

Computer Cartography and Cartographic Knowledge

Gennady Andrienko and Natalia Andrienko

Fraunhofer AiS – Institute for Autonomous Intelligent Systems

Schloss Birlinghoven, Sankt-Augustin, D-53754 Germany

Tel: +49-2241-142329, -142486

Fax: +49-2241-142072

E-mail: gennady.andrienko@ais.fhg.de

URL <http://www.ais.fhg.de/and/>

1. New concept of mapping

Nowadays the concept of map becomes more and more associated in minds of people with display on a computer screen rather than something printed on paper. This applies not only to professionals in analysis of spatial information but even to ordinary public. Thus, route planners gradually substitute street atlases in planning journeys. Lots of people use numerous map-based services available in the Internet.

Not only the use of computer maps increases: map creation becomes a part of professional activities of more and more specialists in different occupation areas. The traditional practice when maps are designed by expert cartographers and distributed for public use no more satisfies current needs. Analysts, planners, decision makers require rapid visualization of the most actual information in a form suited for purposes of the moment.

Maps are used for variety of purposes that can be broadly grouped around two main roles: maps as tools for analysis, problem solving and decision making (“visual thinking”, see [MacEachren 1994, MacEachren and Kraak 1997]), and maps as tools for communication of ideas between people. Although the communicative role of maps seems to fully comply with the cartographic tradition, it should be borne in mind that the concept of cartographic communication has recently substantially extended. Now this is not only professional map design for broad public. An analyst needs maps to communicate analysis results to a decision maker. Participants of cooperative problem solving exchange their ideas and arguments using maps or referring to maps. A student of demography can use computer mapping tools in order to illustrate with maps the main points of her master thesis.

Development of computer technologies, on the one hand, and increasing and widening use of computer maps, on the other hand, pose new challenges to cartographic research. We see the following directions of work to be imperative for the modern cartography:

- Study the new technologies, evaluate their potential for mapping and detect limitations. Propose novel cartographic expressive means utilising these technologies.
- Consider what kinds of data and phenomena are currently subject to mapping or might be mapped given the new expressive opportunities. Develop a typology of “mappable” things and formulate up-to-date principles of cartographic representation (i.e. what should be shown how).

- Investigate for what purposes computer maps are actually used or could potentially be used. Develop a typology of tasks maps can support, including both analytical and communicative tasks. Relate the tasks to the modern cartographic expressive means and techniques that can effectively support them (i.e. what technique is suited for what purpose).
- Make cartographic knowledge available to the broad community of map users, especially active users who manipulate existing maps or create their own maps.

2. New technologies and new properties of maps

The opportunities for mapping offered by modern computers are tremendous: practically unlimited number of available colours, very high resolution of graphical displays, software supporting generation of realistic 3-dimensional scenes, dynamic views (animation), user interaction with displays, dynamic display transformation, interlinking of multiple views, etc. All this is available even on standard personal computers while more complex and powerful equipment can further enhance some of these features.

Due to these new opportunities computer maps acquire completely new properties as compared to their paper predecessors, and this necessitates development of new principles of cartography. To take just one example, one of the purposes of paper maps was to serve as comprehensive inventories of data. It was important to encode values by map symbols in such a way that a user could as precisely as possible decode them back. With an interactive computer map, the user does not actually need to decode values: they can simply be shown in text form when the user points with the mouse on map symbols. Hence, instead of easily decodable symbols the user would appreciate, for example, symbols that facilitate detection of spatial patterns or anomalies.

Interactive maps are for already several years among the main topics of our research [Andrienko and Andrienko 1999a, Andrienko, Andrienko and Savinov 2001]. We design and implement various interactive techniques intended to enhance the role of maps as tools of “visual thinking”. Here are a few examples:

1. Multiple complementary views on the same data set. For example, a map and a non-cartographic display can be dynamically linked by means of simultaneous highlighting of corresponding parts (Figure 1). This gives an opportunity to comprehensively analyse data from different perspectives [Cleveland 1993, Buja, Cook and Swayne 1996].

