CartoService: A Web Service Framework for Quality On-Demand Geovisualisation

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Abstract. The last decades have seen a steady increase of digital spatial data and their effective availability. Embedded in the rapid developments in information and communication technology (ICT) such geospatial data or geodata are globally accessible, mainly via the internet, in a magnitude unseen before. In a parallel development of geographical information systems, computer-assisted cartography and the internet, a vast variety of web-based services have emerged to capture, store, analyse and present geodata. The map output from these systems is frequently suboptimal, lacking graphic expressiveness and effectiveness. This paper discusses a web-based service framework, the CartoService, to improve the geovisualisation quality of mapped geodata and provide laypersons and professionals with quality map graphics.

Keywords: geovisualisation, on demand mapping, web mapping, web cartography, web services, high quality mapping.

1 Introduction

The last decades have seen a steady increase of digital spatial data and their effective availability. Embedded in the rapid developments in information and communication technology (ICT) such geospatial data or geodata are globally accessible, mainly via the internet, in a magnitude unseen before. Today, about 80 percent of all digital data have a spatial dimension [1] and thus are geodata. Spatial data have penetrated our business as well as private life to an extend that Google and its geographical viewing and mapping services (Google Earth, Google Maps, Google Streetview) have become almost iconic representations of the present geoinformation era. At the same time the almost unrestricted availability of both geoinformation (GI) technology and geographic data have massively promoted the use of maps by professional and private users [2].

Today, a broad range of internet-based services for geodata are available on the internet, whether topographic or thematic, map data and maps on various global and regional scales. These services facilitate the acquisition, processing, presentation and dissemination of geographical information. Interactive and dynamic user participation in web-based geoinformation is one key characteristic

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of the so-called Web 2.0 [3]. In fact, web services and the underlying principle of Service Oriented Architectures (SOA) can be identified as the most important driving force in GI development of today.

Motivated by the rich geovisualisation capabilities of thematic (web) mapping techniques, this contribution presents a concept to provide professional cartographic modelling functionality and expertise to the digital production environment of recent maps. The overall objective of the CartoService approach presented here is the improvement of web mapping quality by an informed utilisation of web services for cartographic modelling. Based on a brief overview of relevant concepts of web cartography the respective web services (chapter 2) and the cartographic modelling process is outlined in its components and workflow (chapter 3). Against this background requirements and benefits of a web service for professional cartographic modelling are discussed (chapter 4). From this discussion a concept of the so called CartoService is extracted and presented including its major components and architecture. The present development stage of CartoService is subsequently assessed by relevant use case scenarios (chapter 5). A brief conclusion sums up major finding ot this ongoing research (chapter 6).

2 Cartography 2.0

The ongoing development of GI technology has forever changed and (r)evolutionised the traditional geodata processing disciplines of geodesy and cartography. Cartography has a long and rich tradition in storing and communicating spatial information by analogue map graphics. Originally developed for and applied to paper maps and atlases, cartographic expertise of processing and visualising geodata has accumulated and matured during the last five centuries. Prior to the advent of digital technologies cartographic methods have constantly been adapted to the changing production techniques [4]. Computer-assisted cartography and geoinformation systems have, however, both opened up and required the expansion and re-adjustment of this wealth of geovisualisation expertise. In fact, the adaption of traditional methods and knowledge to present-day geoinformation technology and environment remains the principal challenge of modern cartography, cf. [2], [5], [6].

The global spread of web-based ICT, in particular, has expanded the range of cartographic presentation methods and media, collectively referred to as Web Mapping 2.0 or Web Cartography 2.0 [2]. These and similar terms relate to the underlying ICT development termed Web 2.0 which denotes a "variety of innovative resources, and ways of interacting with, or combining web content" [2]. Accordingly Web Cartography 2.0 includes "Web 2.0 applications that have a spatial frame of reference" [3]. Web Mapping 2.0, in particular, summarises such diverse new geospatial web based applications as GeoTagging, GeoBlogging, Web Map Mashups or interactive geospatial Application Programming Interfaces (APIs) the number of which is still rapidly increasing [3]. The Web 2.0 environment has also been a productive breeding ground for the concept of

Service Oriented Architecture in software development in general as well as in GIS in particular.

