

Advancing Geographic Information Science

The Past and Next Twenty Years

EDITED BY

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Mapping Practices in a Digital World

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Abstract: Current GIS and mapping techniques are highly technologically driven. With advances in the capabilities especially of online mapping platforms but also advanced geovisualization applications for considerably enhancing digital maps, the map has turned into an advanced digital product that goes far beyond the capabilities of a printed paper map. However, digital mapping practices often remain a mere technical challenge while the wider implications of this digital turn for cartographic practice are less discussed. What is needed is a new approach to rethinking cartographic principles in the digital era.

Keywords: Neocartography, digital mapping, computer cartography, cartographic principles, GIS, online, internet.

1 Introduction

The advent of digital technology and the internet has led to the question being asked of how maps can be visualised beyond the traditional paper map. GIS-derived maps make great use of digital technology in the process of their creation, and their great potential to get new perspectives on the world using highly advanced techniques can only be exploited because of the most recent advances in digital technology. Therefore, the question remains whether digital technology beyond its analytical power may also be able to provide new means of cartographic practice to show maps in the digital world.

Changing technologies have a considerable impact on cartography. Several technological revolutions marked important steps in the practice and process of creating maps. Mechanical, optical and photo-chemical technologies changed the way maps were produced. Then, the discovery of electronic capabilities made a new dimension in map production accessible: Not only were most of the design techniques transferred to digital platforms, but also the possibility to deal with huge amounts of data that can hardly be analysed by a single person enables cartographers to find new ways of handling data for cartographic visualisation [32].

This paper puts the issue of cartographical principles into the main focus and discusses in this context what role cartography can play in the digital world and the internet age about thirty years after digital technology has become widely used in cartographic practice with personal computers having become much more affordable in the 1980s [23]. This discussion is framed by a reflection on current digital mapping techniques. Based upon that, exemplary suggestions for directions of cartographic research and practice are made that take the implications of digital and web technology into account. This is also illustrated on some simple examples that link cartographic principles and their technical realisation.

The following remarks are not intended to give a complete overview of developments in digital mapping (see [9] for an extensive compilation of relevant works in the field). The main emphasis is put on the aspect of cartographic principles to demonstrate and propose future perspectives for digital mapping beyond what is currently done.

2 Digital Mapping Techniques

2.1 Geospatial analysis and geovisualization

Geospatial analysis has become a standard operation in data processing. It is not only a necessity given the huge amount of data which many geospatial sciences are working with, but also a result of growing data availability and increasing computing power. The pivotal element in this process often is the geographic information system (GIS), which brings data together and allows performing a large number of geospatial analyses. Many new techniques find their way into GIS applications fairly quickly. Programming interfaces allow a highly specialized customization of these applications and the integration of particular algorithms and techniques in the process of geospatial analysis.

The main purpose of using GIS software is the execution of spatial analysis and the integration of various geospatial-related data. Mapping and cartography are subordinate elements in these applications. Although maps can be designed using a set of design options, these capabilities are rudimentary. This is a weak point of using GIS for geospatial analysis while at the same time aiming for good cartographic practice or looking for innovative visual mapping approaches. Map results derived from GIS software often lack that design component that is essential to convey a message or tell a story with a map beyond the sole purpose of putting data on a map display [21].

Drawing visually appealing maps starts with the way in which data is analysed and how results from this spatial analysis come out of that process. This process of spatial and statistical data processing is essential for the mapping results, but the outcome of the techniques is only a first step that results in a rough draft that needs particular cartographic treatment before it can be seen as a more understandable and as such also more meaningful cartographic representation of the processed data. Visualisation concepts are thus as essential as the underlying methodologies themselves, which makes cartographic concepts so valuable and their outcome a key component of geographic visualisation.

The emergence of geovisualization as a sub-discipline of the so-called GIScience is a result of advances in the field. The debate about whether GIScience can be seen as a scientific discipline for itself or *only* as a powerful technology of scientific visualisation is ongoing [4]. Most important in this rapidly evolving field is that

digital methods of advanced data analysis and data visualisation play a crucial role in the understanding of ever growing amounts of data. New techniques are not only different ways of looking at data, but are central elements in the process of understanding geographic information. Here, geovisualization connects to the very fundamental elements of cartographic research, and with others may lead to the assumption that cartographic practice is part of scientific research as well (for instance part of a communication science [28]).

I do not want to argue for or against the perception of cartography and GIScience as scientific disciplines, although I see them as an integral part of geographical methods. As such research on new geovisualizations (cartographic or else) is part of the scientific advance in geographical science. Anyway, the spectrum of GIS- and cartography- related research is too broad to be categorised in one discipline only or to be linked to only one discipline. As a matter of course all these advances could not be made without a solid geographic background in mind.

As pointed out by many before me, GIS is not the magic black box that produces meaningful results of geospatial analysis and creates stunning images [12, 29, 33]. It is the user who influences that process considerably and needs the knowledge about the methods and the science behind the data. The only problem is that often there is a gap between those who are capable of advancing technology and those who are capable of advancing science.

