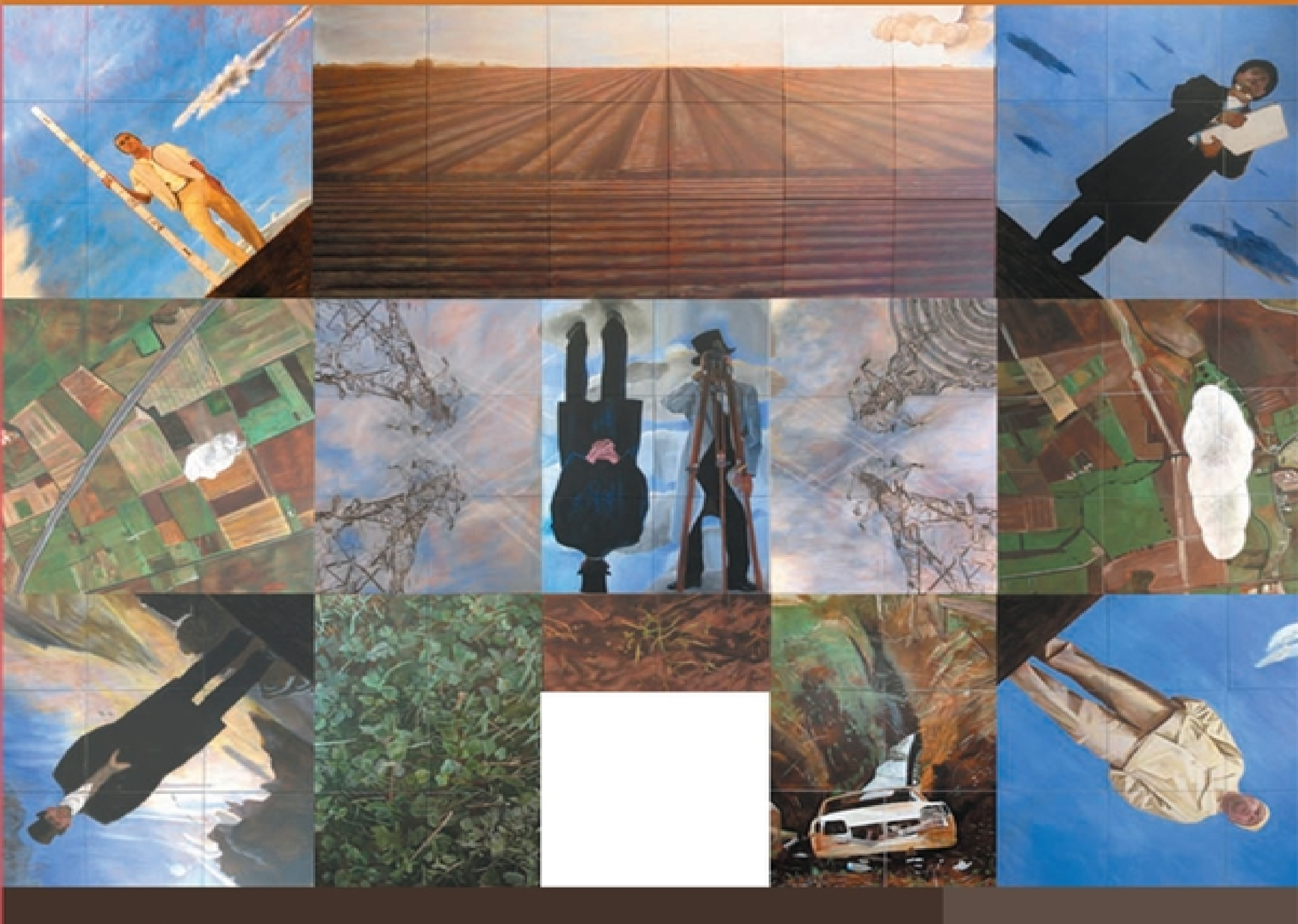
Geographic Visualization

Concepts, Tools and Applications

Martin Dodge | Mary McDerby | Martin Turner



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Martin Dodge dedicates this book to Maggie
Mary McDerby dedicates this book to her mother
Margaret Murray (1944–2006)

Foreword Encounters with (Geo) Visualization

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This volume presents essays that collectively give an overview of the current state of the art in what has become to be known as ‘geovisualization’, the exploratory analysis by graphics of data in which their spatial location is used as an important and necessary part of the analysis. In this forword I examine the scientific, geographical and administrative contexts in which geovisualization has developed in UK, concluding with a series of concerns related to where it is now heading.

