1

The Power of Geographical Visualizations

Martin Dodge, Mary McDerby and Martin Turner

School of Environment and Development and Research Computing Services, University of Manchester

> Now when I was a little chap I had a passion for maps. I would look for hours at South America, or Africa, or Australia, and lose myself in all the glories of exploration. At that time there were many blank spaces on the earth and when I found one that looked particularly inviting on a map (but they all look that) I would put my finger on it and say, 'When I grow up I will go there'.
>
> (Joseph Conrad, *Heart of Darkness, 1902*)

> I believe we need a 'Digital Earth'. A multi-resolution, three-dimensional representation of the planet, into which we can embed vast quantities of geo-referenced data. . . . Imagine, for example, a young child going to a Digital Earth exhibit at a local museum. After donning a head-mounted display, she sees Earth as it appears from space. Using a data glove, she zooms in, using higher and higher levels of resolution, to see continents, then regions, countries, cities, and finally individual houses, trees, and other natural and man-made objects. Having found an area of the planet she is interested in exploring, she takes the equivalent of a 'magic carpet ride' through a 3-D visualization of the terrain. Of course, terrain is only one of the many kinds of data with which she can interact. . . . she is able to request information on land cover, distribution of plant and animal species, real-time weather, roads, political boundaries, and population.
>
> (Former Vice President Al Gore, *The Digital Earth: Understanding our Planet in the 21st Century, 1998*)

Geographic Visualization Edited by Martin Dodge, Mary McDerby and Martin Turner

OTE/SPH OTE/SPH
JWBK144-01 February 20, 2008 10:36 Char Count= 0

1.1 Aims

'Geography' has the potential to provide the key to a whole raft of innovative means of information representation through the use of interactive spatial visualizations. This use is clearly seen in the rapid growth and uptake of geographic information systems (GIS), multimedia cartography, virtual globes and all manner of Web-based mapping tools that are currently available. *Geographic visualization* is a significant and growing area and for this book we take a necessarily broad view of what it constitutes. Drawing upon Harley and Woodward's (1987, xvi) definition of mapping, we see geographic visualization as the application of any graphic designed to facilitate a *spatial* understanding of things, concepts, conditions, processes or events in the human world.

The goal of this book is to explore the 'state of the art' of geographic visualization relevant to the social scientists, in particular, reviewing current and popular methods and techniques, examining software tools, and reporting on the development of new applications to support both research and pedagogy. In some senses this book represents a 10-year updating of the Advisory Group on Computer Graphics-sponsored 'Graphics, Visualization and the Social Sciences'[1] workshop held in May 1997. It is relevant now to see what has changed (for example, affordable mobile tracking and mass market in-car satellite navigation with increasingly sophisticated dynamic graphics) and what unexpected developments have occurred (powerful and accessible 'geoweb' tools for example, Google Maps, Google Earth, NASA World Wind, TerrainView-Globe and Microsoft Virtual Earth). It is also important to see where weaknesses and blockages still lie; so in the future these areas, through further research, can be resolved and social sciences then can exploit geographic visualizations to another level.

1.2 The nature of geographic visualization

To understand the power of visualization, one must grasp how it both stirs the imagination for exploration and works instrumentally in the exploitation of new spaces. As Joseph Conrad's narrator Marlow makes clear in the famous passage from the *Heart of Darkness*, maps (an archetype of geographic visualization) open up space to the imagination, even from a very early age. Furthermore, geographic visualization, primarily in the form of paper maps has, over millennia, provided uniquely powerful instruments by which to classify, represent and communicate information about spaces that are too large and too complex to be seen directly.

The ability to create and use geographic visualizations in the form of cartographic maps has been one of the most basic means of human communication, at least as old as the invention of language and arguably as significant as the discovery of mathematics. The recorded history of cartography, for example, clearly demonstrates the long pedigree and practical utility of geographic visualization in all aspects of Western society, being most important for organizing spatial knowledges, facilitating navigation and controlling territory. Some have gone further, to argue that spatial mapping processes are culturally universal, evident across

[1] Organized by Anne Mumford, Michael Batty and David Unwin; workshop report available at: http://www.agocg.ac.uk/wshop/33/33.pdf.

all societies (Blaut *et al.*, 2003), although the material and semiotic forms of the artefacts produced are diverse. At the same time as working pragmatically, geographic visualizations are also rhetorically powerful as graphic images that frame our understanding of the human and physical world, shaping our mental image of places, and constructing our sense of spatiality. So, in a very real sense, geographic visualization makes our world; and to an increasing extent may become our world.

