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Cartography and Visualization

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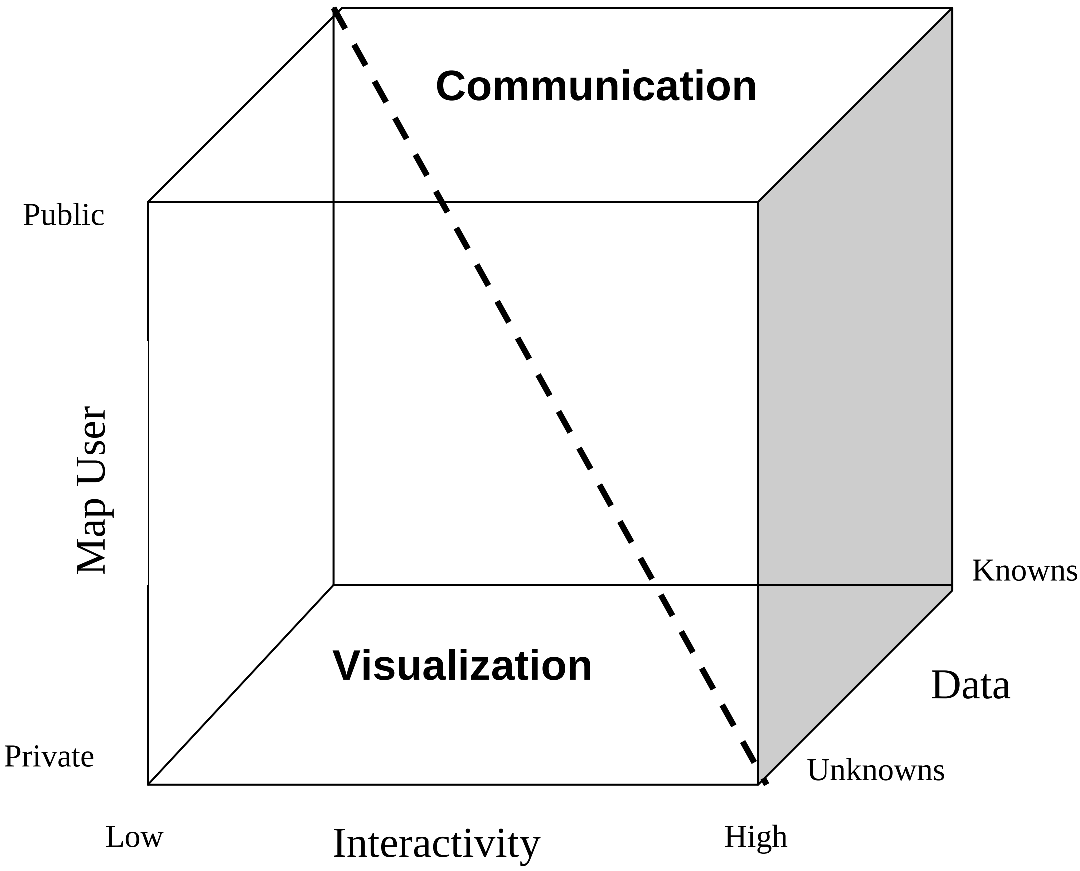
Cartography in the Twenty-first Century

Cartography has always been associated with geography. Indeed, in some people's minds geographers and maps are inseparable. In its traditional sense, cartography is viewed simply as the presentation of geographic information, using hand-drawn maps to express a sense of geography on paper to a wide audience. Such a view is valid but limited. It is challenged by the major technological and conceptual changes that have occurred in cartography during the past fifteen years. These changes are associated with the rapid development of computer technology, the increased availability of digital data and a growing need to understand an ever-complex world. Today maps are drawn very rarely by hand - anyone with access to a computer and mapping software can now create a map digitally and with relative ease. More importantly, cartography is branching out from its traditional rôle of (passively) presenting geographical information. It is currently moving towards a more cognitive rôle where maps are used in an exploratory, research capacity. Twenty-first century cartography is not just about drawing maps to communicate information to others. It is increasingly about using computational methods and visual displays to increase our understanding of the world around us by means of interactive, learning environments (MacEachren and Kraak, 1997). Cartography is now establishing links with disciplines such as computer science and statistics, and as a result, it is shifting its status within geography to be slowly integrated under the banner of ‘geographic information science’ (GISc) or ‘geocomputation’ – which includes Geographic Information Systems (GIS) and exploratory data analysis (EDA) (Unwin, 1999).