To make the innovative potential of the internet platform and architecture fully available to modern cartography, geospatial standardisation organisations like the Open Geospatial Consortium (OGC) are of major importance to the definition and implementation of interoperability standards in web mapping and web cartography. The OGC defines Web services as "self-contained, self-describing, modular applications that can be published, located, and invoked across the Web" [7]. Key functionalities of web services include flexibility (from simple to complex processes) and interoperability (deployed once, discovered, invoked and used frequently). OGC standards, such as the Web Map Service (WMS), Web Feature Service (WFS) or Web Processing Service (WPS), have improved the interoperability of GIS and the dissemination of geoinformation tremendously. Although WMS and WFS are able to respond to the range of clients' requests in different geographical forms and formats, the principle feature of these services is the (technical) interchange of geodata. The informed construction of meaningful maps is neither supported nor supposed. As a consequence, the map output frequently lacks the cartographic modelling quality characteristic of maps generated in accordance with the principles of (thematic) cartography. To specify such deficits and identify potential weak points in recent web map compilation and production, the cartographic modelling process is analysed subsequently.

3 The Cartographic Modelling Process

The main objective for the construction and dissemination of cartographic presentations, e.g. maps, is to communicate geospatial information in an adequate, efficient and intuitive manner. That is why maps are required to have clear-cut content, explicit map symbols, easy-to-comprehend map graphics and an attractive overall map design [8], [9]. It is now generally accepted that maps are models, in particular analogue graphic models, of the environment. Prior to the digital age the analogue map has been the only medium to store and communicate the position of spatial objects (topography) as well as their neighbourhood (topology) at the same time. The spatial structure of any given region can thus be explored at one glance. While the storage of spatial data has become the domain of geo databases, the map graphic has, for the time being, not been substituted by any other medium for the visual analysis of spatial distributions, structures and positions of geographical objects. This is accomplished by generating a graphic spatial model of the environment from a graphic-free data model. Accordingly maps are secondary (graphic) models derived from existing primary (numeric) data models explored and analysed by the individual user. From the map graphic each user creates her individual tertiary (mental) model of the environment (Fig. 1).

Efficient communication of spatial objects and structures via (carto-)graphic models requires a substantial overlap of the reality models involved, particularly of the cartographic and the mental model. The best way to achieve this is to provide the user with a professional graphic representation of the geographical relationships which we term a quality map. Quality maps are composed of abstracted spatial symbols and generalised line and area structures originating from a method-driven cartographic modelling process including technical and mental constraints. Whether conventional or digital, professionally constructed map graphics have a proven record of efficient communication of geographic data, effective visual exploration and analysis facilitating intuitive comprehension and interpretation of complex spatial structures by the user. In the last two decades, this unrivalled capacity of quality maps has successfully been adapted for the "mapping" and representation of non-spatial data by the so-called map metaphor.

3.1 Cartographic Communication Model

It has to be stressed that the cartographic communication model briefly discussed above has been developed in the pre-digital era. In the geoinformation era of almost ubiquitous geodata and geo processing tools it is no longer the trained cartographer who is only able to construct maps and distribute them. It is also the user who can manipulate a map's design, even its data and save as well as disseminate the result, preferably on the internet. As a consequence, the one well-defined roles of map producer and map user have become blurred, which, in turn, necessitates a revision of the classic one-directional cartographic communication model (Fig. 1, a) [10].

