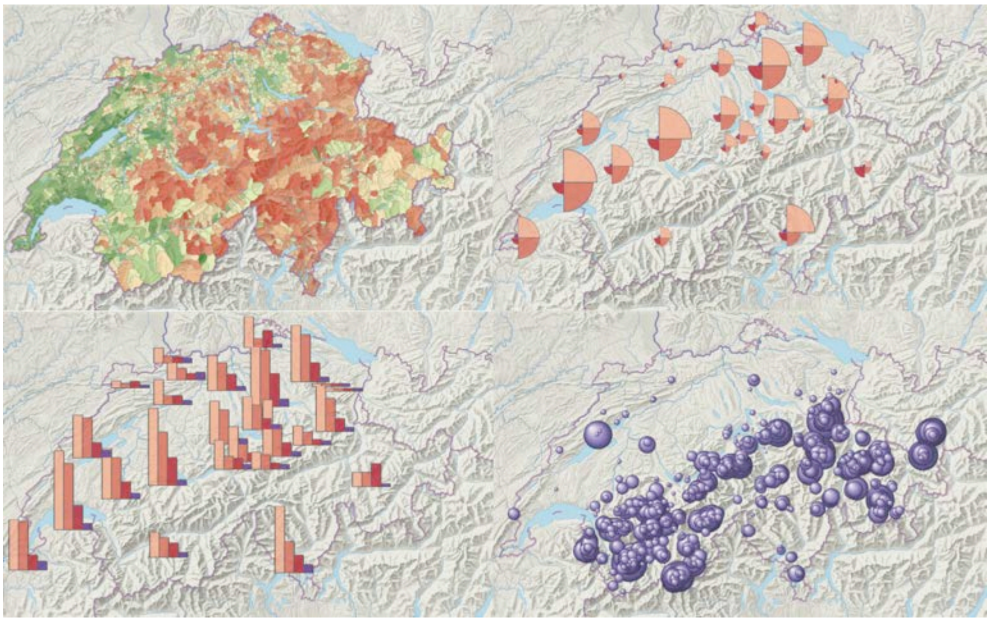

Figure 1. Several types of thematic visualizations recreated using a service-driven approach based on data from Atlas of Switzerland (after Ortner 2011, Iosifescu 2011).

By starting from the same spatial data, we have successfully recreated various types of maps from Atlas of Switzerland (Ortner 2011). In *Figure 1* we present several examples of such maps, recreated to be as similar as possible with the original maps from Atlas of Switzerland. We have to mention that even though *Figure 1* shows only a few selected types of thematic maps, we have recreated many more examples of the most frequent types of maps that are generally found in atlases.

Moreover, we wanted to measure the cartographic quality of the resulted maps and for this purpose the recreated maps were compared to the original representations from Atlas of Switzerland as shown in *Figure 2*.