Contexts: scientific

The scientific background to visualization is both well known and well documented. Traditionally in science, graphical modelling is subservient to mathematical and even statistical analysis: although colloquially we might ‘see’ a result, invariably the preferred form of analysis is by mathematics or statistics. This started to change in the 1960s with the increasing use of computers to draw pictures for which a variety of stand-alone computer programs with names like GHOST, GINO and PICASSO were developed. However, it took a series of other necessary changes before arguments based on graphics became accepted, if not on equal terms with mathematical and statistical modelling, at least as part of the basic toolkit of scientific investigation.

First, throughout the sciences developments in sensor technology and automated data capture now provide data at rates faster than can easilybe converted into knowledge. Second, some of the most exciting discoveries have been associated with non-linear dynamics where apparently simple equations like the finite difference form of the logistic conceal enormously complex, but real-world-like, behaviour that can only be appreciated when displayed graphically. Third, as science has progressed to produce ever more complex simulation models, so it became necessary to use graphics as the only practicable way to assimilate all the model outputs. Particularly relevant examples include the complex, large-scale environmental simulations provided by atmospheric general circulation models used in the verification of the carbon dioxide-induced greenhouse warming hypothesis and complex social simulations of the spatial behaviour of whole populations based on models of individual behaviour. Finally, there have been enormous changes in our computing environment, all of which promote graphics as the major communication medium. It is easy to forget how far we have come. Even as late as the 1980s, colour displays were expensive luxuries needing substantial computer power to drive them, most hard copy was by way of monochrome pen plotters, and software was still in the form of subroutine libraries such as GINO, GHOST and GKS or in visualization systems such as IBM Explorer, AVS and PV-WAVE. If you wanted to use a computer to draw maps, chances were that you were in for a difficult and expensive time. For example, in 1980 the Census Research Unit at Durham University published an atlas of maps of the 1971 UK Census of Population (Census Research Unit, 1980), which used the then-new laser printing technology to produce, at great difficulty and expense, maps with individual colour symbolism for each and every kilometre grid square over Britain. At the time, these were the most detailed population maps at this scale and resolution ever produced.

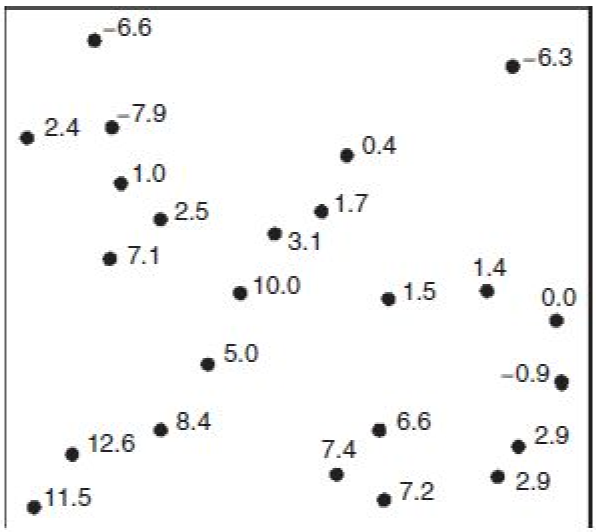
As our computing norm we now have ‘point and click’ graphic interfaces to very large and fast machines equipped with high screen and spectral resolution displays and, thanks to the World Wide Web, graphical communication has become easier and easier. Nowadays, if you want to draw a map, a few mouse clicks using some cheap and easy to use software is all that are required. If you want to explore the map content using visual methods, then the same software will provide all the necessary resolution, colour, linkage back to the data, and so on, that are required. Provided you have the data, high spatial resolution population maps of UK are relatively easy to create on the desktop with standard hardware. In this new environment, the software can take the role of a toolkit to enable the scientist to create data displays that enable the exploratory development and testing of ideas that may later form the basis of more formal hypotheses and mathematical models.