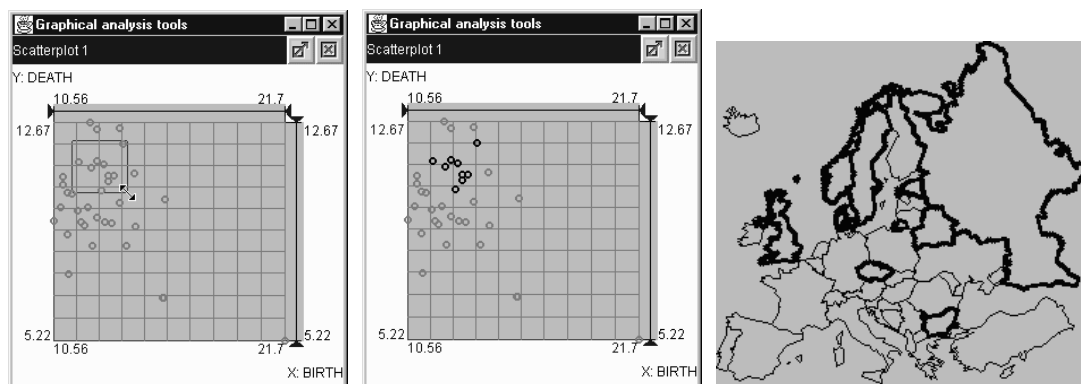


Figure 1. Dynamic linking between a scatter plot and a map. A user has selected a group of objects in the scatter plot using a rectangular frame (left). In the result, all objects from the group become highlighted on the scatter plot (centre) and on the map (right).

2. Variation of visualisation parameters of a map, for example, change of the midpoint of a diverging colour scale [Brewer 1994] on a choropleth map (Figure 2). This operation may facilitate investigation of spatial patterns and trends.

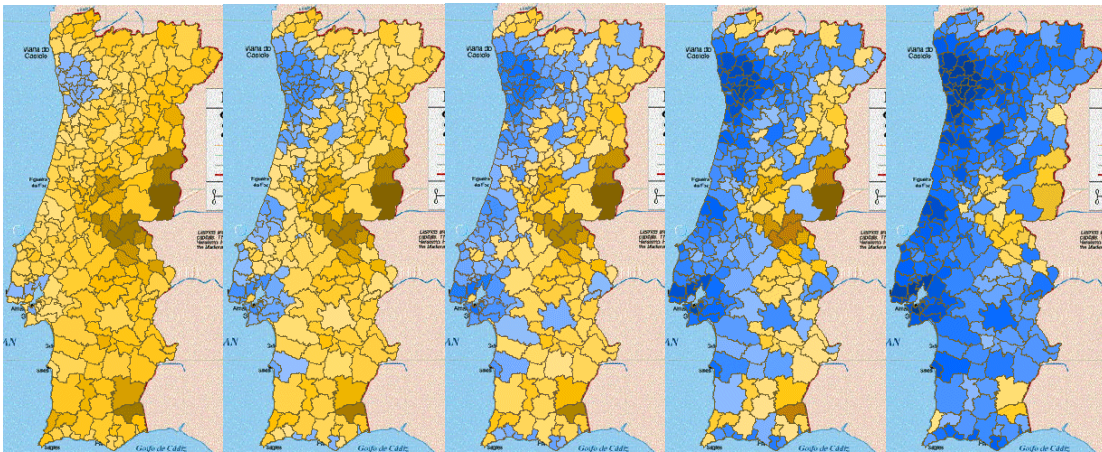


Figure 2. A choropleth map with a double-ended (diverging) colour scale: values below certain specific value (midpoint) are represented by shades of blue while values above the midpoint are shown by shades of brown. Gradual shifting of the midpoint facilitates detection of spatial patterns and trends.

3. Modification of map symbols for supporting specific tasks, for example, interactive pie charts enable comparison of structures for different objects (Figure 3).