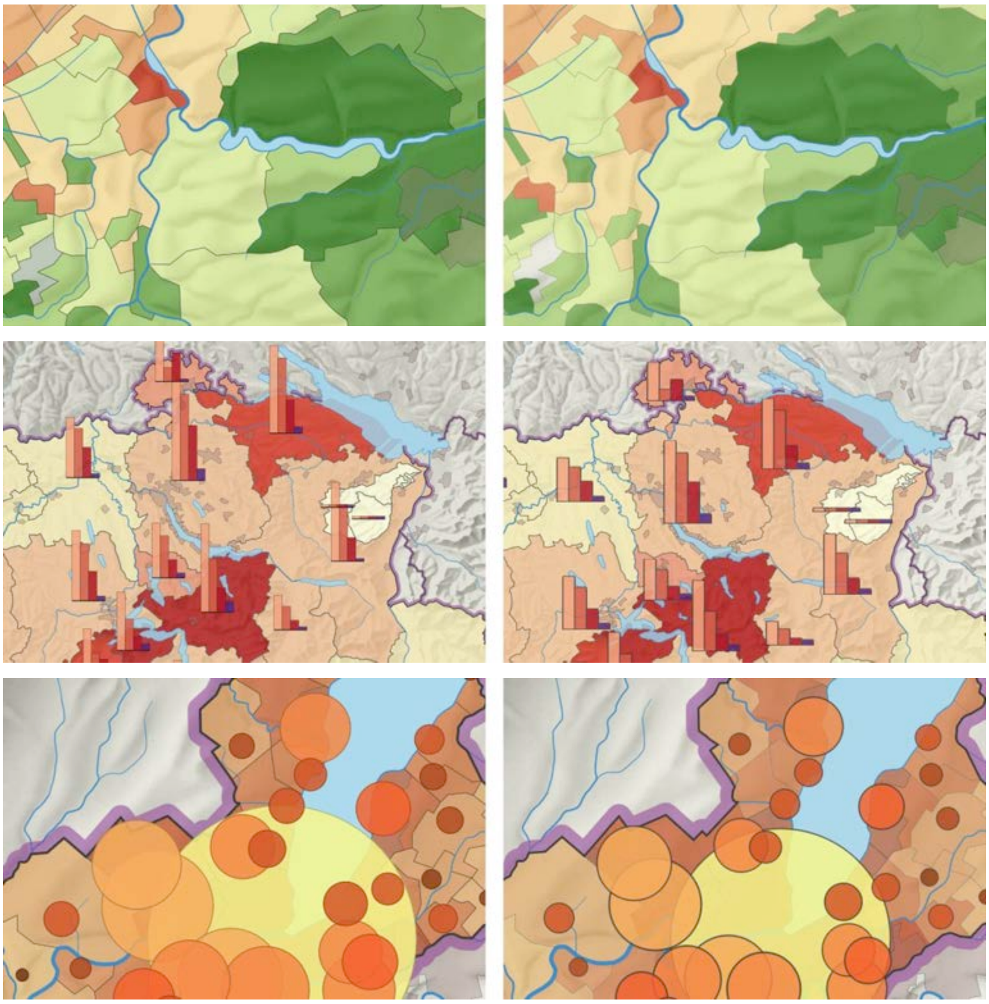

Figure 2. Selected comparisons between the original visualizations from Atlas of Switzerland 3 (left) and their corresponding recreations using service-driven cartography (right) (Ortner 2011).

The detailed comparison demonstrated that the maps recreated using the service-driven technology are of high quality and actually very close to the original maps from Atlas of Switzerland (Ortner 2011).

3.2. Service-driven Cartography for 3D Visualizations

The second step in demonstrating the applicability of service-driven cartography for atlases aims at recreating the 3D visualizations used in Atlas of Switzerland 3, since the combination of 3D technologies with the concept of service-driven cartography in atlases has not previously been explored (Panchaud 2012, Panchaud et al. 2013).

The simplest application of service-driven cartography to 3D visualizations is to use the generated 2D maps as textures in 3D. As shown in *Figure 3*, this simple procedure enables us to obtain block images similar to the ones available in Atlas of Switzerland (Panchaud 2012). Such block images are implemented directly in the Web browser using the WebGL technology (Bär 2012), with the difference that the textures are generated dynamically using service-driven cartography instead of just using predefined images.