Contexts: geographical

The geographical context is perhaps a little less well-known, but given the general changes outlined above, it was inevitable that some cartographers would ‘morph’ into ‘geovisualizers’ and that the two traditions of cartography and scientific visualization using computer graphics would intersect to give what has become known as geovisualization. This union has taken place alongside the increasing use of ‘location’ in almost all walks of life and the increasingly widespread availability and use of geographical information systems software. A brief visit to almost any GIS trade exhibition, or, more to the point, a look at the ‘map gallery’ at the annual ESRI San Diego User Conference (www.esri.com/events/uc/results/map_gallery_results.xhtml), will show that maps continue to be not only the main selling point for GIS and associated data products, but also are one of the principal outputs from such systems. One result of the democratization of mapping, in which every map user can also now become the cartographers, has been a huge increase in the use of maps. Sometimes, as at the ESRI conferences, these are fine examples of the art and science of cartography, but all too often the products show ignorance of quite basic cartographic design, and miss the potentials available had these same data been analysed using modern geovisualization techniques.

It is certainly true that spatial coordinates can be treated simply as just two additional variables added to an existing set to be visualized. From this perspective there is nothing particularly special about adding geographical space. Yet experience suggests that, although the techniques used might look much the same as those used in more general scientific visualization, there is actually something that is special about 'geo'. In part this is to do with the ubiquitous presence in the real world of spatial autocorrelation, but I suspect it is also to do with what for want of a better word I call 'context'. Consider the very simple set of 24 numbers located geographically by the eastings and northings of some geographical grid shown below. These data can be analysed as a simple problem in general scientific visualization by interpolation of a continuous surface passing through them. However, if I provide you with the context that these numbers are mean January temperatures across the Rocky Mountain foothills in Alberta, I strongly suspect that you will realize that your initial analysis is faulty. Adding the real world context provided by spatial location adds much more than just two or more additional columns of data, and I am not sure the same would be said, for example, if these numbers had been the rate of a chemical reaction visualized in a space provided by temperature and pressure coordinates.

Figure F.1 Some numbers to be visualized?



Generations of cartographers have accumulated a great deal of knowledge of how these real world contexts can be addressed in their mappings, of what ‘works’ and what does not ‘work’. Just because this knowledge has resisted formalization is no reason to ignore it. There is a continuing educational agenda here, in coupling those who have only recently discovered how useful maps can be to the community of cartographer/geovisualizers whose work is reported here and to the accumulated cartographic knowledge they bring into their work.

Contexts: organizational

This volume has a direct ancestral link back to a similar workshop sponsored by the (UK) Association for Geographic Information’s Education and Research Committee and organized by the ESRC Midlands Regional Research Laboratory in Loughborough in 1992. The result then was an edited book which took the workshop title *Visualization in*

Geographical Information Systems (Hearnshaw and Unwin, 1994; see also Unwin, 1994). In turn this spawned two further workshops on *Visualization in the Social Sciences* (1997, reported at www.agocg.ac.uk) and *Virtual Reality in Geography* (Fisher and Unwin, 2002). The second and third workshops were sponsored by a group set up by the UK academic research councils as their Advisory Group on Computer Graphics (AGOCG), a body I had been invited to join some time in the early 1980s as a representative of some hypothetical 'typical user' of graphic output from computers. As a geographer with a strong interest in cartography, sitting at meetings of this group was very instructive. First, as perhaps might have been expected, working with people very much at the cutting-edge of scientific research in computer graphics in UK, I became aware of the possibilities for cartography inherent in the newly developed and developing technology (see Brodlie *et al.,* 1992). Second, what perhaps was not so expected was the realization of the potential that cartography had to offer scientific visualization in areas such as what, for want of a better word, I will call the theory of graphics and graphical understanding, the use and perception of colour in graphics, symbology and so on. In the computer graphics community, the various works of Tufte were some sort of gospel and the work was conducted in almost complete ignorance of over a century of accumulated experience in the mapping and display of thematic spatial data. Much as I admire the spirit in which they were produced, the various books by Tufte are neither the only nor the last, word in graphical excellence. Dogmatic and essentially pre-computer he may be, but at the time even Bertin (1967, 1981) had much to offer this community (see Muller, 1981).

But … what questions remain?