Historically geographic visualizations visually represent a physical landscape often using the cartographic norms of a planar view – looking straight down from above – and a consistently applied reduction in scale. However, with the range of approaches available today it is impossible to neatly define geographic visualization according to a single type of mapping phenomena, the particular mode of presentation or their medium of dissemination. Geographic visualization has traditionally been in the form of printed maps and globes used as static storage devices for spatial data, but now they are much more likely to be interactive tools displayed on a computer screen. So today, we live in a map-saturated world (Wood, 1992), continually exposed to conventional geographic maps, along with many other map-like spatial images and media (for example three-dimensional city models, MRI scans of the brain, virtual globes on the news). Contemporary developments in computer-based geographic visualization are opening up unique ways to visually understand the complex, multivalent and intangible nature of space and society; some of this was considered within the now prophetic speech by former Vice President Al Gore when describing a possible future *Digital Earth* (Gore, 1988), which would be a geographically data-rich and selectively data-interactive globe representation.

Geographic visualization now covers a range of different scales from individual properties up to global scale visualization of vast landscapes of data and contains the graphical data-mining of the daily interactions of millions of people. Some of the geographic visualizations adhere to established conventions of cartographic design, but many more are employing quite different visual vocabularies. Some geographic visualization applications are beautiful; many more are really rather ugly in terms of aesthetic values. Some are actually quite useful as practical tools for social science analysis, but many visualization tools are not workable for real-world analysis.

This diversity in geographic visualization approaches can be usefully conceptualized into three broad epistemological classes. These classes we might call by the shorthand: 'looking', 'querying' and 'questioning'. Each class has increasing power to augment the human capacity in order to analyse and understand the world.

- '*Looking*': these are presentation graphics, thematic maps and charts that display data according to spatial coordinates. They have proved to be relatively easy to produce and are widely used in reports and papers. The next generation of presentation graphics (on websites with flash for example) go beyond just static images to utilize animation and interactive 2.5D data landscapes as well as fully 3D layered information spaces. The user is able to navigate through the landscape and animate it to display time-oriented information, make simple interactive queries on data items, and perhaps even calibrate display parameters (for example symbology, scales and classifications).

- '*Querying*': these are visual interfaces designed for information access. Based on database and data-mining techniques, they focus on enabling users to navigate through complex information spaces in order to locate and retrieve task-relevant subsets of information.

Supported user-tasks involve searching, backtracking and history-logging. User interface techniques attempt to preserve user-context and support smooth transitions between locations.

- ‘*Questioning*’: these are full visual discovery and modelling structures. These systems combine the visual insights communicated by presentation graphics with an ability to probe, drill-down, filter and manipulate the display to answer the ‘why’ questions as well as the ‘what’ question. The difference between answering a ‘what’ and a ‘why’ question involves highly interactive operations and the capacity to simulate change. Interaction techniques let the user directly control the display of data, for example through projections, filtering, zooming and linked displays and brushing. Real-time response is necessary and often the linkage of multiple visualizations metaphors. Distortion techniques can also help in the interactive exploration process by providing a means for focusing while preserving an overview of the data (so-called ‘focus + context’).

1.3 The visualization process

In essence, geographic visualization exploits the mind’s ability to more readily see complex relationships in images, and thus provide a clear understanding of a phenomenon, reducing search time and revealing relationships that may otherwise not have been noticed. It is a process which works essentially by helping people to see the unseen, premised on the simple notion that humans can reason and learn more effectively in a visual environment than when using textual or numerical description.