With the recent trends and advances in geovisualization, visualising geospatial data has left the domain of cartography, and maps or map-related visuals have become only one option to show geographical information. The line between digital cartography and data visualisation has vanished. Visual designers as well as geographical information science researchers see maps as one of many ways to make sense of data and information. Despite the boom in data visualisation in the digital world, advances in cartographic visualisation in academic geography remain limited. Kessler & Slocum [21] make the disconcerting finding of an overall low quality of map design in an analysis of thematic maps in two major geographical academic journals. They argue that geography as a core discipline of mapping should embrace map design as a vital component of geographic education, and that good practice of mapping needs to be actively promoted and easy to perform. Digital technology can be one part of that process that reduces the barriers to create better maps with new and easier to use tools that do not require the advanced skills that are needed to perform more complex geospatial analysis.

2.2 Mapping tools

There are growing numbers of tools for digital mapping and geovisualization outside GIS environments that do not require the corresponding technical knowledge about the use of geodata and GIS techniques. The range of tools is widespread and contains different degrees of complexity and specialisation of currently available visualisation environments. Many other resources exist, and the developments and advances in this field are very dynamic.

Other digital mapping tools include specialised but easy to use resources that solve specific cartographic tasks. The examples shown in Figure 1 demonstrate the range of tools and resources that have become available with digital technology. These are targeted at users who produce maps in the common map design environments, such as Adobe InDesign. All applications have basic cartographic

principles built into their functionality that supports inexperienced users to make the right design choices in creating maps. GIS software fails to provide a similarly simple assistance, which then results in the often bad mapping practice of the *Modern Dark Ages* of map design [10].



Figure 1: Digital cartography in the internet. A: *Natural Earth* geodata repository (<http://www.naturalearthdata.com>), B: *Colorbrewer* map colour guide (<http://colorbrewer2.org>), C: *Typebrewer* map typography guide (<http://www.typebrewer.org>), D: *Indiemapper* online cartography application (<http://www.indiemapper.com>)

The importance of the development of such mapping applications with digital technology should not be underestimated in its value for cartographic practice. Not only can better mapping practices be promoted with these tools, but they can also help to encourage the academic use of cartographic visualisations to make scientific work and results from academic research visible and understandable. Cartographic methods are also an important element of communicating geographical science.

Advances and new concepts in geographic visualisation require approaches different from easy to use mapping tools. Here, the investigation of new ways of data analysis and new ways of visualisation are essential, and can only be carried out in specialised computer environments. GIS software is one main part of these tools, but other applications with different capabilities can be used for digital mapping and data visualisation, such as the statistics software *R* or the visualisation programming environment *Processing* to name only two of many non-commercial applications that have become popular in this field in the last years.

3 The Role of Maps in Digital Publishing

The recent advances in digital mapping demonstrate how digital technology has become a standard element in the process of creating maps in manifold ways. This applies to the traditional cartographic practices that are nowadays often performed using graphic design software such as Macromedia Freehand or Adobe Illustrator. Here, principles of map design are generally transferred to the digital world, and basic cartographic principles are used as in the non-digital process of creating a map. In this context, digital technology mainly has the role of reducing the manual work and simplifying and automating the work stages.

Digital technology has also become a routine element in analysing and generating scientific raw data for a map or a geovisualisation, which is then finalised in the design software and dedicated mapping tools, or which is further visualised in new visualisation environments such as Processing. The degree of expertise that is needed to create maps is slowly declining. New tools are becoming available that allow map making following basic cartographic principles also for less experienced users. Advanced cartographic works, however, remain part of the work for trained experts. Computers play a crucial role in the task of analysing and visualising data in novel ways or using new approaches, which require expert knowledge to be realised. Many mapping techniques were impossible to realise without present-day computing power. The digital turn in cartography thus has not led to a simplification of the process of making maps, but has enabled new dimensions of data analysis and new ways to visualise that data.

Often the result of using digital technology in the mapping process remains some form of paper map, which still is seen as the ultimate final product of the cartographic visualisation process. Even if the final map remains a digital entity that is only used on a computer screen, it is treated as being a paper map, and the screen only resembles the paper. This is a widespread phenomenon in digital media. Digital equivalents of analogue products are often oriented in their appearance to the real world, resulting in the creation of effects that resemble a physical product. A paramount example of this is the visual page turning effect in digital books on portable computers and tablets.

Publishers are struggling with adapting to new media concepts that embrace the capabilities of advancing digital technology, which at present can be described as an experimental phase of creating innovative new concepts for media on digital devices. One key problem is to find new applications that enhance the usability or add value to digital media. Current attempts of that often fail because they do not add significant value [5, 11,15].

What is described here is a general issue that affects the publishing scene more than it perhaps affects cartography as a discipline. Nevertheless, it reveals a gap in cartographic research ever since digital technology arrived in the discipline: While cartographic practice was translated into digital techniques, and geospatial analysis was introduced to the spectrum of (geo)scientific methods [26] – arguably resulting in the creation of GIScience as a discipline between geosciences, cartography and informatics – the map as a publishing product itself has changed little.