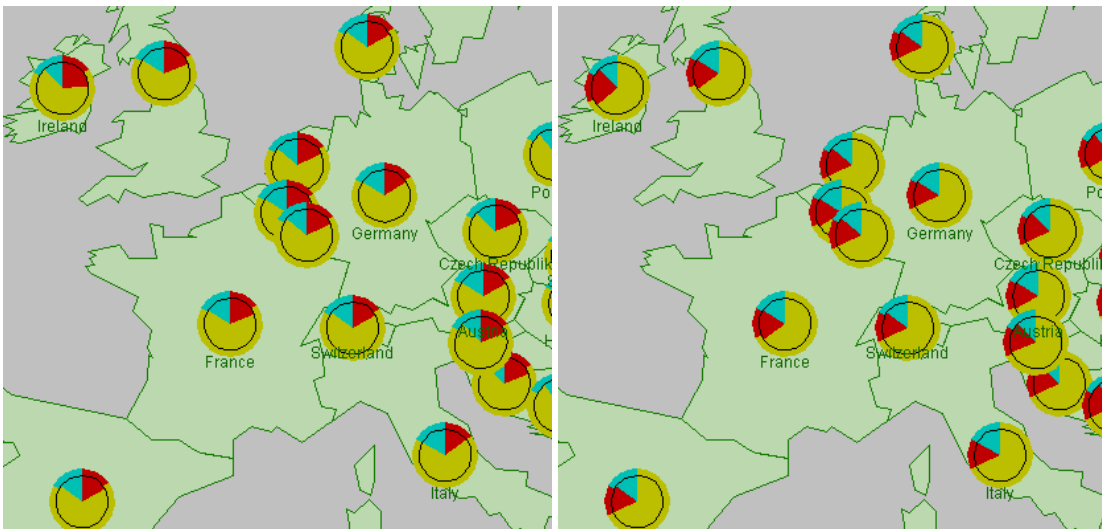


Figure 3. Comparison of structures using a special form of pie charts. Age structure in each European country (inner parts of the diagrams) is compared to that in Italy (outer parts). Another reference country for comparison can be selected by just clicking on it in the map. On the left, the order of pie segments is better suited for comparison of proportions of children and elderly people. On the right, the order of the segments has been changed so that proportions of adult population are easier to compare: the corresponding segments conveniently start from the vertical base line of the diagrams.

It is important to bear in mind that interactivity can radically change properties of traditional, well-known cartographic representation methods. Thus, it is customary to regard choropleth maps as unsuitable for comparison of values. However, the use of a diverging colour scale, as

is shown in Figure 2, and the possibility to interactively change the midpoint of this scale allows one not only to see which of two objects has higher value but to compare an object simultaneously to all other objects present on the map. For this purpose one only needs to set the value associated with this object as the midpoint of the colour scale. In our implementation this is done simply by clicking on the object in the map.

Hence, computer technologies offer new expressive means and enhance capabilities of traditional cartographic techniques. Therefore there is a need in thorough investigation of the new opportunities in order to propose appropriate ways of their utilisation.

3. Mappable data and phenomena

Modern computer technologies may extend applicability of maps to data and phenomena that were hard to represent on paper. For example, representation of phenomena changing in time has always been a hard task for cartographers. Now there is an opportunity to show changes of a phenomenon by interactive linked displays [Monmonier 1990] or by dynamically changing (animated) maps. Currently tools for building dynamic presentations are included in many mapping software packages (see, for example, [Edsall and Peuquet 1997, Slocum et al. 2000, Andrienko, Andrienko and Gatalsky 2001]). A task for theoretical cartography is to develop a typology of dynamic spatial phenomena and formulate principles and rules of representation of different kinds of changes (appearing and disappearing of objects, spatial movement, changing sizes or shapes, or changing thematic characteristics). Another possibility for representation of time is to use the third dimension in 3-dimensional views. This possibility must also be thoroughly investigated: what kinds of phenomena can be represented in this way, how understandable and how effective such displays are, what cartographic symbols could be recommended for use in such views, etc.

At the same time modern life often requires to map such things that were hardly ever considered as mappable subjects in the traditional cartography. For example, in distributed environments for cooperative problem solving in a spatial context people often need to represent on a map the course of discussion (see [Rinner 1999]): alternative suggestions, arguments pro and contra, comments, etc. It is important to discover such new needs and propose adequate cartographic means to satisfy them.

4. Two major roles of maps

The role of maps as tools of “visual thinking” is in the centre of attention of the ICA Commission on Visualisation and Virtual Environments. Development of typology of analytical tasks that can be supported by maps is among the main topics of the Commission’s research agenda for the nearest years [Fairbain et al. 2001]. At the same time the communicative role of maps is out of the scope of this agenda. However, it is equally important to develop a typology of communicative tasks and relate these tasks to appropriate cartographic tools. For example, the cartography could try to answer what kind of map display should be built to attract attention to a particular feature, to convince an opponent, to warn about a danger, or to refute a widely spread opinion.