The ability of geographic visualization to elucidate meaningful patterns in complex data is clearly illustrated by some of the ‘classics’ from the pre-digital era, such as John Snow’s ‘cholera map’ of 1854 (Johnson, 2006), Charles Joseph Minard’s ‘Napoleon map’ of 1869 (see Chapter 15) or Harry Beck’s ‘Tube diagram’ of 1933 (Garland, 1994). Even though these were all hand-drawn on paper, they are nonetheless still effective today and show the potential of geographic visualization to provide new understanding and compelling means of communicating to a wide audience. Their novel visual forms mean they also demonstrate the extent to which geographic visualization can be a creative design practice in and of itself. The best geographic visualizations go beyond merely representing to become a kind of cognitive shorthand for the actual places and processes themselves, as is illustrated in Beck’s celebrated diagrammatic design of the London Underground (the Tube map), which has become such a powerful spatial template for the ‘real’ layout of London in the minds of many visitors and residents.[2]

Geographic visualization works by providing graphical ideation to render a place, a phenomenon or a process visible, enabling the most powerful human information-processing abilities – those of spatial cognition associated with the eye–brain vision system – to be directly brought to bear. Visualization is thus a cognitive process of learning through the active engagement with graphical signs that make up the display, and it differs from passive observation of a static scene, in that its purpose is also to discover unknowns, rather than

[2] The ‘problem’ is that, although Beck’s visualization works well for underground movement, it can be confusing for surface navigation because it famously sacrifices geographic accuracy for topological clarity.

to see what is already known. Effective geographic visualization should reveal novel insights that are not apparent with other methods of presentation. In an instrumental sense, then, geographic visualization is a powerful prosthetic enhancement for the human body: '[l]ike the telescope or microscope, it allows us to see at scales impossible for the naked eye and without moving the physical body over space' (Cosgrove, 2003, p. 137).

1.4 Digital transition and geographic visualization

The development and rapid diffusion of information and communication technologies in the last three decades has affected all modes of geographic visualization, changing methods of data collection, cartographic production and the dissemination and use of maps. This has been termed the 'digital transition' in mapping (Pickles, 2004) and it is continuing apace (for example, developments in mobile communications and location-based services; see Chapter 16; Raper *et al.*, 2007). As such it is a vital component in understanding the milieu in which new modes of geographic visualization are emerging. Nowadays, most geographic visualizations are wholly digital and created only 'on demand' from geospatial databases for temporary display. The Web mapping portal MapQuest.com, for example, has already generated more digital maps than any other publisher in the history of cartography (Peterson, 2001); the popularity of Google map's API,[3] launched in the summer of 2005, has inspired an explosion of new online mapping tools and hacks (Gibson and Erle, 2006), and there is even the prospect that GIS itself will begin to adapt and evolve around such a Web services mapping model (Miller, 2006).

Cheap, powerful computer graphics on desktop PCs, and increasingly mobile devices, enable much more expressive and interactive geographic visualization that are potentially available to a growing number of people. The pervasive paradigm of hypertext as a way to structure and navigate information has also influenced digital geographic visualization and increasingly it is being used as a core component in larger multimedia information resources where locations and features on the map are hot-linked to pictures, text and sounds, to create distinctively new modes of geographic interaction (see Chapters 6 and 9). In design terms, the conventional planar map form itself is, of course, only one possible representation of geographic data and new digital technologies have enabled much greater diversity of forms, including pseudo 3-D landscape views, interactive panoramic photo image-maps, fully 3-D fly-through models and immersive VR space (see Chapters 9–11; Dykes, MacEachren and Kraak, 2005). Developments in computer graphics, computation and user interfaces have enabled visualization tools to be used interactively for exploratory data analysis (typically with the interlinking of multiple representations such as statistical charts, 3-D plots, tables, and so on).