Mobile mapping applications and GPS-technology are part of geospatial research that does not focus on the map itself or on visualisation problems. Here basic

mapping principles have been conducted by pragmatic and technology-led decisions, which have often been initially set by technology companies rather than geovisualisation research. Most research in this field currently focuses on advancing database structures and queries, and analytical algorithms that better connect the increasing amount of geospatial information [3]. Geovisualisation in these digital map products has only become more relevant with advancing display capabilities that include more complex information, with the aim to improve the visualisations towards a more realistic appearance (rather than alternative concepts of visualising complex data). Despite being in the centre of the visualisation of the information shown in mobile mapping applications, the map itself as a cartographic element plays a subordinate role, while major efforts are put into the analytical capabilities [22, 25, 26].

Online maps and cartographic geovisualisations in the internet move maps away from their static character towards interactive and versatile multimedia products. Maps in the internet are widely used and appear in diverse forms.

The development of GoogleMaps and OpenStreetMap both date back to the years 2004/05. GoogleMaps quickly gained high user numbers, which was further encouraged by the implementation of interfaces to allow the integration into external websites and the combination with external datasets. OpenStreetMap took longer to attract a wider perception, because the initial phase included the compilation of a geodatabase, which GoogleMaps could acquire from commercial providers of geodata. Meanwhile, there is no significant difference in data quality for many parts of the world, and in some regions OpenStreetMap even provides more data than GoogleMaps [2, 31, 36].

The direction of these services is largely driven by technological advances that Google implements in its platform(s). Google increasingly adds functionalities that aim to make an online replica of the world. The recent additions of live traffic information and similar services appear to help the Google mapping platform remain successful in the digital world, significantly influencing the way online maps are created and consumed. OpenStreetMap follows a different direction that is not driven by monetary considerations. It is more open to user input and therefore relies on individual projects that push the technical progress ahead. The increasing implementation of OpenStreetMap in scientific applications may turn OpenStreetMap into a non-commercial alternative to integrating scientific data in dynamic and interactive mapping environments [36].

The web interfaces of GoogleMaps and OpenStreetMap are very similar in terms of cartographic capabilities. Some basic cartographic principles, such as different levels of detail at changing scales, colour schemes for the major geographic features and other elements are well integrated in these platforms. Advantages of the digital world include the large degree of interactivity using simple navigation tools to zoom in and out, and pan the map inside the display window. In terms of usability, these mapping services are major improvements to earlier online mapping attempts in the late 1990s and the first years of the 21st century, which were in very experimental stages of development with sluggish interfaces. These examples hardly exist anymore, not least because of the possibility to integrate GoogleMaps, OpenStreetMap, and other web mapping services into self-made map projects.

Further advanced cartographic elements or new cartographic practices are less prevalent so far. The user adaption of maps based on online mapping services remains very limited to adding new layers onto the basemaps, and depicting basic

geometric elements such as lines or points in form of the infamous (but customisable) pushpins to depict locations. Cartographic design for this additional information lies in the hand of the user who creates map mashups, but is nevertheless limited to what general digital mapping tools provide.

Digital map design principles are extensively discussed in cartographic literature (see e.g. [1, 16, 17, 18, 19, 35]). Topics focus on specific design guidelines for digital technology and the investigation of cartographic principles in relation to the specific technological configurations. Issues such as screen typography, colour rendition, and map navigation tools to simplify the user interaction are among the well discussed issues that solve some of the key problems in transferring existing cartographic practice to the (not so) new digital environments [19]. Problematic remains their implementation in some of the most commonly used and mainly technology-driven web mapping services. More open projects such as OpenStreetMap are more progressive in this regard, also because their ties with academic research and GIScience are much closer and the prime interest is not commercial.

Digital mapping in the online world shows a divided picture. Online maps are largely based on digital mapping services that serve as a fundament for the actual mapping and provide the main framework for controlling and visualising the topic of interest. Improvements that benefit from digital technology include considerable technical advances of the underlying geographical databases, and the improved capabilities to interact with maps by moving them around, changing scales, showing dynamic changes in animated form, or interactively selecting the relevant information. These are capabilities that mark clear advances over static (and therefore printed) maps. On the other hand, the standards upon which these digital interfaces and usability are based are largely set by commercially driven decisions to extend the capabilities of digital mapping platforms, rather than well-considered choices on the best practices and most elegant forms of visualisation. Online maps still resemble to a great degree paper maps, with a little bit more interactivity, but otherwise with all the concepts of the analogue world translated into the digital world – sometimes better, sometimes worse, just like good and bad maps in the offline world.

Online maps are currently a major focus of the developments in digital mapping, and the underlying more technically oriented GIS-related areas of research in this field are major subjects of methodological advances in this field (see e.g. [1, 23, 25]). Work on more cartography-oriented practices of digital mapping and new approaches that focus on maps as a publishing product (e.g. [17, 34]) are less common fields of cartographic research.