An important and interesting research topic is how to effectively combine maps with other communication media. Even for such traditional combinations as maps plus text or maps plus images there are now new promising possibilities. For example, an interactive caption may alter the corresponding map when a reader points on sensitive spots in the text [Preim et al. 1998]. Images of tourist attractions and their descriptions may appear when a tourist points on symbols on a tourist map. At the same time modern technologies allow one to generate

presentations that involve not only vision but also other human senses. In particular, combination of map displays with sound [Kang and Servigne 1999, Muller, Scharlach and Jäger 1999] does not require any complex and expensive equipment. A solid theoretical and methodological basis would be very valuable for those who designs multimedia presentations based on maps or involving maps.

5. Need in cartographic knowledge

Since more and more people without special cartographic education become involved not only in map use but also in map creation, it is the task of cartographers to make cartographic knowledge available to the masses. There are two complementary ways of approaching this goal. One of them is education that can be done not only by reading books or attending courses but also by participating in activities that involve the use of computer maps. A good example is the Naturdetektive project (www.naturdetektive.de) in which German schoolchildren use interactive maps to register their nature observations and trace routes of migratory birds on animated map displays.

Another way is to incorporate cartographic expertise into mapping software. There are some examples of expert systems that recommend the users how to correctly represent their specific data on a map [Jung 1995, Zhan and Buttenfield 1995, Andrienko and Andrienko 1999b]. However, these systems mostly incorporate the design principles formulated by Bertin [1967, 1983] for static, non-interactive maps and graphs. Recently we started to develop a knowledge-based software component, called task support guide, that proposes the users appropriate interactive techniques for accomplishing specific data analysis tasks and explains how to apply these techniques (Figure 4). The guide is integrated in our mapping system CommonGIS [Andrienko and Andrienko 2001]

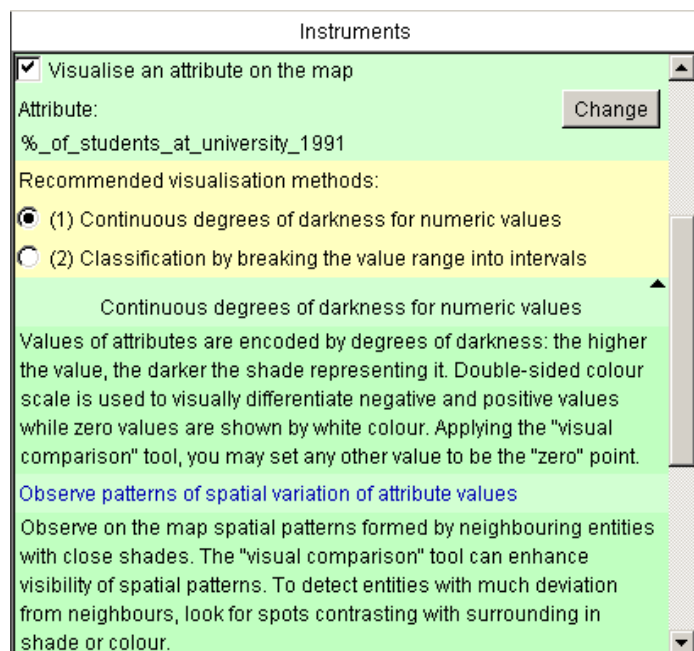


Figure 4. The knowledge-based guide explains how to use the double-ended continuous scale of degrees of darkness.

A great problem for those who tries to develop up-to-date knowledge-based software for computer mapping is the absence of systematised knowledge concerning building and use of interactive, dynamic maps. It is a vital task for cartography to fill this gap.