The recent changes in cartography have occurred partly in response to the emergence of scientific visualization (McCormack et al., 1987). This emphasizes the use of visual methods (or, ‘ways of seeing’) as an important part of the way knowledge is constructed. The motivation of scientific visualization is to ‘seen the unseen’ in the increasingly large and complex digital data sets used by scientists, and in this respect computational mapping is regarded as being a potentially excellent device to be used in the exploration of spatial digital data. To help conceptualise these innovations, DiBiase (1990) and MacEachren (1994b) have developed conceptual models that explain the different uses that maps can have. In DiBiase's typology, maps can be used for visual thinking (*exploring* geographic information) or visual communication (*presenting* geographic information). These categories are not mutually exclusive, however. In visual thinking, maps are used as research tools to help investigators search for properties in the data - revealing patterns and relationships and flagging unusual events. They are used in the exploratory and confirmatory stages of research and are not intended as a 'finished publication' or the 'final result'. They are intended to help the researcher. In contrast, maps associated with visual communication are used to illustrate a point, present ideas or demonstrate relationships to a general audience. They are intended to help other people. MacEachren (1994b) extends this model by incorporating the interactive and dynamic element afforded by computer technology. His model of cartography, shown in Figure 1, is referred to as **[CARTOGRAPHY]^3** with the space within the cube distinguishing maps used for visualization (visual thinking) and maps used for communication (visual communication). Using this model MacEachren argues that cartographic visualization is a private activity in which unknown facts are revealed in a highly interactive environment. In contrast, cartographic communication involves the opposite: a public activity in which known facts are presented in a non-interactive environment (Slocum, 1999). Both of these cartographic activities have an important rôle to play in our understanding and communication of geographical data. However, whereas we know a great deal about cartographic communication, our knowledge of cartographic visualization is still very much in its infancy.

Figure 1: **[CARTOGRAPHY]³** - a graphical representation of how maps are used. Axes relate to the user of the map, objectives of data use and the degree of interaction in the mapping environment. Within the cube, cartographic visualization is contrasted with cartographic communication along the three dimensions.



Source: Adapted from MacEarchren, 1994b, Fig. 1.3, 6.

Cartographic Visualization: seeing the unseen

Although cartography has always been concerned with visual thinking, the growth of computational cartography and the interactivity that this affords has qualitatively changed what people can do with maps. Maps that allow a high degree of interaction allow brushing, panning, zooming, rotation, dynamic re-expression (where the map is automatically updated after a change has been made) and dynamic comparison (linked views) as part of their functionality (Dykes, 1997). A linked view allows the user to select a point in one map to identify its location in another, for example. Such functions can be used in the exploratory analysis of spatial data and allow data to be analysed for unknown relationships, or answer questions such as 'what is the nature of the data set?' and 'is there a spatial relationship between different features?'. Another important innovation in cartographic visualization has been the introduction of dynamic visual variables such as animation, multimedia and virtual reality (Orford, et al., in Press). Together, dynamic visual variables and interactive tools can allow greater insights in a data exploration environment. They are particularly useful at the start of a visualization session when the user is 'getting to grips' with the data.

Perhaps one of the most influential innovations to affect cartography during the past decade has been the World Wide Web (WWW). Its highly graphical nature and also its multimedia content means that the WWW is an ideal medium for producing cartographic visualizations. Its interactivity and flexibility has enabled the growth of 'mapping on demand' (Cartwright. 1997). Map presentation is rapidly incorporating the interactivity of the WWW to allow dynamic and interactive dissemination of mapped information. For a good introduction to Web-based cartography students are referred to the book edited by Kraak and Brown (2001).

In 1990 Tufte (p. 9) wrote: "*The world is complex, dynamic, multidimensional; the paper is static, flat. How are we to represent the rich visual world of experience and measurement on mere flatland*?"