4 Creating Maps using Web Technology

4.1 The advent of digital technology in mapping

The examples of the use of maps in contemporary digital platforms demonstrate how using computer technology considerably enhances the value of maps. Cartographic practice is an indispensable foundation for these new technologies. Principles of cartography and mapping techniques are the underlying common ground of these innovations, and the emergence of the field of geovisualisation finds its manifestation in these new digital mapping platforms [24, 25]. Although

taken for granted in most industrialised societies – as is the internet in general – these techniques have only become available a decade ago, many of which we use today are even much younger.

Before that, digital mapping was generally more focused on experimenting with the multimedia capabilities of the first multitasking operating systems. First maps as digital media products were developed for a small group of people and not the wider public. Home computers only became a standard configuration in many households and in education in the 1990s, but did not immediately become a primary source for media consumption [23].

The first digital mapping products in the 1990s were often complementary to existing publications, such as an additional CD-ROM that accompanied textbooks, or similar extras for printed atlases [8, 32]. The main aim was an additional incentive for buying, or multimedia products were targeted at people exploring the new technologies. These early digital mapping products were less the inevitable move of map products away from paper form to digital, but rather an early explorative phase of a wider trend to create multimedia content for the new media devices that started to occupy the mass markets.

Media consumption on digital devices has accelerated in recent years [6, 30]. Digital media has not yet replaced traditional publishing. Books, newspapers, magazines and their likes still outnumber their equivalents on digital devices. But their profits are falling sharply, while digital content has started to be a major source for consuming news and other content, including maps and map-like visualisations.

It may not be a daring assumption that the majority of maps nowadays are consumed in digital form. Satnav systems (replacing paper maps), location based services on mobile phones (replacing maps in guidebooks, and guidebooks themselves), online route planners (replacing the road atlas), and many other of these examples introduced before are these new digital maps that people consume. Content created by the *new mapmakers* (who often have no cartographic training) published online is widely consumed solely online. If their likes are used in analogue media, they often have a digital origin, which is where the majority of their audience has accessed them (not least because of their more widespread and immediate availability).

What is needed to enhance the value of digitally published maps are new ways of visualising and presenting them. New forms of map presentation in the digital world need to make optimum use of technical capabilities, and new approaches should be as unconstrained as possible to create a map that can be consumed regardless of the specific nature of the digital platform or device on which the map is accessed. Cartographers produced analogue maps so that the final product can be printed in a book, in a magazine, on a poster, and in many other similar ways. Traditional cartographic practices are suitable for all these ways of publishing, because their analogue nature does not allow much innovation in this regard. The same products can be used in digital media, but that remains an incomplete map product that makes best use of digital technology. The maps published in the Worldmapper project for example face similar problems and demonstrate this dilemma. The maps on the project's website (www.worldmapper.org) are produced with very recent technological advances using state of the art GIS methods, but the end product is a static map that works on screen as it does on printed paper. The website itself makes some

use of digital technology by providing additional material and allows accessing all relevant data, but the maps that stand in the centre of the project remain static.

What is needed apart from the technological advances is a standardisation of rules for digital cartographic practice that go beyond the mere translation of existing principles. The principles for digital mapping need to be extended by new, very basic concepts of designing and creating digital maps. The development of new principles obviously has to be oriented on technical capabilities, but should not be driven by them and has to be formulated outside the specific ways of technical realisation. Just as there are principles defined for the creation of map elements, symbols, colours, without explaining how these are implemented using pen and paper or using a design software, there should be new principles defined for digital maps that become part of the toolbox for digital cartographers.

Cartographic practices for digital publishing platforms must be examined and defined in a way that they can be realised in different ways and using different tools and applications, therefore must not be restricted to the capabilities of a specific software or hardware platform. They should be independently applicable and make use of the new capabilities of digital devices.

Cartographic textbooks try to consider the most recent trends by adding sections about web mapping and virtual environments (e.g. [4, 26]). Often these are already out-dated at the time of print, and quickly need to be adjusted if not rewritten. HTML5 and the recent more serious attempts to monetise digital publishing products may change this, which is why for cartography it could prove valuable to look into these technologies to provide innovative concepts for publishing maps in the digital world.

4.2 Examples of digital mapping with HTML5 and jQuery

To demonstrate in a very basic manner how HTML5 in combination with an extension by JavaScript libraries can improve digital maps and help to define new principles for digital cartography, I looked at some basic applications that can be used to enhance the digital presentation of the gridded cartograms from my own geospatial research [14]. These two examples are clearly technology-driven realisations of what is possible (and commonly used) in online mapping, but the actual aspect of translating these two examples into some more general principles are the key points that are relevant. The realisation of such principles will always require an adequate technical solution, while the underlying principles could be defined much more general than it is being done at the moment.

All concepts developed in this section can be applied to a basic HTML5 project that works online as well as offline and is not restricted to be used as an internet website, but as a digital map product that can be integrated in other forms of digital publishing. Looking back at my own research on cartograms [14], creating an animation to demonstrate the transition between a conventional map and a cartogram or two versions of a cartogram is time consuming and can be highly technical. An alternative concept would be the interactive presentation of the original and the transformed state of the map where the map reader can use an interactive slider element to switch between the two maps. This can also be a useful way to compare two different states presented in a map. A functionality that overlays two maps and lets the map reader interactively switch between them is an interactive image slider (Figure 2).