Developments in networking and computer-mediated communications, and the rise of the World-Wide Web in the mid 1990s, means that now geographic visualizations are very easy to distribute at marginal cost and can be accessed 'on demand' by almost anyone, anywhere. The provision of Web mapping and online GIS tools is significantly shifting the accessibility to geographic visualization and spatial data, as well as altering the user

[3] An API (application programming interface) allows technically savvy users direct access to the database enabling sophisticated and novel third-party applications to be developed.

perception of what they can do. There are clear signs that geographic visualization will be seen as simply one of many available 'on demand' Web or portal services to the general public and integrated or 'mashed-up' within a multitude of other applications. As geographic visualization becomes more flexible and much more accessible, it is also, in some respects, granted a less reified status than the printed artefacts of the past. Visualizations will increasingly be treated as transitory information resources, created in the moment and discarded immediately after use. In some senses, this devalues the geographic visualization as it becomes just another form of ephemeral media, one of the multitude of screen images that barrage people everyday. Geospatial data itself is just another informational commodity to be bought and sold, repackaged and endlessly circulated.[4]

The production of geospatial information has always been dependent, to a large degree, on the available methods of data collection. These are being greatly augmented in the digital transition. The widespread importance of new digital measurement was noted by US National Science Foundation Director Rita Colwell (2004, p. 704): 'new tools of vision are opening our eyes to frontiers at scales large and small, from quarks to the cosmos'. Geographic visualization's ability to 'capture' the world has been transformed by digital photogrammetry, remote sensing, GPS-based tracking and distributed sensor network. Cartography can not only 'see' the world in greater depth (Pickles, 2004), but it can also 'see' new things (including virtual spaces), and with new temporalities.

Vast digital geospatial databases underlie many powerful geographic visualizations, such as the Ordnance Survey's Digital National Framework, comprising over 400 million features.[5] These are growing as part of the 'exponential world', being fed in particular by high-resolution imagery from commercial satellites. In the future, much of this growth will come from people gathering geospatial data as they go about their daily activity, automatically captured by location-aware devices that they will carry and use (see Chapter 16). From this kind of emergent mobile spatial data capture, it will be possible to 'hack' together new types of geographic visualization rather than be dependent on the products formally published by governments or commercial firms. Such individually made, 'amateur' mapping may be imperfect in many respects (not meeting the positional accuracy standards or adhering to the TOPO-96 surveying specifications, for example), but could well be better fit-for-purpose than professionally produced, generic visualization applications. There is also exciting scope for using locative media to annotate individual geographic visualization with ephemeral things, personal memories and messages for friends, which are beyond the remit of government agencies or commercial geospatial industry (Kwan, 2007).

1.5 The politics of visualization

The process of geographic visualization is also engendered because the objects are often visually appealing in their own right. The aesthetics of well-designed cartographic maps or

[4] However, the emergence of open-source cartography, as exemplified by the OpenStreetMap project, has the potential to challenge the commercial dominance over geospatial data by developing a 'bottom-up' capture infrastructure that is premised on a volunteerist philosophy.

[5] Source: www.ordnancesurvey.co.uk/oswebsite/media/news/2001/sept/masterchallenge.html.

globes, for example, is central to their success in rhetorical communication and means they are widely deployed as persuasive devices to present ideas, themes and concepts that are difficult to express verbally, as well as serving as decorative objects. The result, according to Francaviglia (1999, p. 155), is that '[c]artographers draw maps that have the power to both inform and beguile their users'. Most of the geographic visualization encountered on a daily basis (often with little conscious thought given to them) are maps used in the service of persuasion, ranging from the corporate marketing map to the more subtle displays such as states' claims to sovereign power over territory, implicitly displayed in the daily weather map seen on the news (Monmonier, 1996).

The production of geographic visualization involves a whole series of decisions, from the initial selection of what is to be measured, to the choice of the most appropriate scale of representation and projection, and the best visual symbology to use. The notion of 'visualization as decision process' is useful methodologically because it encourages particular ways of organized thinking about how to generalize reality, how to distil inherent, meaningful spatial structure from the data, and how to show significant relationships between things in a legible fashion. Geographic visualization provides a means to organize large amounts of, often multi-dimensional, information about a place in such a fashion as to facilitate human exploration and understanding. Yet, visualization practices are not just a set of techniques for information 'management'; they also encompass important social processes of knowledge construction. As scholars have come to realize, vision and culture are intimately entwined and inseparable (Pickles, 2004). Geographic visualization then is both a practical form of information processing and also a compelling form of rhetorical communication.

