MISSING THEORIES AND METHODS IN DIGITAL CARTOGRAPHY

Meng, L.

Department of Cartography, Technical University of Munich,
Arcisstr. 21, D-80333 Munich, Germany.
E-mail: meng@bv.tum.de. Website: http://www.carto-tum.de

ABSTRACT

Technical possibilities in digital cartography seem to have elaborately compensated the inherent constraints embedded in traditional mapmaking process such as geometric transformation from 3D to 2D, introduction of artificial sheet lines and restricting or changing the sensomotor interaction with the real world to visual perception. Meanwhile, the expressiveness of digital maps has been extended to accommodate the ever growing complexity of geo-data. Standard maps are flanked by a much larger number of map-like presentations or self-explaining info-graphics. Realities and virtual realities can be arbitrarily shuffled in front of observers.

However, the development of cartographic theories and methods lags far behind the technical evolutions. Instead of following the motto "Today's theory is the key of tomorrow's practice", today's mapmaking activities tend to be more and more technique-oriented and cartographic products have become more and more functional. A majority of cartographic processes, especially those integrated in commercial GIS, simply aim at making things work by providing default solutions.

This paper brings together the constraints for purpose-driven and user-centred map design, thus reveals the mismatch between the function and the usability of maps. The consequences of technique-orientation in cartography are analysed with the intention to raise the awareness of missing theories and methods. With a number of examples, open questions and possible answers the author appeals to cartographers for more attention to usability study and more effort towards the design of geo-services.

1. BACKGROUND

Cartography is a field in which many other disciplines can find and have found their playground. At the same time, components of cartography are being increasingly integrated in a number of neighbouring disciplines. The multidisciplinary interchange spreads worries among professional cartographers over their future, but brings them new survival opportunities as well. Recent years, cartography has indeed profited a great deal from modern information technologies characterized by Internet, multimedia, wireless communication and location-based services. As a result, teaching modern cartographic courses with their ever changing contents has become a challenge for educators due to following facts: First, mathematical cartography characterised by well-established projection theories has been successfully integrated as a closed or open-ended toolbox in existing commercial GIS as well as mathematical software. Conversion among different projections can take place in real time. Generation of unbiased plan views is no longer the major concern in constructing new projections. For instance, a growing number of projections used in virtual reality environments are based on central perspective geometry with varying projection centre or curved perspective rays for specific visualisation purposes. Geometric distortions are no longer the unwanted side effect of map projections. Often they are applied as a useful design means to emphasise important map regions or contents. These changes force cartographers to redefine the optimisation criteria for the evaluation of map projections. Secondly, the traditional division into topographic and thematic cartography can hardly cover the scope of cartographic subject field when more and more mapmakers and users refer to geo-spatial information layers that can be based on not only themes, but also criteria such as level of details, volatility, actuality etc. Consequently, the map typology that has been established on the basis of topographic maps and thematic maps can no longer well represent new maps types, especially those map-like products. Terms such as Internet cartography, media cartography, telecartography and mobile cartography that respectively emphasise the web connection, multimedia, wireless communication and mobile use context have therefore a more or less provisory nature due to the lack of an extensive typology, although they have considerably contributed to the prosperity of cartography. Thirdly, the boundary between mapmaking and map use has been increasingly blurred since the introduction of interactivity into cartographic processes. The production cycle has been shortened, sometimes to a single action of pressing a button. Often diversified new maps are being created while interactively using a map.

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One can hardly tell when the mapmaking stage goes over to a map use stage. Mapmaking is no longer a black box to which only cartographers have the key. Therefore, the role of the cartographer has been interwoven with that of map users. No wonder that many cartographers get confused with regard to their traditional responsibility realm.

The development of cartographic theories and methods lags far behind the technical evolutions. Today's mapmaking and map use activities tend to be more and more technique-oriented and cartographic products have become more and more functional. Instead of following the motto “Today's theory is the key of tomorrow's practice”, cartographers have been spending the majority of their effort in learning the latest and often very volatile technologies as if keeping pace with technical developments were the only choice that could protect them from becoming loser in the super-competitive society. Although new technologies help to make the cartographic practice work better, they do not necessarily yield better products and more usable systems (Figure 1). In the long run, the lack of theories and methods that should guide cartographic processes may cause the degradation of the scientific value of cartography.