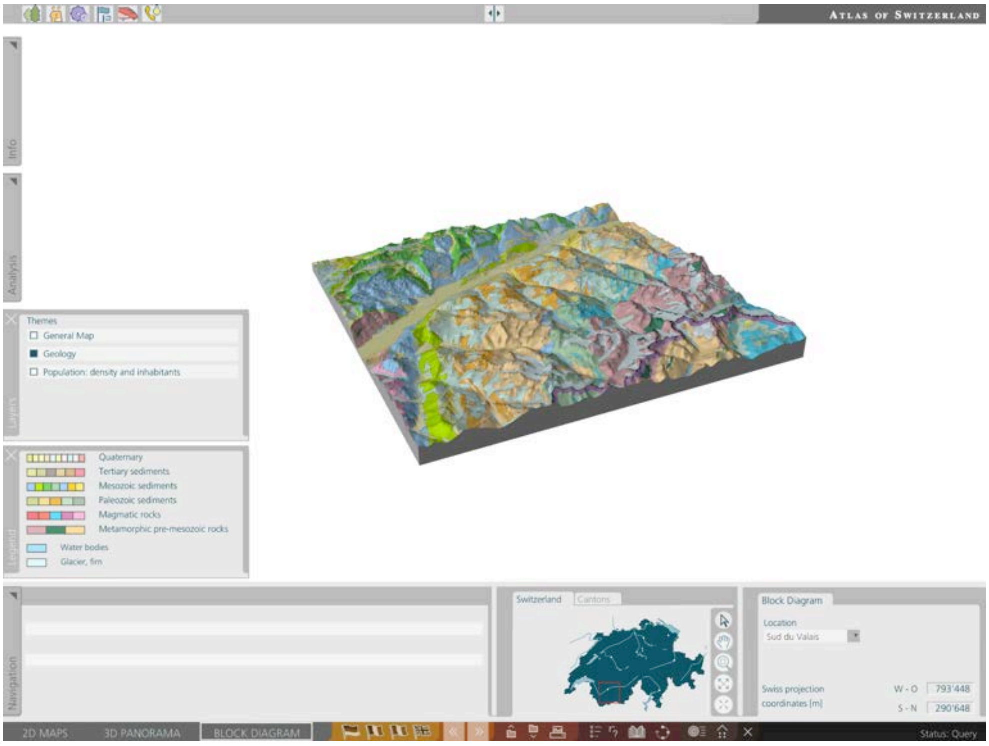

Figure 3. WebGL block image using a service-driven generated 2D texture (Geology), recreated to look similarly to corresponding 3D visualization from Atlas of Switzerland (Panchaud 2012).

A more complex service-driven solution can be applied also for generating panoramas similar to the ones available in Atlas of Switzerland, as shown in *Figure 4* (Panchaud 2012).

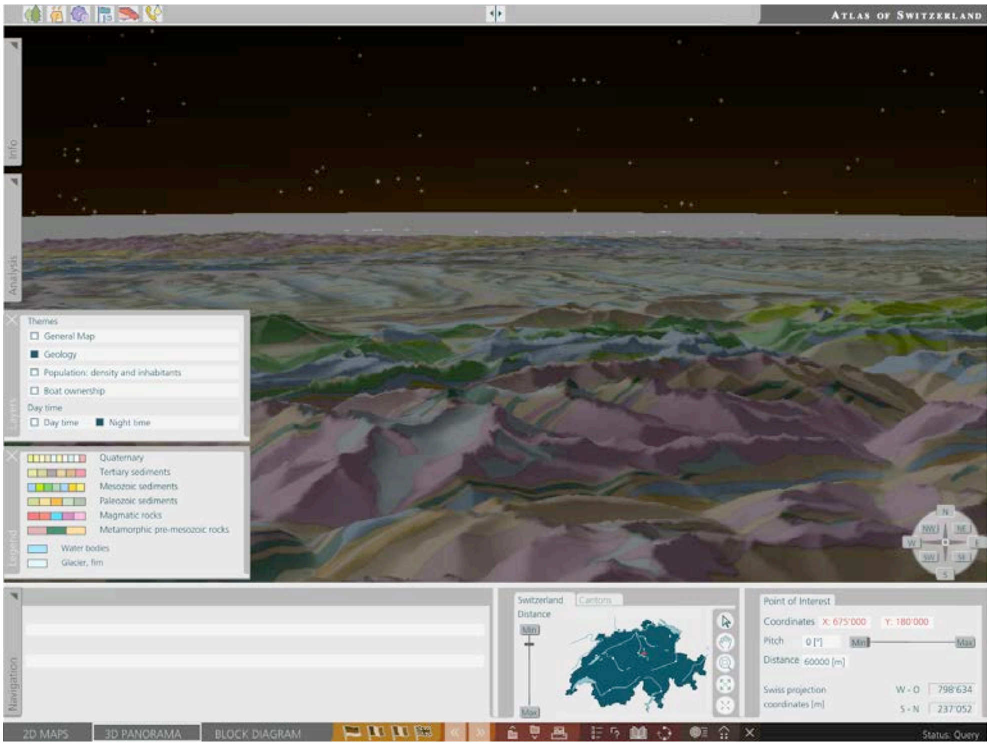

Figure 4. Service-driven generated panorama (Geology, Night time) recreated to look similar to the corresponding 3D visualization from Atlas of Switzerland (Panchaud 2012).

In order to enable plugin-free viewing of the panorama in the Web browser, we needed to chain an additional service, namely the Globe Capture Service (GCS). The GCS is a custom 3D Web service developed by the Atlas of Switzerland based on an early prototype implementation of the Atlas of Switzerland version 4. This service works in a similar manner to a map service, with the difference that it generates perspective views as images to be displayed in the Web browser. For generating the panorama, the CGS service is using textures that are rendered dynamically using service-driven cartography (Panchaud 2012, Panchaud et al. 2013). Therefore, chaining the CGS service with the map service produces the panorama image. Furthermore, every spatial interaction performed by the user in the interface triggers another request to the service chain for producing the corresponding panorama view, which effectively allows the user to navigate freely in space.