It must be recognized that geographic visualization is a process of creating, rather than revealing, spatial knowledge. Throughout the process of visualization creation a large number of subjective, often unconscious, decisions are made about what to include and, possibly more importantly, what to exclude, how the visualization will look, and what message the designer is seeking to communicate. In this fashion, geographic visualization necessarily becomes imbued with the social norms and cultural values of the people who construct them.

While contemporary geographic visualization developments, such as Google Earth and other online virtual globes (see Chapter 2), can be seen as a logical and even 'natural' evolution of 'flat' map representations, whose aim is to enhance users' knowledge of new spaces, making navigation and commerce more efficient and increasing the 'return-on-investment' in existing geospatial data by facilitating wider distribution on the Web, we would argue that the situation with geographic visualization is also more contestable. Only certain geographic visualizations get made and they show only certain aspects, in certain ways. They are not inherently 'good' and will certainly not be beneficial to all users. The visualization of geographic space is not a benign act, instead particular visualizations are made to serve certain interests. These interests may reflect dominant power relations in the society, especially when individuals and institutions with power commission a great deal of geographic visualization and control access to underlying data resources. Thus geographic visualizations are not objective, neutral artefacts but a political view point onto the world (Monmonier, 1996; Pickles, 2004). The prospect of propaganda and deceptive manipulation with geographic visualization always at times may rear its ugly head.

1.6 The utility of geographic visualization

Geographic visualizations have long been used in scholarly research of social and physical phenomena. They are, of course, a primary technique in geography but they are also widely used in other disciplines such as anthropology, archaeology, history and epidemiology, to store spatial data, to analyse information and generate ideas, to test hypotheses and to present results in a compelling, visual form. Geographic visualization as a method of enquiry and knowledge creation also plays a growing role in the natural sciences (for example, biological brain functional sensor mappings). This work is not limited to cartographic mapping; many other spatial visualization techniques, often using multi-dimensional displays, have been developed for handling very large, complex spatial datasets without gross simplification or unfathomable statistical output (for example, volumetric visualization in atmospheric modelling).

Within many social science disciplines there are growing signs of a ‘spatial turn’ as research questions and modes of analysis centre around geographic location and understanding of spatial relations and interactions come to greater prominence. Many social science disciplines are exploiting the spatial components of large data that they have collected or generated to facilitate their analysis. Interactive geographic visualization is then a crucial research tool.

Outside of academia there is also a great deal of excitement in so-called neogeography (Turner, 2006) and geographic visualization. This is most evident in terms of popular online mapping of data and new types of application – such as map ‘mash-ups’ using Google maps, the map hacking and open-source mapping activists using cheap GPS to visualize the world afresh. The value of high-resolution aerial photography and satellite imagery for ‘backyard’ visualization is being unlocked into easy (and fun) browsable interfaces such as Google Earth and Microsoft Local Live.

1.7 Conclusions

Although geographic visualization is a powerful research method for exploration, analysis, synthesis and presentation, it is not without its problems. Three particular issues are worth discussing: practical limitation, ethical concerns and political interests. Firstly, there are many practical issues to be faced and it is important to acknowledge the investment of time and effort necessary to make effective and appropriate geographic visualizations. Certain processes are now much easier to do today than in the past, but it is not necessarily a quick fix. Like any chosen research technique, the potential of geographic visualization has external practical constraints, including data quality and the level of user knowledge.

There are also issues to consider relating to the ethics and responsibility of researchers producing geographic visualization. As noted above, the processes of data selection, generalization and classification and the numerous design decisions mean that one can never remove the subjective elements in the process. Accordingly, Monmonier (1993, p. 185) argues in relation to thematic maps (and equally applicable to other geographic visualization):

> . . . any single map is but one of many cartographic views of a variable or a set of data. Because the statistical map is a rhetorical device as well as an analytical tool, ethics require that a single map not impose a deceptively erroneous or carelessly

> incomplete cartographic view of the data. Scholars must look carefully at their data, experiment with different representations, weigh both the requirements of the analysis and the likely perceptions of the reader, and consider presenting complementary views with multiple maps.