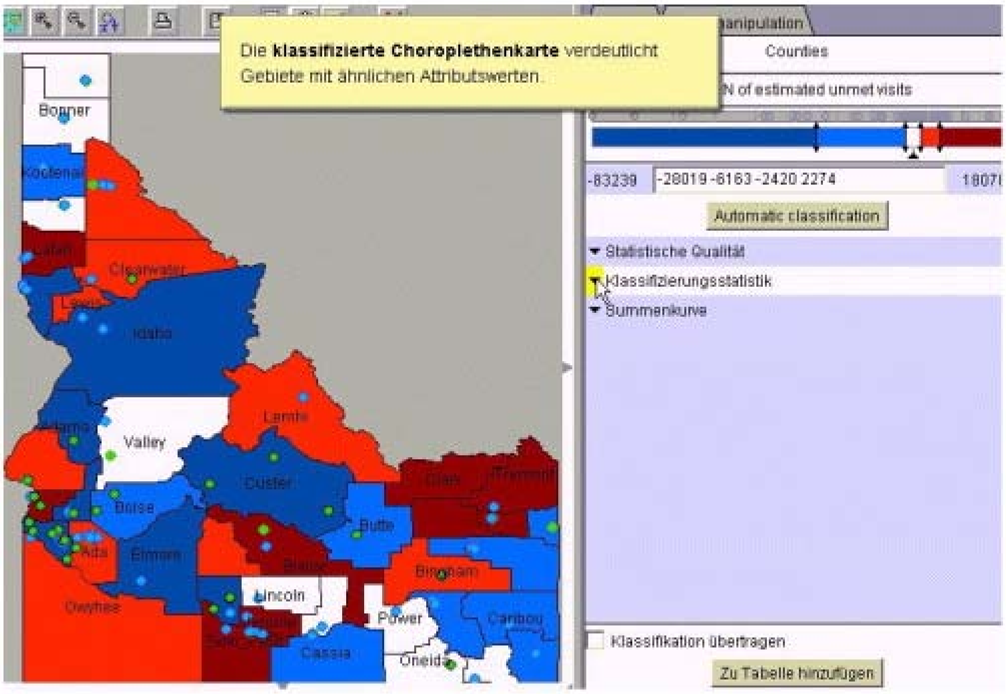

Figure 1. An on-the-fly mapping tool with obviously missing design principles

2. CHANGING CONTEXTS OF MAPMAKING

Mapmaking, or cartographic visualisation, is a cognitive process that brings geo-objects, their relationships and processes into view on a usually 2D display surface. A series of transformations take place in such a cognitive process. First, the 3D geo-space together with its semantic attributes must be crushed onto a flat surface. Thus, the two spatial dimensions of a map have to carry both spatial and non-spatial meanings. Second, the seamless real world must be folded up, scaled and layered so that the presentation contents can be accommodated within an arbitrarily defined window size. Third, various perception modes of the real world must be trimmed to the visual mode in a map. While a visible object can be easily converted to a graphic symbol, a more complicated cognition is necessary to visualise those invisible and abstract concepts. In spite of these inherent constraints, cartographers have always found solutions to present geoinformation in different visible ways. As a well-known fact, traditional map design is very much purpose-driven. In principle, the digital environments have opened up the possibility to include user requirements into the design process. However, the current cartographic practice is still strongly purpose-driven. Depending on its intended purpose, a digital map can be designed as a view-only graphics, a window of analytical geoinformation systems [16] or a thinking instrument of explorative geoinformation systems [13].

2.1 Map as view-only graphic

Similar to its printed counterparts, a view-only digital map works as both the storage and the presentation medium of geoinformation. It is intended to communicate the knowledge of a mapmaker to his target users. However, many of the design issues for printed maps that deal with map field, typography, colour management, piece composition, legend, title, margin decoration and back side etc. do not suit the screen reading any more [1]. With help of view functions such as zooming, panning (scrolling) and integrated legend, the limitations of display size and screen resolution can be largely compensated. Moreover, techniques such as multimedia, animation and anamorphosis have considerably increased the design flexibility, thus opened up many new perspectives to look at the map. In fact, conventional map graphics are now flanked by a much larger number of map-like presentations. Realities and virtual realities can be arbitrarily shuffled in front of observers. However, users are still supposed to be passive information receivers. How far a user is able to distil the useful information for his application is largely dependent on his general visual literacy, his domain knowledge and his ability to detect the visual cues that are purposefully built in the map by the mapmaker. Since the reliability of the gained information can only be judged by the graphic quality of the map, aesthetic aspects of view-only maps matter as much as the mapped contents. Despite of their heterogeneous graphic structures, view-only maps usually fall into the two design styles: naturalistic presentation and symbolic presentation.

A naturalistic presentation, be it a photorealistic depiction or a sketchy drawing, aims at reproducing the overall visual impression of the real world as much as possible. Upon seeing a naturalistic presentation, the comprehender will likely dive into the underlying real world because the cognitive "distance" between the presentation and its referent is absent. Those known and concrete objects in a naturalistic presentation are immediately understandable, whereas the non-visual aspects tend to be ignored. For this reason, naturalistic presentations are not suitable to convey abstract ideas.