So far, we have focused our service-driven implementations on two types of 3D visualizations, namely panoramas and block images. An additional type of 3D visualization, namely a globe, was not investigated because in Atlas of Switzerland (version 3) only the panorama and the block image modes are available for comparison. However, the same service-driven techniques used for the panorama are easily portable for an entire globe, since the GCS is using a globe mode for its 3D rendering.

However, the applicability of service-driven cartography for generating textures to be used in 3D visualizations is not without problems. The usability of the texture is limited to spatial features containing areas and lines to be displayed in 3D as flat objects. Spatial features that are needed to be displayed in their full three-dimensionality (such as buildings), as well as point symbols, diagrams and labels are not suitable to be displayed in this manner. They will appear distorted or hidden in 3D because they are flattened on the 2D texture that is being used to generate the block image or panorama as shown in *Figure 5*.

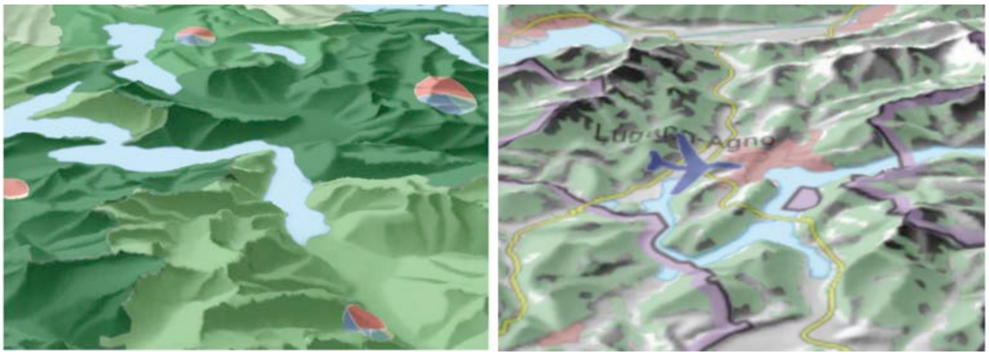

Figure 5. Deformations visible for diagrams (left) and point symbols and labels (right) when using a service-driven generated texture for point features (Panchaud 2012).

Therefore, point symbolization and labeling require a different service-driven implementation. For handling 3D objects such as buildings it is necessary to render them as 3D objects by using a 3D service instead of simple 2D textures. This is an area where we can profit from the advances in computer graphics, since true 3D rendering still remains computationally expensive for large areas, an issue that translates in poor application performance. Furthermore, for correctly visualizing point symbols, diagrams and labels, yet another Web service may be necessary. This additional Web service would deliver these types of symbols in a similar manner to billboards, but precisely positioned in the perspective view so that such symbols are always visible and oriented towards the point of view (Panchaud 2012). Such a perspective billboard service may alleviate some of the performance problems associated with true 3D rendering.

3.3. Service-driven Cartography for Interactive Functions

The third and final step in demonstrating the applicability of service-driven cartography for atlases investigated the support for interactive functions, since interactivity is a major topic in Atlas Cartography and Multimedia Atlas Information Systems (Hurni 2008).

According to Cron (2006) and Ortner (2012), the most frequent map-related atlas functions can be roughly classified in navigation functions (e.g. zoom, pan), GIS-functions (e.g. position display, thematic queries) and cartographic and visualization functions. The class of cartographic and visualization functions can be further classified in map manipulation functions (e.g. turning layers on and off, change of projection, change of symbology), redlining (e.g. drawing of custom map elements and labels) and functions related to exploratory data analysis (e.g. change of classification).

Among the atlas functionalities, we consider the change of symbology and the change of classification to be some of the most demanding, from the technical point of view. However, as shown in *Figure 6*, the implementation of these two functionalities can be done in a straightforward manner using service-driven cartography.