The slider is a simple example of how the basic design capabilities of the jQuery library [20] can be exploited for digital map displays. The resulting digital map has a substantial added value that embraces digital technology. Rather than simply showing two maps opposing each other, the map reader can explore the two maps, and unlike in similar examples from GoogleMaps mashups, the full implementation here is realised on the local computer system only using the HTML document in conjunction with the JavaScript library and the actual map files. The gridded cartograms can therefore be shown with different layers in comparison or different information, or in comparison to a conventional map projection to highlight the areas where the map changes most.

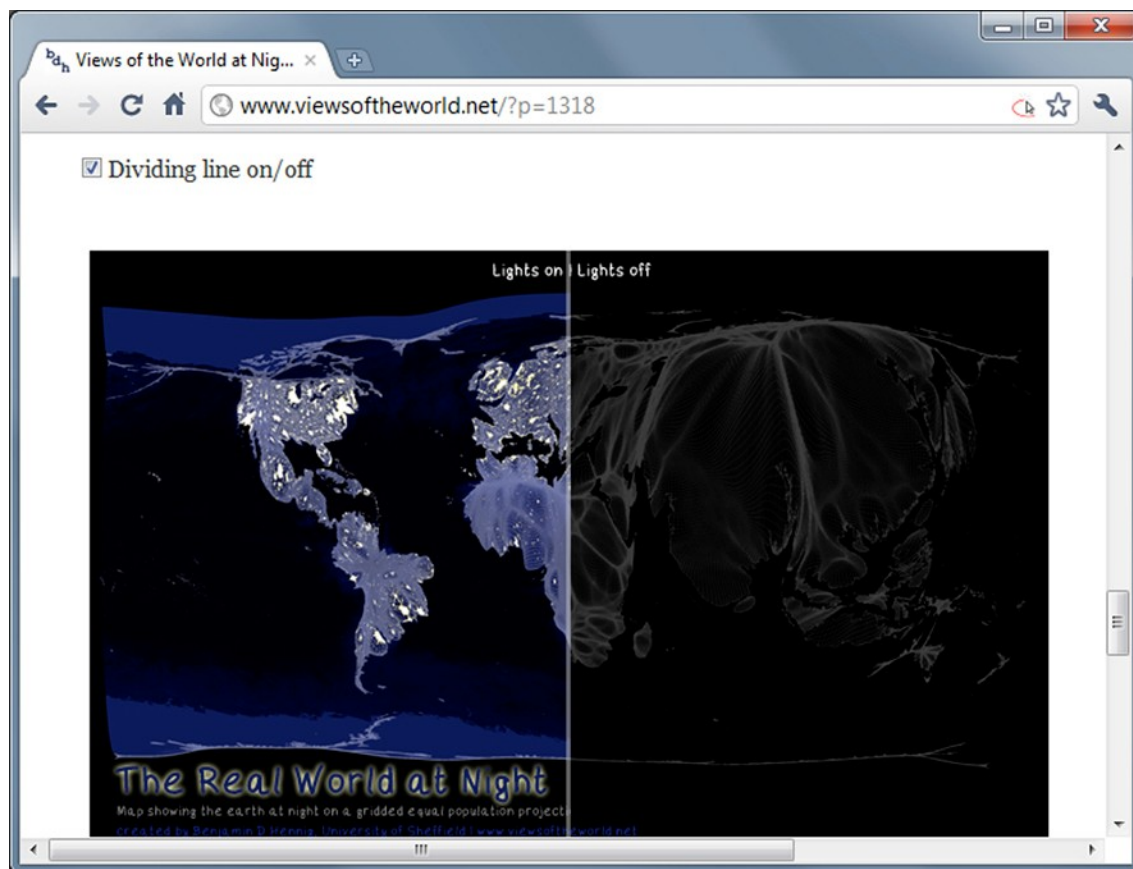


Figure 2: Interactive slider on a gridded population cartogram. The dividing line can be moved to the left and right to switch interactively between the two maps.

A different implementation is the integration of a virtual magnifier that does not only magnify the areas in the map, but can use a second map file for the enlarged view in the magnifying view, so that two different maps with different levels of detail can be prepared to give a less complex overview and highlight details in the magnified view. The implementation of such a concept can be achieved with the *Zoomy* plugin that connects to the jQuery library [20].