6. References

1. Andrienko, G. and Andrienko, N., 1999a, Interactive maps for visual data exploration. *International Journal Geographic Information Science*, **13** (4), 1999, 355-374.
2. Andrienko, G. and Andrienko, N., 1999b, Knowledge Engineering for Automated Map Design in DESCARTES. In C.B.Medeiros (ed.) *Advances in Geographic Information Systems*. Proceedings of the 7th International Symposium ACM GIS'99, Kansas-City, November 5-6, 1999, NY: ACM Press, pp.66-72
3. Andrienko, N. and Andrienko, G., 2001, Intelligent Visual Data Analysis Service in the Internet. *Web Information Systems Engineering WISE 2001*, Conference and Workshop, Kyoto, Japan, 3-6.12.2001, proceedings, pp.439-445
4. Andrienko, N., Andrienko, G., and Gatalsky, P., 2001, Exploring Changes in Census Time Series with Interactive Dynamic Maps and Graphics, *Computational Statistics*, Special Issue on "Data Mining and Statistics", 2001, v.16 (3), pp.417-433
5. Andrienko, G., Andrienko, N., and Savinov, A., 2001, Choropleth Maps: Classification revisited, In Proceedings ICA 2001, Beijing, China, vol.2, pp.1109-1219
6. Bertin, 1967, 1983, *Semiology of Graphics. Diagrams, Networks, Maps*, The University of Wisconsin Press, Madison, 1983.
7. Brewer C.A., 1994. Color Use Guidelines for Mapping and Visualization, *Visualization in Modern Cartography*, MacEachren A.M. and Fraser Taylor, D.R. (Eds.), Elsevier, pp. 123-147.
8. Buja, A., Cook, D., and Swayne, D.F., 1996, Interactive high-dimensional data visualization. *Journal of Computational and Graphical Statistics*, **5**, 78-99
9. Cleveland, W.S., 1993, *Visualizing Data* (Summit: Hobart Press).
10. Fairbain, D., Andrienko, G., Andrienko, N., Buziek, G., and Dykes, J., 2001, Representation and its relationship with cartographic visualization: a research agenda. *Cartography and Geographic Information Science*, Special Issue "Research Challenges in Geovisualization" (Edited by A.M.MacEachren and M.-J.Kraak), 2001, v.28 (1), pp.13-28
11. Edsall R. and Peuquet, D., 1997. A Graphical User Interface for the Integration of Time into GIS. Proceedings of the *1997 American Congress of Surveying and Mapping Annual Convention and Exhibition*, Seattle, WA, pp.182-189.
12. Jung, V., 1995, Knowledge-based visualization design for geographic information systems. *Proceedings of the 3rd ACM International Workshop on Advances in Geographic Information Systems* (Baltimor, 1995), ACM Press, pp.101-108

13. Kang, M., and Servigne, S., 1999, Animated Cartography for Urban Soundscape Information, *proceedings of the 7th International Symposium on Advances in Geographic Information Systems*, November 5-6,1999, Kansas City, MO, USA, pp. 116-121
14. MacEachren, A.M., 1994, "Visualization in modern cartography: setting the agenda". In *Visualisation in Modern Cartography* (NY: Elsevier Science Inc.), pp.1-12, 1994
15. MacEachren, A.M. and Kraak, M.-J., 1997, "Exploratory cartographic visualization: advancing the agenda". *Computers and Geosciences*, 23 (4), pp.335-344, 1997
16. Monmonier, M., 1990. Strategies for the visualization of geographic time-series data, *Cartographica*, 27 (1), pp. 30-45.
17. Muller, J.-C., Scharlach, H., and Jäger, M., 1999. Noise in Urban Environment: Problems of Representation and Communication, *Proceedings of the 19th International cartographic Conference*, August 14-21 1999, Ottawa, Canada, pp. 955-964
18. Preim, B., Michel, R., Hartmann, K., and Strothotte, T., 1998. Figure Captions in Visual Interfaces, *Proceedings of the Working Conference on Advanced Visual Interfaces (AVI'98)*, L'Aquila, Italy, May 24-27, 1998, pp. 235-246
19. Rinner, C, 1999, Argumentation Maps, In Ch. Freksa (Ed.) Poster Presentations at CoSIT'99, Kognitionwissenschaft Hamburg, 1999, pp.118-135
20. Slocum, T., Yoder, S., Kessler, F., and Sluter, R., 2000. MapTime: Software for Exploring Spatiotemporal Data Associated with Point Locations, *Cartographica*, 37 (1), pp. 15-31.
21. Zhan, F.B., and Buttenfield, B.P., 1995, Object-oriented knowledge-based symbol selection for visualizing statistical information. *Int. J. Geographical Information Systems* 9, 3 (1995), 293-315.

Last updated: April 30, 2008