Reading the contributions to this volume makes it clear that much of what in the 1990s seemed to be at the cutting edge, such as the use of visually realistic displays, density estimation to visualize point patterns, area cartograms, linking and brushing, and map animation, have become commonplace. First and foremost, this volume reports immense progress in the further harnessing of the available technology to facilitate the visualization of geographic data. However, what I think stands out plainly from a comparison with the outputs from the history I have outlined is just how enduring some of the underlying themes have become. Examples in no special order include the balance between photo-realism and cartographic generalization in virtual reality, animation, projection (cartograms), conveying error/uncertainty graphically and temporal change. I suspect that there is more to this than at first meets the eye and that it is symptomatic of maybe three underlying problems in geovisualization.

The first concerns the interplay between the data that are being visualized, their geographical context and the technology used. Given that we have a research need to use visualization to generate, test and present ideas about some geographic data, three basic strategies might be recognized. The first is the geovisualization route, to provide affordances that enable interactive exploration of these data using object linking, brushing, and so on, but, by and large, leaving the data intact. The second is the spatial analytical route, to modify the numbers to be mapped by some form of arithmetic manipulation, for example by conversion into density estimates, probabilities against some hypothesized process or the derivation of 'local' statistics to isolate areas of specific research interest. The third, and least commonly adopted, is what I chose to call Tobler's way, which is to re-project these same data into a space, such as an area cartogram, in which some notion of geographic reality is better evident. For a ludicrously early and perceptive example of this see Tobler (1963).

Currently, work seems to be channelled down one or other of these three routes, yet it should be clear that most progress is likely to be made by combining them. The recent paper by Mennis (2006) provides an example of careful visualization of the results of the local statistical operation known as geographically weighted regression. Similarly, a classical spatial analytical tool, the Moran 'scatterplot' (Anselin, 1996), seldom makes much sense unless it is object-linked back to a choropleth map of the individual values. Doubtless the reader can provide other examples.

My second issue is that, despite the best efforts of some cartographers and members of the geographic information science community, as yet we seem to have little by way of 'well found' theory to enable us to answer basic visualization questions such as 'what works?', 'why does it work?' and even 'what's likely to be the best way of displaying these data?' What we have are some moderately well-articulated design rules, some interesting speculation based in, for example, communication theory or semiotics, some results from usability and perception experiments, and appeals to our instincts. The result is that in geovisualization we can be accused of finding tricky ways of turning one complex, hard-to-understand graphic and its associated data into another that is equally complex and hard to understand. It may well be that the basis for such theory exists and that what is lacking is the required synthesis, but it may also be that it cannot be formalized.

My third and final issue relates to the use of geovisualization and its relationship to the derivation, testing and presentation of social scientific theory. It was not the intention of any of the authors of the chapters in this volume to address this issue, but I doubt that in social science any hypothesis generation *ab initio* using graphics is either possible or even desirable. If this proposition seems unduly heretical in a forword to a book such as this, by way of evidence in its favour, I would point out that we do not to my knowledge have any published examples of pure hypothesis generation from graphics. Perhaps nobody is willing to come clean on the issue? The interplay between graphics, theory and prior domain knowledge seems to me to be always more complex than we usually recognize.

What I think we have in social science are examples of its use as a means of *testing* existing hypotheses. Nowhere is the relation of graphic to underlying theory better documented than in recent deconstructions of John Snow's 'iconic' 1854 map of cholera deaths in Soho, London, and its visual demonstration that a single polluted water supply pump was its cause and not the then popular notion of a 'miasma' in the air. Armed with the digitized data, numerous people have used statistical analyses to verify Snow's visual association (see Koch and Denke, 2004), but it is the role of the map that has attracted most attention. Many people – myself included – have cited Snow's mapping as a classic example of a geovisualization that in some sense led to the hypothesis that cholera is water-borne. What emerges from the more recent debates (see Brody *et al.,* 2000; Koch, 2004, 2005; Johnson, 2006) is that Snow already had his hypothesis and that the map was a very specific *test* against the 'air-borne' alternative.

Of course the entire episode remains a superb example of what this volume's editors refer to as the 'power in visualizing geography'. This power may have developed and have been best articulated in the physical and natural sciences, but it is of particular relevance to the social sciences where, like John Snow over 150 years ago, we have complex, multi-dimensional data with a variety of measurement scales from which it is necessary to test often contested and mutable theories. This volume not only shows how much progress has been made, it also points to many ways by which geovisualization will develop in the future.

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Martin, Mary and Martin

The University of Manchester, September 2007

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