Further, some of these new forms of geographic visualizations open up society to a new kind of surveillance, revealing interactions that were previously hidden in unused transactions and databases. The act of visualization itself may constitute an invasion of privacy (Monmonier, 2002). If the appeal of some spaces is their anonymity, then people may object to them being placed under wider scrutiny, even if individuals are unidentifiable. Here, public geographic visualization and analysis may well represent an infringement of personal rights, especially if the individuals were not consulted beforehand and have no means to opt out. Thus, it is important to consider the ways in which, and the extent to which, geographic visualizations of social spaces are 'responsible artefacts' that do not destroy what they seek to represent or understand.

Lastly, it should be recognized that geographic visualization is also a cultural process of creating, rather than merely revealing, knowledge. All the sophisticated, interactive geographic visualizations have politics, just the same as any other form of representation, and we must be alert to their ideological messages. Geographic visualization for social scientists can prove to be very valuable, but at the same time they can never be value-free.

The future still requires research in many key unknown and under-explored areas, including uncertainty mapping, true temporal understanding and limits of human visual perception – but the future also is becoming more socially connected and geographic visualization may indicate a way forward.

References

Blaut, J. M., Stea, D., Spencer, C. and Blades, M. (2003) Mapping as a cultural and cognitive universal. *Annals of the Association of American Geographer* 93(1): 165–185.

Colwell, R. (2004) The new landscape of science: a geographic portal. *Annals of the Association of American Geographers* 94(4): 703–708.

Conrad, J. [1902] (1994) *Heart of Darkness.* London, Penguin.

Cosgrove, D. (2003) Historical perspectives on representing and transferring spatial knowledge. In *Mapping in the Age of Digital Media*, Silver, M. and Balmori, D. (eds). New York, Wiley-Academy, pp. 128–137.

Dykes, J., MacEachren, A. M. and Kraak, M.-J. (2005) *Exploring Geovisualization.* London, Elsevier.

Francaviglia, R. 1999. Walt Disney's Frontierland as an allegorical map of the American West. *The Western Historical Quarterly* 30(2): 155–182.

Garland, K. (1994) *Mr Beck's Underground Map.* Middlesex, Capital Transport Publishing.

Gibson, R. and Erle, S. (2006) *Google Mapping Hacks.* Sebastopol, CA, O'Reilly & Associates.

Gore, A. (1998) *The Digital Earth: Understanding our Planet in the 21st Century.* California Science Center, Los Angeles, CA, 31 January. Available at: www.isde5.org/al_gore_speech.htm.

Harley, J. B. and Woodward, D. (1987) *The History of Cartography, Volume 1. Cartography in Prehistoric, Ancient and Medieval Europe and the Mediterranean.* Chicago, IL, University of Chicago Press.

Johnson, S. (2006) *The Ghost Map*. London, Allen Lane.

Kwan, M.-P. (2007) Affecting geospatial technologies: toward a feminist politics of emotion. *The Professional Geographer* 59(1): 22–34.

Miller, C. C. (2006) A beast in the field: the Google maps mashup as GIS/2. *Cartographica* 41(3): 187–199.

Monmonier, M. (1993) *Mapping It Out*. Chicago, IL, University of Chicago.

Monmonier, M. (1996) *How To Lie With Maps*, 2nd edn. Chicago, IL, University of Chicago Press.

Monmonier, M. (2002) *Spying with Maps: Surveillance Technologies and the Future of Privacy*. Chicago, IL, University of Chicago Press.

Peterson, M. P. (2001) The development of map distribution through the Internet. *Proceedings of the 20th International Cartographic Conference*, Vol. 4, pp. 2306–2312.

Pickles, J. (2004) *A History of Spaces: Cartographic Reason, Mapping and the Geo-Coded World*. London, Routledge.

Raper, J., Gartner, G., Karimi, H. and Rizos, C. (2007) A critical evaluation of location based services and their potential. *Journal of Location Based Services* 1(1): 5–45.

Turner, A. 2006. *Introduction to Neogeography*. Sebastopol, CA, O'Riley Media.

Wood, D. 1992. *The Power of Maps*. New York, Guilford Press.