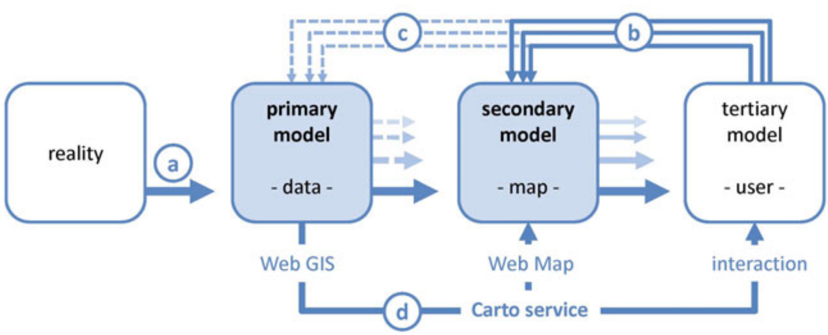

Fig. 1. Cartographic communication model; a: the classic one-directional cartographic information flow; b: interaction; c: information access through the map interface; d: representing the CartoService bus; [10]

Modern web-based maps offer dynamic, interactive (two-way) communication and information exchange [11]. They facilitate extensive interactive map use by providing user access to the map graphic (the secondary model) as well as the interconnected map data (the primary model)(Fig. 1, b, c). In fact, the map graphic can be considered the graphic of the map dataset which allows the user to select and filter objects, properties and relations from the graphic-free primary data. In the wider context, digital networks, such as the internet or intranet, offer numerous alternatives to access and use a wide range of dynamically scalable storage and processing components to process complex tasks interactively in acceptable answer time. Both, the IT environment and the capabilities of the web-based map generation are a prerequisite for the development and provision of a high quality cartographic visualisation service on the internet.

In the conceptual phase of such cartographic visualisation service the process of proper map construction needs to be broken down in to a sequence of components each of which requires further consideration. The resulting component structure is modular and generic and can thus be adapted to changing input data or mapping task requirements. The definition of connections between the map construction components is of particular importance in the conceptual development of such service framework to ensure generation of a meaningful map construction workflow.

3.2 Map Construction Components and Workflow

Map construction, whether conventional or web-based, can be anatomised into five major components, cf. [9], [12], [13]. In the web-based CartoService under development these components are coupled by a one-directional workflow (Fig. 2).