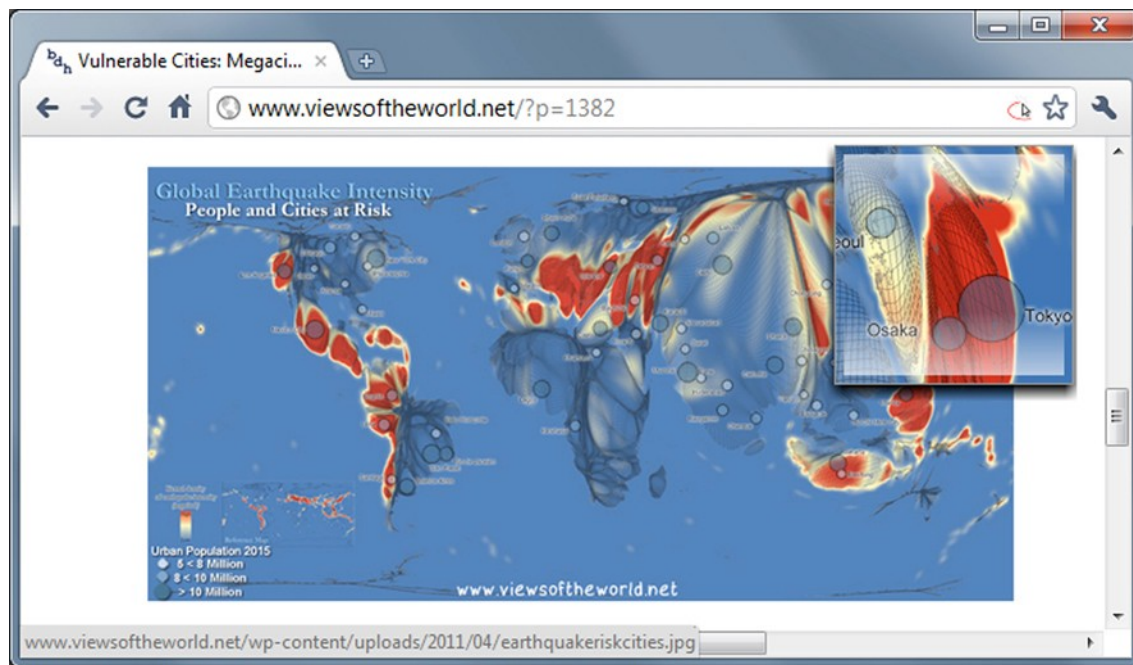


Figure 3: Interactive magnifier on a gridded population cartogram. The magnifier in the top right corner can be used to interactively enlarge sections of the map.

This example is a view of an earthquake risk map shown on a gridded population cartogram [13] which displays additional information about the largest cities of the world in the enlarged view of the magnifier. It can be interactively investigated by moving the mouse over the map. The complex appearance of the gridded cartograms can be made more understandable by allowing the map reader to investigate the map with different levels of information and in an interactive way, where the initial view does not contain too complex information, but the additional information can then be accessed in an intuitive and easily accessible way making more advantage of the possibilities of a digital mapping environment as compared to a printed map.

5 Discussion: New principles for digital cartography

This paper investigated current digital mapping practices and their implications for cartographic practice. Mapping techniques are highly technology driven, and ongoing advances in the capabilities especially of online mapping platforms but also advanced geovisualisation applications have considerably enhanced digital maps. Digital map products have entered multifaceted aspects of people's lives, and the map has turned into an advanced digital product that goes far beyond the capabilities of a printed paper map.

The advances made in this field do not only move digital mapping into an area where digital cartographers need to be highly skilled, but also lead to welcoming trends in the development of tools and applications that allow less experienced users to create maps based on good cartographic practice. This is a promising development to improve the overall quality of maps that even in academic geographical publications showed a decline in their cartographic quality [21]. The

advances in digital mapping may help to encourage better mapping practices for the less experienced users, while research in cartography and geovisualization continues to discover new forms of geospatial data analysis and visualization.

While technological advances are generally necessary and important, the focus of cartographic research should, at the same time, be turned on the development of new digital design principles. Currently existing rules define technical settings for map representations on the screen (such as image resolutions, color spaces, symbol sizes) and even have the potential print output of screen maps in mind in these guidelines [7]. Design principles that focus on maps specifically created for the digital world and that make more use of digital capabilities, in contrast exist only to a small degree.

The simple examples using HTML5 and JavaScript technology are very basic illustrations of improved functionalities and of the type design principles that need to be developed for online mapping, while the focus here has to move away from the mere technical aspects of the issue towards a more general conceptualization how digital map content can be displayed.

This will be even more relevant with digital publishing becoming slowly a mainstream way of publishing content, and digital media becoming increasingly a main part of media consumption. Books, newspapers and magazines are increasingly consumed on digital devices (the online book retailer Amazon announced in May 2011 that the number of e-books sold in April have for the first time exceeded the number of printed books sold [27]), and also scientific journals are moved to the online world. The concepts of creating maps as a (static) printed product should therefore be extended by new map elements that allow novel ways of presenting maps digitally and might even make some map principles for printed maps obsolete in the digital world.

Digital publishing can be seen as a chance for maps to evolve, and for cartographic research to actively contribute to this process by examining new techniques and translating them into general principles for good cartographic design in digital publishing. It is necessary to move design principles from isolated applications into overall solutions that work across the different digital platforms. The implementation of corresponding techniques can then follow. The technical realization and its description is necessary to test and understand the underlying principles, but the resulting map elements can be turned into more generalized digital mapping practices that do not require an extensive technical documentation of how they can be realized.

The technical examples outlined before are very simple examples of such digital mapping principles. Further cartographic work should also focus on how their specific realization is achieved best: The use of a slider as an element in digital maps that show two different states of the map (or compare a map and a satellite image) and the use of a magnifier element to show additional information are the underlying principles of these technically outlined examples. They are as useful elements for an improved digital presentation of the gridded cartograms as the realisation of animations, but they may also prove useful and valuable for maps other than cartograms.