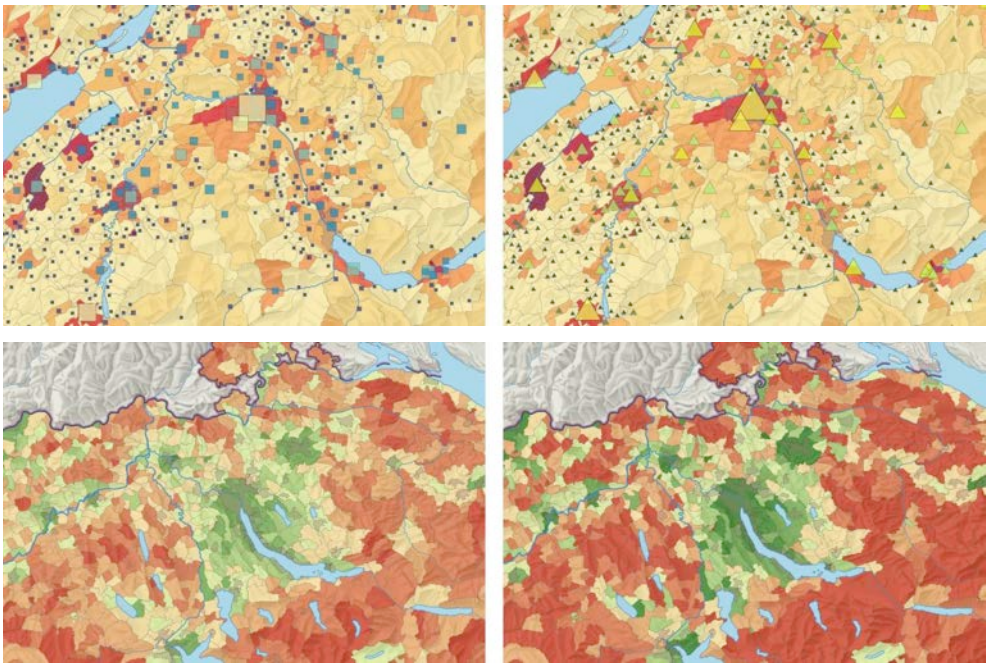

Figure 6. Change of symbology (upper part) and classification (lower part) from the default (left) to a user-defined visualization (right) (after Ortner 2012).

These results are achieved by transforming the user input into the corresponding map representation and by applying the newly defined map representation to the source spatial data in order to change the map symbology or classification from the default to the user-defined visualization. Furthermore, since the core of these atlas functions are performed on the server-side, a Web atlas needs only to implement a user interface on the client-side in order to collect the user input as shown in *Figure 7* (Ortner 2012).

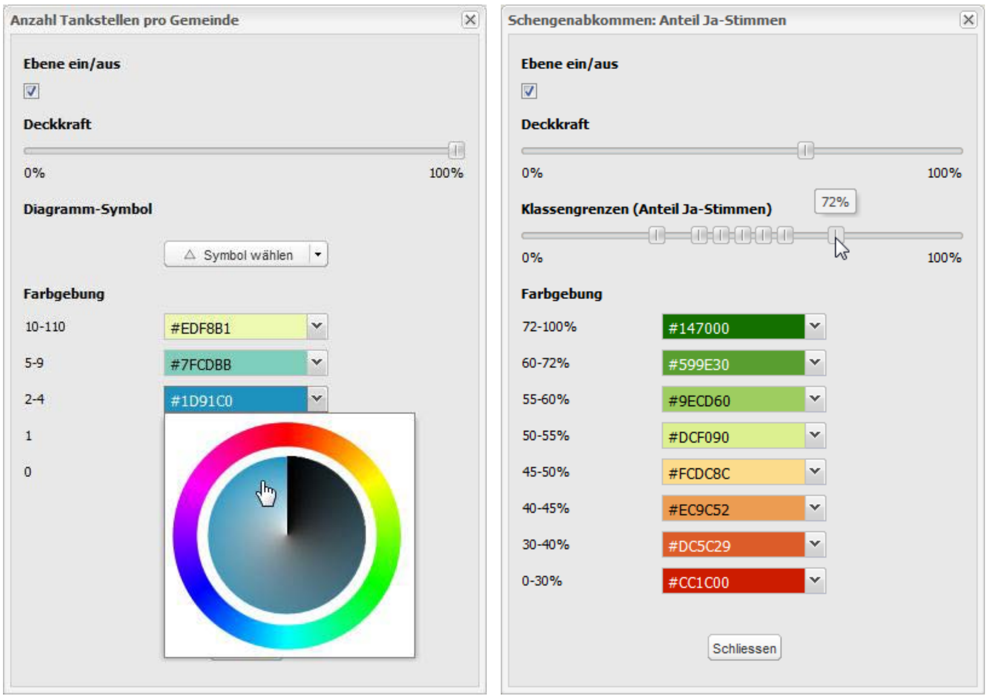

Figure 7. Example of possible user interfaces collecting user inputs for the interactive change of symbology (left) and classification (right) with a service-driven solution (Ortner 2012).