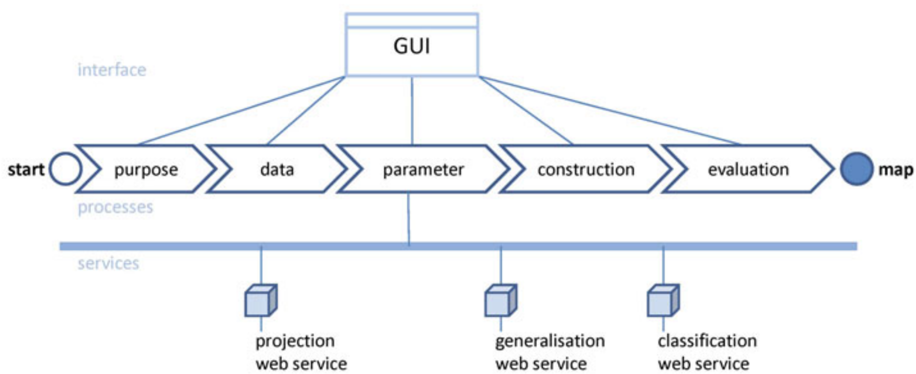

Fig. 2. Modular map construction workflow with coupled web services

To compile a complete map the whole process chain has to be processed sequentially. The map compilation can only be continued with the second component when the first component has been processed etc. Once the map construction process is initiated (Fig. 2: start) the first component is the *map purpose* component necessitating a decision on the map purpose. Parameters of choice include general public map, scientific map; screen map, print map; view-only map, interactive map etc. Depending on the selection of map purpose the *data* component governs the identification and acquisition of the data required using appropriate catalog services. Data sources can range from hard copy files or geospatial databases to certain feature sets provided by web services (e.g. WFS). The data selected are subsequently processed according to the decision taken in the *modelling* component. Defined by the choices made in the map purpose and map data components, respectively, data modelling is governed by parameters such as map scale, classification of the source data or level of semantic and graphic generalisation. The non-graphic modelling of map data is a prerequisite for the actual generation of the map graphic in the *construction* component. This component facilitates the selection of map style, symbol, colour, text and label placement etc. The construction component concludes the map compilation, composition and rendering process. This component provides both a preview and the final map graphic. In the final *evaluation* component the map graphic generated is validated, modified and re-processed, if necessary. The selection parameters of each component can be re-adjusted via a graphical user interface (GUI) and an API as well (Fig. 2: GUI). While the user interface facilitates the interactive visual control of parameters and workflow, the programming interface provides a suitable connection to other external software components or services. The CartoService approach can therefore be understood as a workflow management service which is able to select, orchestrate and chain catalog, data and processing services due to the user and map purpose requirements [14].

4 The CartoService Approach

At present, the concept of a web-based CartoService, as outlined above, is in its development stage. Its sequential ordering provides the layperson with an easy-to-understand guide to quality map production. Such quality web-map service is not available on the internet to date. A brief look at the map production functionalities of current web-based atlas information systems (AIS), such as the national atlases of Canada [15] and the USA [16] or the series of Australian regional atlases [17], will readily confirm this assessment. Basically, web maps created from those AIS are graphic presentations of the non-graphic geodata modelling results (primary model) in the AIS-GIS. To the layperson the resulting map graphic may look like a map. However, a professional appreciation will find that the map-like graphic lacks almost all quality features that define a proper map. The most notable of these is the separate graphic modelling of the map graphic (secondary model) on the basis of the data model. Well known from visual outputs of such AIS and geographical information systems these map-like presentations are referred to as displays [18]. For the time been this secondary (graphic) modelling process can not be automated. Automated transformation of the primary data model into the secondary data model has not been achieved yet and remains an unsolved research problem, cf. [6]. As a consequence, the majority of web maps (like the majority of digital maps) generated by a simple graphic presentation of the data model fall short of cartographic quality as put forward by [18], [19] and [20]. Such suboptimal map graphics, in essence, lack the indispensable potential to communicate, explore and analyse spatial data visually. CartoService aims to address this fundamental cartographic problem by providing a rule-based framework for quality map-production including the proven techniques of thematic cartography and map types. For that purpose, CartoService offers a component-based environment for quality map production. As has been presented above, each component provides the resources or services required to go through the modelling and visualisation process. The architecture, components and processes of CartoService are based on the principles of SOA, in particular the publish-find-bind paradigm and the loose coupling [21].

4.1 CartoService Requirements

CartoService first and foremost attempts to improve the graphic modelling quality of web-based maps by limiting the amount of visual clutter in the map graphic. For that purpose, three different aspects have to be addressed: first, improvement of the map graphic itself (resolution, colour space), second, implementation of principle methods of (thematic and topographic) cartography into the automated construction of internet maps, and, third, integration of interaction and map dynamics into the map construction workflow.

Aspects one and two roughly correspond to the criteria of expressiveness and effectiveness[1] [22], when applied to cartographic symbol language. The first aspect (map graphics quality) is related to improvements in the rendering quality, resolution, data formats and colour space of digital web map graphic. Specific cartography-related map graphic (quality) criteria are object-symbol-relation, graphic density relating to topic and scale, level of graphic generalisation and colour schemes.