The important principles that need to be considered in the implementation of the elements (how are such maps created, etc.) need to be further investigated, and the final result of such very traditional cartographic research should result in a new set of digital cartographic design principles that extend and possibly also replace some of the existing cartographic rules developed for printed maps.

Existing cartographic principles describe for example how symbols are created and which rules should be followed in their creation, as outlined very basically in a handbook by the British Cartographic Society [7]. The statements about digital maps (or screen maps, as they are called there) focus on the limitations of digital technology, rather than constituting a set of new tools for maps created for the digital world. A structured analysis of specific advantages of digital devices, and a new set of rules could change the way in which digital maps are produced and help to bring cartographic principles into the world of digital mapping (Figure 4), while reducing the risk to create technical instructions for specific digital map applications that become outdated faster than they can be established in cartographic practice.

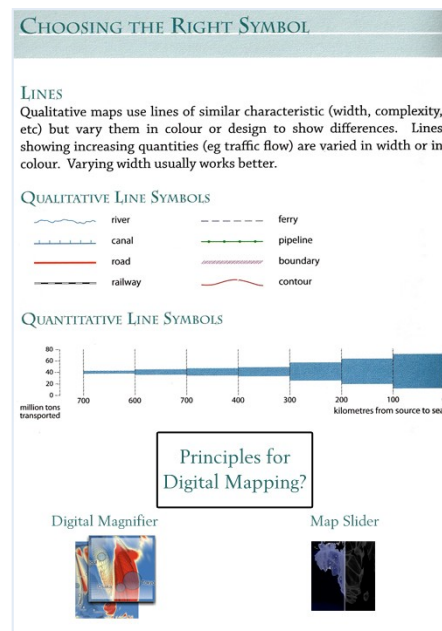


Figure 4: Good cartographic practice today ~ ...and tomorrow? (modified from [7])

Promoting good digital cartographic practice can also include the capabilities of very specific map services like GoogleMaps and similar products, by investigating how the elements implemented here can be valuable additions for digital maps. The option to zoom in and out and change the level of detail in the cartographic information could similarly be translated into basic principles without the need to produce a technical documentation of the specific realisation. There are many different technical ways to implement such functionality, so that the description of these new approaches to cartographic practice can and should be much less dependent on specific technical implementations that change so quickly.

6 Conclusion

Digital technology has made the process of map making and geographic visualisation easier and more complex at the same time. New tools and applications have a great potential to lower the obstacles for inexperienced users to create better maps, and can also encourage the general use of cartographic visualisations to illustrate geographical research. New digital developments and web applications are

promising steps towards a better use of cartographic practice that previously required a solid theoretical and technical background in specialised mapping environments.

Digital technology has also extended our capabilities to visualise large amounts of data by digital processing methods. For achieving that, a number of new tools and applications have emerged in the last years. They specialise in the different tasks of statistical analysis and visualisation, which allows more and more advanced geovisualisation concepts and new forms of working with data outside the domain of informatics and pure computer sciences.

The perspective of new concepts being integrated into common mapping tools for normal users is an essential part in the process of new visualisation techniques and should always be an objective for new techniques. This allows the broader acceptance and wider use by non-experts, while specialised visualisation algorithms that remain not (or badly) integrated in common mapping tools, will less likely succeed as successful geovisualisation concepts despite their promising capabilities.

Digital technology has also changed the way we consume maps, which so far is often neglected in the development of digital mapping applications. Therefore, it may also be essential to extend cartographic practice into the digital domain and to look at new ways of presenting maps in digital environments.

Creating new cartographic principles and hence novel rules can be a major challenge to move digital mapping from an innovative but highly technical and very fragmented entity towards an integral part of cartographic practices, and move digital mapping (not opposed to but still in contrast to GIS or GIScience) towards being part of a cartography for the 21st century.

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References

- [1] ASCHE, H. AND HERRMANN, C. Web.Mapping 2. Heidelberg: Wichmann, 2003.
- [2] BENNETT, J. OpenStreetMap. Birmingham, Packt Publishing, 2010.
- [3] BERNARD, L., J. FITZKE AND WAGNER, R. Geodateninfrastruktur. Grundlagen und Anwendungen. Heidelberg, Wichmann, 2004.
- [4] CARTWRIGHT, W. Advancing global cartography and GIScience. The Cartographic Journal, 48 2 (2011), 81-85.
- [5] CHAPMAN, N. AND CHAPMAN, J. Digital multimedia. Edinburgh: Wiley, 2009.
- [6] COULDRY, N. AND MCCARTHY, A. Mediaspace: place, scale and culture in a media age. Abingdon, Routledge, 2004.
- [7] DARKES, G. AND SPENCE M. Cartography - an introduction. London, The British Cartographic Society, 2008.