When using a service-driven approach, the remaining map-related atlas functions have even a more direct technical implementation. Any map service based on the WMS standard provides spatial navigation functions, layer management, change of projection, as well as limited thematic queries by design. Furthermore, functions such as position display and drawing of custom map elements and labels are implemented in most current Web mapping frameworks such as OpenLayers[6].

Finally, due to the formalism and reusability of the map representation as described in *Section 2*, we can even propose two new interactive functions

[6] http://openlayers.org/, accessed on 12 April 2013

for Web atlases, namely a “save map symbology” and a “copy map symbology“. The former would allow the Web atlas users to retain the personalized map content instead of the default one between different sessions, and the latter would allow the atlas users to either transfer the symbology from a map they like to another one (i.e. make one map look as another), or to use an existing map symbology that was previously defined by other users.

4. Additional Services in Service-driven Cartography

In addition to map services, there is a collection of possible services that might be used for the implementation of a complex Web cartographic application or Web atlas.

Some examples of additional services are illustrated based on the latest developments implemented in the frame of the GeoVITe ("Geodata Visualization and Interactive Training Environment") project. The main goal of the GeoVITe project is to create an easy-to-use online portal for the distribution (visualization and download) of geodata to the ETH researchers (Iosifescu C. et al. 2011). Furthermore, the GeoVITe geoportal is also used as a Web-GIS platform (the GIS Platform for Interdisciplinary Environmental Research)[7] for the distribution of more exotic types of spatial data (e.g. sensor data) in environmental projects such as SwissExperiment and OSPER - Open Support Platform for Environmental Research (Iosifescu et al. 2010, SwissExperiment 2013).

In the latest development version of the GeoVITe geoportal (and, by extension, of the Web-GIS Platform), cartographic Web services are providing the main functionality of the platform for the visualization of spatial data. However, such a portal may have much additional interactive functionalities that need to be supported by back-end services. For example, geocoding services might be used to provide search functionalities for in-map locations and geoprocessing services might be used to provide data clipping and extraction functionalities.

Fortunately, there are two main assets that help us leverage the power of services for complex service-driven Web mapping applications. The first asset is represented by the standardized specifications from OGC for various geospatial services such as the Web Feature Service (WFS) or the Web Processing Service (WPS) that are also implemented in ready-to-use open-source or commercial software. The second major asset is the body of research performed by the Computer Science community related to Web Services in general and to rapid service composition in particular.

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[7] https://geodata.ethz.ch/gis/, accessed 14 April 2013

For example, the latest versions of geoprocessing services implemented in the GeoVITe platform made the transition from services based on ArcGIS Server to flexible geoprocessing services based on GDAL (Geospatial Data Abstraction Library)[8] that are orchestrated though the JOpera service composition platform. JOpera is defined to be a rapid service composition tool for building distributed applications out of reusable services (JOpera 2013), while GDAL offers a strong basis for implementing geoprocessing services. This is proven by the many useful functionalities already implemented in GDAL and OGR utilities[9] such as *gdal_translate* for clipping raster data with control of the output raster format, *ogr2ogr* for clipping and reprojecting vector data with control of the output vector format, *gdalwarp* for reprojection of raster data, *gdaladdo* for generating pyramids for raster datasets or *gdalbuildvrt* for generating a virtual raster mosaic from many independent tiles without being forced to physically merge them. As a result, the effort required for the implementation of complex interactive functionalities with a service-driven approach has been lowered thanks to the existence of free and open-source software.

5. Conclusion

Web service-driven cartography deals with the development of high-quality interactive cartographic online applications based on an interworking of Web services and Web technologies. The main innovation in Web service-driven cartography is represented by cartographically enriched, standards-compatible map services, that allow a documented and precise cartographic representation of geospatial data sources based on map descriptions. The map description is especially important, because it contains all the necessary information needed to generate the target map. Consequently, a map description offers important advantages in terms of flexibility, automation and reusability to any cartographic product based on a service-driven solution.

Previously, service-driven cartography has been successfully applied mainly in the field of environmental management and geoportals. In this contribution we have shown, through recent developments, that service-driven cartography is applicable to Web atlases, more specifically for creating high quality 2D maps, 3D visualizations and support for the implementation of interactive functions. These recent advances in Web service-driven cartography demonstrate that it is possible to create Web cartographic products with a comparable quality as in established atlases.