The second aspect relates to a particular phenomenon primarily found in web maps which, as yet, has rarely been discussed. This phenomenon can be characterised as the lack of cartographic principles in web map visualisations. The bulk of web maps use rather simple visualisation techniques, as a glance at the AIS mentioned above will confirm. Even well-established visualisation principles like the visual variables [23] or dynamic visual variables described by [24] and [25] are hardly made use of. A cursory analysis of the map graphics of internet maps shows that the vast majority of these are suboptimal to inappropriate. Equivalent to GIS presentations most of those maps are missing generalisation, adequate symbolisation and text and label placement [18]. In fact, the majority of thematic web maps are either of the choropleth type or simple composition of point, line or area symbols. From the ten professional methods to visualise geospatial data ([8],[9]) and a total of eleven graphic variables [26] only a few are applied in web map construction. More complex or sophisticated methods of geodata visualisation are rarely found in recent internet maps. The implementation

[1] Expressiveness determines "whether a graphical language can express the desired information", whereas effectiveness determines "whether a graphical language exploits the capabilities of the output medium and the human visual system."

of thematic mapping methods and techniques in standard web mapping services, in particular, is an ongoing research topic in geovisualisation (e.g. [27], [28], [29], [30]). To make available the entire spectrum of cartographic visualisation methods for automated web map production including a data- and purpose-specific summary, is a major task addressed by CartoService. Through its modular composition CartoService will filter, present and apply relevant cartographic visualisation methods to user specific datasets and presentation purposes, respectively. The third major objective is the integration of interaction and dynamics into the automated map construction process. In the current development and implementation phase of CartoService this last aspect is subordinated.

4.2 CartoService Components and Architecture

The CartoService web map environment is conceptualised as a management web service which itself is able to search, select, orchestrate and chain different web services. These services are integrated as loosely coupled components embedded in the generic architecture of the CartoService framework. The management functionality of CartoService offers user- and purpose-centred support for high quality map compilation. Basic components of CartoService are: the graphical user interface, data filter and analyst, method selector, compiler, the style library and the rendering machine. Each component is linked and managed by CartoService via a service programming interface. Because of its generic architecture the integrated components (services) can be flexible exchanged in the framework if requirement. General service processing and parameter setting is controlled through the GUI and stored in a user and task specific profile. The CartoService processing chain will be initiated by the input of spatial dataset(s) or data service delivered feature set(s). After reading the input dataset(s) CartoService will process a standard workflow which uses default values for each component and component parameters. In the first implementation phase default values are derived from expert knowledge and cartographic expertise. At a later implementation stage feedback from the evaluation of CartoService maps will add information on about cartographic quality to the rule base.

The provision of CartoService functionality is based on the well-known publish-find-bind paradigm in SOAs (Fig. 3). To allow for requests to CartoService a registry is published in machine readable form, which is available to clients via internet. Using the registry, clients are able to locate the service host, link to it and receive a description of the service functionality provided. Subsequently the information required is exchanged and the service can be used to send, process geodata and finally to request appropriate geovisualisation in web map form. Users (human clients) are able to access CartoService through a GUI provided on the CartoService website. An alternative option to use CartoService functionality is through plug-ins or extensions of standard proprietary or open source GI and map construction systems.

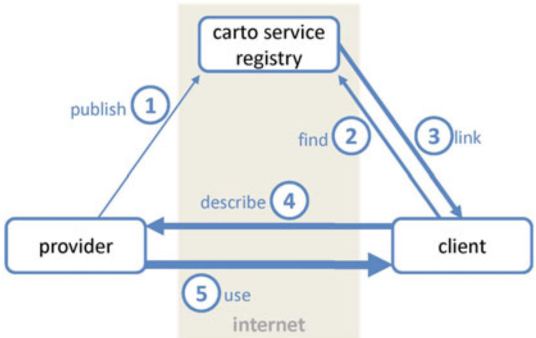

Fig. 3. CartoService architecture

5 CartoService Use Cases and Evaluation

Based on CartoService and its components, architecture and requirements described above a number of use case scenarios for CartoService have been designed and analysed prior to full-scale implementation. In a first stage an operational prototype has been developed and selected features have been evaluated.