- [8] DENT, B. D. *Cartography: thematic map design*. Boston: William C Brown, 1999.
- [9] DODGE, M., R. KITCHIN AND PERKINS, C. *The map reader*. Chichester: Wiley-Blackwell, 2011.
- [10] FRIENDLY, M. A brief history of data visualisation. In *Handbook of data visualisation*, C. Chen, W. Härdle and Unwin, A., Eds. Berlin / Heidelberg: Springer, 2008, pp. 15-56.
- [11] GRAHAM, G. AND SMART A. The regional-newspaper industry supply chain and the internet. *Supply Chain Management*, 15 3 (2010), 196-206.
- [12] GUERIN, S. M. Peeking into the black box: some art and science to visualizing agent-based models. In *Proceedings of the 36th conference on Winter simulation* (Orlando, FL, 2004).
- [13] HENNIG, B. D. Gridded cartograms as a method for visualising earthquake risk at the global scale. *Journal of Maps*, 10 2 (2014), 186-194.
- [14] HENNIG, B.D. *Rediscovering the World: Map Transformations of Human and Physical Space*. Heidelberg / New York / Dordrecht / London, Springer, 2013.
- [15] HIRST, M. *News 2.0: Can journalism survive the internet?* Sydney: Allen & Unwin, 2011.
- [16] JENNY, B. Geometric distortion of schematic network maps. *Bulletin of the Society of Cartographers SoC*, 40 (2006), 15-18.
- [17] JENNY, B., H. JENNY AND RÄBER, S. 2008. Map design for the internet. In *International perspectives on maps and the internet*, ed. M. P. Peterson, 31-48. Berlin/Heidelberg/New York: Springer, 2008.
- [18] JENNY, B., T. PATTERSON AND L. HURNI, L. Flex projector: interactive software for designing world map projections. *Cartographic Perspectives*, 59 (2008), 12-27.
- [19] JENNY, H., A. NEUMANN, B. JENNY AND HURNI, L. A WYSIWYG interface for user-friendly access to geospatial data collections. In *Preservation in Digital Cartography*, ed. M. Jobst, 221-238. Berlin / Heidelberg / New York, Springer, 2010.
- [20] JQUERY PROJECT jQuery API. http://docs.jquery.com/Main_Page (last accessed 2015-03-01).
- [21] KESSLER, F. C. AND SLOCUM, T. A. Analysis of thematic maps published in two geographical journals in the twentieth century. *Annals of the Association of American Geographers*, 101 2 (2011), 292-317.
- [22] KIM, B. AND JEONG, S. A comparison of algorithms for origin-destination matrix generation on real road networks and an approximation approach. *Computers and Industrial Engineering*, 1 56 (2009), 70-76.
- [23] KORDUAN, P. AND ZEHNER M. L. *Geoinformation im Internet: Technologien zur Nutzung raumbezogener Informationen im WWW*. Heidelberg, Wichmann, 2008.
- [24] KRAAK, M.-J. From geovisualisation toward geovisual analytics. *The Cartographic Journal*, 45 3 (2008), 163-164.

- [25] KRAAK, M. J. AND ORMELING, F. Cartography: visualisation of geospatial data. Boston, MA, Pearson Education, 2010.
- [26] LONGLEY, P. A., M. F. GOODCHILD, D. J. MAGUIRE AND D. W. RHIND, D. W. Geographic information systems and science. New York, NY: John Wiley & Sons, 2011.
- [27] MILLER, C. C. AND BOSMAN, J. E-books outsell print books at Amazon. http://www.nytimes.com/2011/05/20/technology/20amazon.html?_r=1&Dscp=2&Dsq=amazon&Dst=cse (last accessed 2015-03-01).
- [28] MORRISON, J. L. The science of cartography and its essential processes. *International Yearbook of Cartography*, 16 (1976), 84-97.
- [29] POORE, B. S. The open black box: the role of the end-user in GIS integration. *The Canadian Geographer*, 47 1 (2003), 62-74.
- [30] POSTER, M. Consumption and digital commodities in the everyday. *Cultural Studies*, 18 2 (2004), 409-423.
- [31] RAMM, F., J. TOPF AND CHILTON, S. OpenStreetMap: using and enhancing the free map of the world. Cambridge, UIT, 2010.
- [32] ROBINSON, A. H., J. L. MORRISON, P. C. MUEHRCKE, A. J. KIMERLING AND GUPTILL, S. C. Elements of cartography. New York, NY, Wiley & Sons, 1995.
- [33] SCHUURMAN, N. The ghost in the machine: spatial data, information and knowledge in GIS. *Canadian Geographer*, 47 1 (2003), 1-4.
- [34] SWIENTY, O. Attention-guiding geovisualisation. A cognitive approach of designing relevant geographic information. PhD thesis. München, Technische Universität, 2008.
- [35] TURNER, A. J. Introduction to Neogeography. Sebastopol, CA, O'Reilly Media, 2006.
- [36] ZIPF, A. OpenStreetMap - Datenqualität und Potentiale der Nutzung mit OpenGIS Diensten in 2D und 3D. In GIS-Report 2010/11, B. Harzer, Ed. Karlsruhe, Bernhard Harzer Verlag, 2010, pp. 33-58.