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[8] http://www.gdal.org/, accessed 14 April 2013

[9] http://www.gdal.org/gdal_utilities.html, accessed 14 April 2013

6. Acknowledgements

This work was partially supported by the Competence Center Environment and Sustainability of the ETH Domain (CCES)[10], through the SwissExperiment/OSPER projects and the FILEP/Innovedum[11] fund of ETH Zurich through the GeoVITe project. The authors would like to thank all the project partners and funding organizations for their support of cartographic research.

References

Alonso G., Casati F., Kuno H., Machiraju V. (2004) Web Services. Concepts, Architectures and Applications. Springer, Berlin.

Bär H. R. (2012) Digital Cartography – Exercises (unpublished). Institute of Cartography and Geoinformation, ETH Zurich, Switzerland.

Cron J. (2006) Graphische Benutzeroberflächen interaktiver Atlanten - Konzept zur Strukturierung und praktischen Umsetzung der Funktionalität, Diploma Thesis, Dresden University of Applied Sciences, Dresden, Germany.

Erl, T. (2008) SOA: Principles of Service Design. Prentice Hall, USA.

Hurni, L. (2008) Multimedia Atlas Information Systems. Encyclopedia of GIS, Shekhar, S. and Xiong, H. (Eds.), Springer, pp. 759-763.

Iosifescu C., Iosifescu I., Jenny H., Hurni L. (2011). Geovite - a Service-Driven Solution for an on-Demand, User-Friendly Web Access to Geodata. Proceedings the 25th International Cartographic Conference, Paris, France.

Iosifescu I. (2009) Design of a General Architecture for GIS. Master Thesis, ETH Zurich, Switzerland.

Iosifescu I. (2011) Cartographic Web Services. Doctoral Thesis, ETH Zurich, Switzerland.

Iosifescu I., Hugentobler M., Hurni L. (2009) Web Cartography with Open Standards – A Solution to Cartographic Challenges of Environmental Management. Environmental Modelling and Software, doi: 10.1016/j.envsoft.2009.10.017.

Iosifescu I. and Hurni L. (2010) GIS Platform for Interdisciplinary Environmental Research. Proceedings of the 7th ICA Mountain Cartography Workshop, Borsa, Romania.

JOpera (2013) JOpera – Process Support for Web Services. http://www.jopera.org/. Accessed 20 March 2013.

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[10] http://www.cces.ethz.ch/, accessed 14 April 2013

[11] http://www.innovedum.ethz.ch/index_EN/, accessed 14 April 2013

Klopfer M., Simonis I., (Eds.) (2009) SANY – An Open Service Architecture for Sensor Networks, ISBN 9-783000-285714.

Lorenz C. (2013) Interaktive benutzerdefinierte Symbolisierung von Vektordaten mittels erweiterten OGC-Standards, Master Thesis, ETH Zurich, Switzerland.

Ortner F. (2011) Dienstbasierte Kartengenerierung für Web-Atlanten unter Anwendungen erweiterter OGC-Standards. Master Thesis, University of Zurich, Switzerland.

Ortner F. (2012) Interaktive Funktionen in dienstbasierten Web-Atlanten. Cartography Lab, ETH Zurich, Switzerland.

Panchaud N. (2012) Service-Driven 3D Atlas Cartography. Master Thesis, ETH Zurich, Switzerland.

Panchaud N., Iosifescu I., Eichenberger R., Sieber R., Hurni L. (2013) Service-Driven 3D Atlas Cartography. Proceedings of the 26th International Cartographic Conference. Dresden, Germany (in print).

Sieber R., Geisthövel R., Hurni L. (2009) Atlas of Switzerland 3 – A Decade of Exploring Interactive Atlas Cartography. Proceedings of the 24th International Cartographic Conference ICC 2009, Santiago de Chile. Chile.

Sieber R., Hollenstein L., Odden B., Hurni L. (2011) From Classic Atlas Design to Collaborative Platforms – The SwissAtlasPlatform Project. Proceedings of the 25th International Cartographic Conference.

Swiss World Atlas (2013) The Swiss World Atlas, http://schweizerweltatlas.ch/?lang=en. Accessed on 20.03.2013.

SwissExperiment (2013) The Swiss Experiment Platform. http://www.swiss-experiment.ch. Accessed 20 March 2013.