5.1 Purpose versus Data-Driven Demand

The two most important use cases for CartoService are: first, the purpose-driven and, second, the data-driven use case. The purpose-driven use case focuses on the task or communication related objectives of the map maker (user). Her task can be described by: I want to communicate geospatial information. What is the most appropriate visualisation method? Where can I find relevant data resources? Which media-specific visualisation modes can be applied? The (second) data-driven use case can be described as: I have particular geospatial data or data services about which I don't know details. Which geospatial information is accessible by the application of geovisualisation methodology?

While the first use case addresses a typical, traditional question in map construction, the second reflects present-day objectives (exploration) and user centricity (layperson) in the usage of geospatial data and map production. It is almost paradoxical that the ubiquitous availability of geodata has not increased the knowledge about the origin and features of such data in the same way, let alone basic knowledge of proper visualisation of this data. The controversial discussion about Google's streetview data, at least in central Europe, provides a clear proof of this knowledge deficit. CartoService advises the user to select and apply the best-fitting visualisation method by analysing the data (with data mining techniques) and providing the adequate geovisualisation (Fig. 4). The resulting quality map can then be further refined by the user in an iterative, interactive manipulation process. However, the underlying basic methodical decisions cannot be revised.

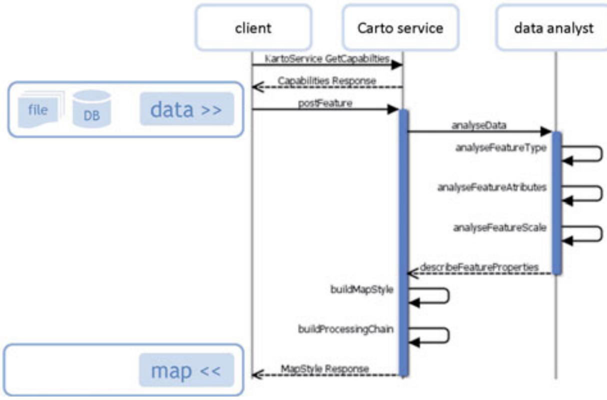

Fig. 4. Part of the simplified CartoService sequence diagram

The map produced can then again be disseminated via standard web map services (WMS). In addition CartoService stores and, on demand, provides the processing and styling information for each component service used in the workflow. Stored as user and workflow profiles such information can be used to establish user, purpose or data specific visualisation patterns. These patterns can be utilised to produce maps with similar (corporate) cartographic design and quality.

5.2 CartoService Process Chain Evaluation

In the ongoing research the development of CartoService has left its conceptual stage. Because of the complexity presented above it has not been implemented yet. However, a first assessment can be made by evaluating the process chain of the service components and the relevant parameter settings. Existing cartography-related web services have been investigated and utilised to simulate the CartoService processing chain. The frames of reference of this research have been the principle components and processes of cartographic modelling. As dynamic binding and linkage of resources is not available to date, data had to be loaded and exchanged manually. Apart from services providing geographical data in vector (WFS) or raster format (WMS) e.g. by Geoserver or Mapserver, web services have been used to generalise data. Other services have been used to detect and apply colour schemes to visualise datasets already classified. The MapShaper [31] and ColorBrewer [32] services were used here. Not all components conceptualised in the CartoService framework are available as web services to date. That is why missing components, e.g. classification, were be substituted by GI software for the time being. As [33] and [34] have shown such GIS functionality can be implemented into a SOA-based environment.

The CartoService process chain has also been evaluated for purpose-driven use case scenarios. For this assessment, the map construction purpose was the visualisation of population density in the German federal state of Brandenburg in

2003 at county level. First results of the application of the CartoService workflow to the test data are shown in figure 5. The results of this first application of CartoService are promising when it comes to improve cartographic quality. A full and detailed evaluation of the CartoService mapping quality has not been done at this stage, further research and implementation efforts are required. The evaluation of this component remains a major issue in the ongoing research.