As we have identified, technological innovations may yet allow cartographic visualization to break free from a two-dimensional and inert worldview. However, the research concerned with cartographic visualization is still very much in the development stages and many issues remain unresolved. For instance, unlike the conventional techniques used in cartographic communication, virtually nothing is known about good practice - when it is good to use cartographic visualization techniques and when it is not (Dorling, 1998). For example, using animation to explore changes in the data is not necessarily easy, especially if many changes occur within a specified display time and all over the display area. Remaining blind to the most important trends or patterns is a frequent problem in visualization (MacEachren and Ganter, 1990).

Cartographic Communication: why good maps are important and why getting it right requires practice.

Despite the changing research emphasis towards a more complex visualization, for the vast majority of users cartography is still about producing maps to present geographical information. Ironically, the development of computerised and Web-based cartography has enabled both a ‘democratization’ of map-making and also a proliferation of rather inadequate maps! Thus Kraak and Brown (2001) have argued a case for a ‘back-to-basics’ in cartography. Since most geography students will still predominately use cartography for visual communication (as opposed to visual thinking), an understanding of the principles of cartographic design remains essential.

The principles of cartographic design are set of standard rules and procedures that have been developed to allow maps to be understood by general users. There are many good texts that explain these in detail (some are included in the reference list) and students are advised to refer to them for more detail. Briefly, however, cartographic design follows five basic stages. In the first stage the purpose of the map is identified together with the potential users. Usually geographers are interested in drawing ‘thematic’ maps that display the spatial variations of one or more variables, as opposed to ‘topographic’ maps that are used to emphasize the location of spatial phenomena. In the second stage, appropriate data are obtained and issues of planimetric position, projection system and scale are addressed. In stage three the data are simplified by identifying the spatial dimensions of the features being mapped - point, line, polygon (areal) or surface (volume) - and classified according to the scale of the data (nominal, ordinal, interval or ratio). In stage four the features are mapped using standardized graphics in a process called symbolization whilst other graphical elements, such as a legend, are also added. In the final stage, the map is assessed to determine whether users would find it useful and informative.

Of the five stages, stage four is perhaps the most important in determining the success of a map in communicating information. The process of symbolization is the critical step and it has been the focus of a great deal of research in cartographic design. There is no room to discuss these design issues in any depth here, but a few of the issues will be expanded upon. Although maps contain a lot of different types of graphics, these can all be classified into eight basic visual variables: size, colour value, texture, colour hue, orientation, shape and the two dimensions of the plane of a sheet of paper (Bertin, 1983, p. 42). Table 1, adapted from MacEachren (1994a), shows how these

Table 1: The relationships between visual variables and the characteristics of the features to be mapped.

	Nominal	Ordinal	Interval/ Ratio	Point	Line	Polygon
Location	G	G	G	G	G	G
Size	P	G	G	G	G	M
Colour Value	P	G	M	G	G	G
Colour Hue	G	M	M	G	G	G
Texture	G	M	M	M	P	G
Orientation	G	M	M	G	P	G
Shape	G	P	P	G	M	G

G = Good; M = Marginally effective; P = Poor

Source: Adapted from MacEachren, A.M. 1994a, Fig. 2.28., 33.

eight visual variables relate to the spatial dimension and data scale of the particular feature to be mapped. Visual variables vary in their ability to display different types of information on a map and the skill of the cartographer is to know which one to choose to best display the information. A good example is the use of colour. Colour printing has become much more common in recent years making it easier for students to use colour in their maps. But colour should be used carefully since although it can be effective at showing differences between nominal categories, it is not so good at showing differences in numerical data (Bertin, 1983). It is also worth bearing in mind that traditional publication mediums may find reproduction of coloured maps difficult and costly. Bertin's framework has since been adapted and expanded to include new visual variables such as pattern, clarity (MacEachren, 1995) and projection (Dorling, 1992; 1994). These allow a greater degree of detail to be added to a map.

Once the data has been symbolized, other graphical elements are added so that the map communicates the information clearly and with as little ambiguity as possible. Although the principles of graphical design are contested (e.g. Tufte, 1983; 1990; 1997; Cleveland, 1985) it is generally accepted that the following five elements need to be included: title, legend, source of data, north arrow, and scale. The title should explain the major theme being mapped, the geographic region and the date of the data and should be placed near the top of the map. The legend should include a clear explanation of what each symbol represents with the text written to the right of each legend symbol. Larger values should be shown at the top of the legend and smaller values at the bottom. The source of the data should be placed at the bottom of the map and include information on where the data was obtained, when it was collected and by whom. Other graphical elements may also be included such as labels indicating features on the map that may be of interest. However, it is bad practice to clutter the map with unnecessary information or 'chart-junk' (Tufte, 1983) - decoration that may draw attention away from the important information on the map. When the map is finished it should appear visually balanced with no large empty spaces. For more information on issues of cartographic design see Slocum (1999), MacEachren (1995), or Robinson, et al. (1984).