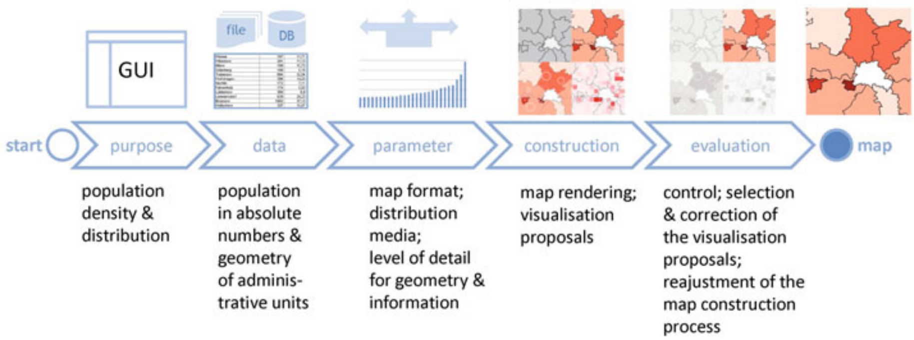

Fig. 5. CartoService process applied to population density visualisation

6 Conclusion

For the time been CartoService has not been implemented completely and evaluated. At the present stage of development it has, however, been demonstrated that the approach presented here offers significant potential to improve web mapping quality in an extensive automated map construction workflow. It has also been shown clear intelligent chaining and orchestration of web mapping related services, completed by functionalities of user interaction and manipulation, can generate a consistent SOA-based web mapping workflow and related service quality. CartoService provides the basic management and control components as well as the architecture to improve geovisualisation quality throughout the complete map construction workflow. Thanks to its modular and generic structure, dynamic functionality and interoperability CartoService empowers laypersons and professional map makers alike to add cartographic visualisation expertise to their mapping purpose. Eventually CartoService will thus help to safeguard minimum map quality standards in any geodata visualisation.

References

1. Franklin, C.: An Introduction to Geographic Information Systems: Linking Maps to Databases. Database, 13–21 (April 1992)
2. Peterson, M.P.: The brave new world of online mapping. In: Proceedings of ICC 2009, Santiago de Chile (2009)

3. Gartner, G.: Applying WebMapping 2.0 to Cartographic Heritage. Online Journal: e-Perimetron 4 (2009)
4. Monmonier, M.: Technological transition in cartography. Madison (1955)
5. Kraak, M.J., Brown, A. (eds.): Web cartography: developments and prospects, p. 213. Taylor and Francis, London (2001)
6. Virrantaus, K., Fairbairn, D., Kraak, M.-J.: ICA research agenda on cartography and GIScience. Cartography and Geographic Information Science 2(36), 209–222 (2009)
7. Open Geospatial Consortium (OGC): Glossary: Web Service (2007), http://www.opengeospatial.org/ogc/glossary/ (accessed 2011-02-11)
8. Dent, B.D.: Cartography: thematic map design, vol. 5. WCB/McGraw-Hill, Boston, Mass (1999)
9. Slocum, T.A.: Thematic Cartography and Visualization, 2nd edn. Pearson Prentice Hall, Upper Saddle River (2004)
10. Dickmann, F.: Einsatzmöglichkeiten neuer Informationstechnologien für die Aufbereitung und Vermittlung geographischer Informationen – das Beispiel kartengestützter Online-Systeme, p. 182 S. Verlag Erich Goltze GmbH & Co. KG, Göttingen (2004)
11. Visvalingam, M.: Cartography, GIS and Maps in Perspective. Cartographic Journal 26(1), 26–32 (1989)
12. Witt, W.: Thematische Kartographie, vol. 2. Jänecke, Hannover (1970)
13. Engemaier, R., Schernthanner, H.: Kartenkonstruktion mit Freier und Open-Source-Software. In: Strobl, J., Blaschke, T., Griesebner, G. (eds.) Angewandte Geoinformatik 2010. Beiträge zum 22. AGIT-Symposium Salzburg, July 7-9, 2010, Universität Salzburg, Heidelberg (2010)
14. Alameh, N.: Chaining Geographic Information Web Services. IEEE Internet Computing 7(5), 22–29 (2003)
15. The Atlas of Canada (2011), http://atlas.nrcan.gc.ca/ (accessed 2011-02-11)
16. National Atlas of the United States (2011), http://www.nationalatlas.gov/ (accessed 2011-02-11)
17. Atlas of South Australia (2011), http://www.atlas.sa.gov.au/ (accessed 2011-02-11)
18. Van der Merwe, F.: GIS, Maps and Visualization. In: Proceedings of ICC, Durban, South Africa (2003)
19. Buckley, A., Frye, C., Buttenfield, B.: An information model for maps: towards cartographic production from GIS databases. Mapping approaches into a changing world. In: Proc. 22nd Intern. Cartogr. Conference A Coruna [CD-ROM], July 9-16, 2005, International Cartographic Association, A Coruna (2005)
20. Hardy, P.: High-Quality Cartography in a Commodity GIS: Experiences in Development and Deployment. In: ICA symposium on cartography for Central and Eastern Europe [CDROM], February 16-17, Technische Universität Wien/ International Cartographic Association, Wien (2009)
21. Melzer, I.: Service-orientierte Architekturen mit Web Services: Konzepte - Standards - Praxis. - 4. Aufl. Spektrum Akademischer Verlag, Heidelberg (2010)
22. Mackinlay, J.D.: Automating the Design of Graphical Presentations of Relational Information. ACM Transactions on Graphics 5(2), 110–141 (April 1986)
23. Bertin, J.: Graphische Semiologie - Diagramme, Netze, Karten. In: Übersetzt und bearbeitet nach der 2. Französischen Auflage, Walter de Gruyter, New York (1974)
24. MacEachren, A.M.: How Maps Work - Representation, Visualization and Design. The Guilford Press, London (1995)

25. Robinson, A.H., Morrison, J.L., Muehrcke, P.C., Kimerling, A.J.: Elements of Chartography. John Wiley & Sons, Chichester (1995)
26. Ellsiepen, I.: Methoden der effizienten Informationsübermittlung durch Bildschirmkarten. Dissertation, Bonn (2004)
27. Dietze, L., Zipf, A.: Extending OGC styled layer descriptor (SLD) for thematic cartography - Towards the ubiquitous use of advanced mapping functions through standardized visualization rules. In: 4th Int. Symp. on LBS and Telecartography (2007)
28. Hugentobler, M., Iosifescu-Enescu, I., Hurni, L.: A Design Concept for Implementing Interoperable Cartographic Services based on reusable GIS Components. In: Proceedings of ICC, Moscow (2007)
29. Rita, E., Borbinha, J., Martins, B.: Extending SLD and SE for Cartograms. In: Proceedings of the GSDI 12 world conference, Signapore, 19-22 October (2010)
30. Sae-Tang, A., Ertz, O.: Towards Web Services Dedicated to Thematic Mapping. OSGeo Journal, Vol. 3 (accessed 2011-02-20) (2007), `http://www.osgeo.org/files/journal/v3/en-us/final_pdfs/ertz.pdf`
31. Harrower, M., Bloch, M.: Mapshaper.org: A map generalisation web service. IEEE Computer Graphics and Applications 26(4), 22–27 (2006)
32. Brewer, C.: A Transition in Improving Maps: The ColorBrewer Example. Cartography and Geographic Information Science 30(2), 159–162 (2003)
33. Brauner, J.: Providing GRASS with a Web Processing Service Interface. In: GI-Days 2008, Münster (2008)
34. Bergenheim, W., Sarjakoski, L.T.: A Web Processing Service for GRASS GIS to Provide on-line Generalisation. In: Proceedings of the 12th AGILE International Conference on Geographic Information Science, pp. 1–10. Leibniz Universität, Hannover (2009)