Final Comments

Cartography has experienced rapid change during the 1990s as a response to swiftly evolving technologies and new concerns within science regarding data exploration and analysis. However despite the fact that the majority of cartographic research today is geared towards the use of highly interactive map displays for visual thinking, the principal applications of cartography by students currently remains in the realm of visual communication. The growth of computerised and Web based-cartography means that more people than ever can create maps and hence there is a real need to foster 'back-to-basics' in cartography. The construction of a well designed map that supports queries such as 'what is?' or 'where is?' and communicates facts effectively to the user is of increasing important as the scientific and social communities demand speedier access to geographically referenced information.

References

Bertin, J. 1983: *The Semiology of Graphics*. The University of Wisconsin Press. Madison, Wisconsin.

Cartwright, W. 1997: New media and their application to the production of map products. *Computers and GeoSciences,* 23 (4), 447-456.

Cleveland, W.S. 1985: *The Elements of Graphing*. Wadsworth advanced books and software. Monterey, California.

DiBiase, D. 1990: Visualization in the earth sciences. *Earth and Mineral Sciences, Bulletin of the College of Earth and Mineral Sciences, PSU* 59 (2), 13-18.

Dorling, D. 1992: Visualizing people in space and time. *Environment and Planning B,* 19, 613-637.

Dorling, D. 1994: Cartograms for visualizing human geography. In D. Unwin and H. Hearnshaw (eds), *Visualization and GIS,* London: Belhaven Press, 85-102.

Dorling, D. 1998: Human Geography - when it is good to map. *Environment and Planning A,* 30, 277-288.

Dykes, J.A. 1997: Exploring spatial data representation with dynamic graphics. *Computers and GeoSciences,* 23 (4), 345-370.

Kraak, M.J. and Brown, A. (eds) 2001: *Web Cartography*. London: Taylor and Francis.

MacEachren, A.M. 1994a: *Some truth with maps: A primer on symbolization and design.* Association of American Geographers.

MacEachren, A.M. 1994b: Visualization in modern cartography: setting the agenda. In MacEachren, A.M. and Taylor, D.R.F. (eds), *Visualization in Modern Cartography*. Pergamon, Oxford, 1-12.

MacEachren, A. M. 1995: *How maps work: representation, visualization and design*. New York, Guildford Press.

MacEachren, A.M. and Kraak, M-J. 1997: Exploratory cartographic visualization: advancing the agenda. *Computers and GeoSciences*, 23 (4), 335-343.

MacEachren, A.M. and Ganter, J.H. 1990: A pattern identification approach to cartographic visualization. *Cartographica,* 27 (2), 64-81.

McCormick, B.H. DeFanti, T.A. and Brown, M.D. (eds.) 1987: Visulization in scientific computing - a synopsis. *IEEE Computer Graphics and Applications,* 7 (7), 61-70.

Orford, S. Dorling D. and Harris, R.: *Introduction to Visualization in the Social Sciences*. Concepts and Technquies in Modern Geography, Norwich: Environmental Publications. In Press.

Robinson, A.H., Sale, R.D., Morrison, J.L. and Muehrcke, P.L. 1984: *Elements of cartography*. 5th Edition, Chicherster: Wiley.

Slocum, T.A. 1999: *Thematic Cartography and Visualization.* Prentice-Hall, Inc.

Tufte, E.R. 1983: *The visual display of quantitative information*. Cheshire, Connecticut: Graphics Press.

Tufte, E. R. 1990: *Envisioning Information*. Cheshire, Connecticut: Graphics Press.

Tufte, E.R. 1997: *Visual Explanations: images and quantities, evidence and narrative*. Cheshire, Connecticut: Graphics Press.

Unwin, A. 1999: Requirements for interactive graphics software for exploratory data analysis. *Computational Statistics,* 14 (1), 7-22.