A symbolic presentation, on the contrary, visualises the characteristic aspects of the real world in terms of a symbol language. The cognitive "distance" between the symbolic presentation and its referent grows when the adopted symbols change from pictograms, icons to abstract geometric signs. Since the presentation is not to be mixed up with the underlying real world, the mapmaker has the freedom to apply different symbol languages and connect them to any messages other than the visual appearance. However, a comprehender is not automatically able to reconstruct the complete meaning of the presentation even if he could detect its characteristic fraction. Learning efforts and legends are therefore required because symbol languages are far from being standardised and they always reflect the zeitgeist and home culture of its designers.

Apart from discussion on technical possibilities and limitations, there is not yet a systematic study of view-only digital maps concerned with their aesthetic values for different applications, their cross-media publishing issues and their screen-oriented design essentials. International map exhibitions have so far focused on the evaluation of printed maps. Masterpieces of view-only digital maps are unknown. As a result of insufficient design principles, the majority of today's screen maps tend to be copies of their paper counterparts and their layout design aspects remain largely neglected.

2.2 Map as a window of analytical GIS

In an analytical GIS, maps work as windows that connect users with a geo-database. Through a window, users can selectively look at the contents as well as the structure of the geo-database. Here, maps have to represent both the geographical world and the hyper-dimensional information space spanned by the geo-database. The geo-data retrieval takes place by means of various analytical functions ranging from viewing, highlighting, queries, manipulation of data layers, activating default presentation styles to various statistical calculations.

Since the major concern of analytical GIS lies in the understanding the geo-database, multiple views are preferred to a single view because the former can better reveal the spatial invariance. Each view should be designed as transparent as possible and distract users as little as possible. Unambiguous graphic coding methods that allow a fast and sure interpretation are preferred. For the purpose of legibility, positions of map symbols can be biased from their corresponding objects as long as a unique connection between both geometries can be easily found. Unlike the communication process of view-only maps, here knowledge is successively revealed through user interactions. In other words, users get more or less involved in the design process. They are given much freedom to arrange maps at their convenience, select layers, define windows, and construct new maps by changing design parameters in allowed ranges. Moreover, multimodal access modes can be made available to enhance the perception and information acquisition [2], [10]. The intensive interactions can largely compensate the possible disability of visual cognition of users, thus help them to get an objective insight into the geo-database. While the cartographer has shifted his main task from mapmaking to designing analytical services, users have to accordingly spend more mental effort in understanding the various analytical functions than interpreting the map itself.

Maps in most of the current analytical GIS tend to be entirely disconnected to their design elements in favour of geo-data retrieval. Indeed, an overwhelming part of these maps are merely a graphic transcription of the object geometry (Figure 2). While some users may have got used to the plain look of these "maps", many others do miss the aesthetic effect a map ought to provide. It can also be argued whether the plain-looking maps are really more easily understandable than those elaborately designed maps, whether maps in analytical GIS can play the role of interface without having to sacrificing its function as presentation medium because the information acquisition through a map and within a map is not necessarily contradictory.

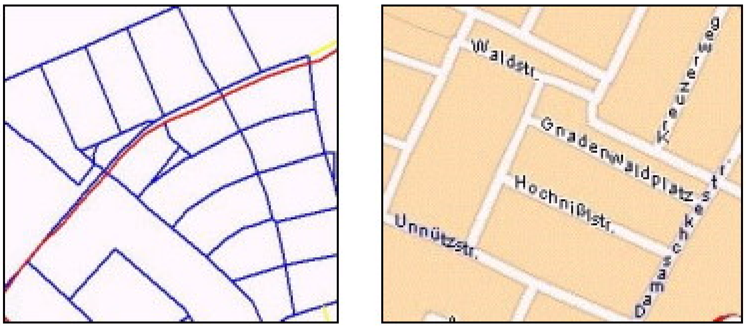

Figure 2. Examples of screen maps with minimal design efforts

What is also missing or at least insufficiently studied so far are design principles for analytical functions. Statistically, 45% of the design and 50% of the implementation time for interactive applications were devoted to their user interface [3]. The symbolisation of analytical functions has proved a less straightforward task than design of map contents because each analytical function is related to a certain operation or procedure that can be formalised as “someone does something with some tool in some manner to reach some result”. Whether the symbol should characterise the “someone”, “does”, “something”, “some tool”, “some manner” or “some result” of the function depends on many factors such as the common sense knowledge of the user, his preference, the conventions he is familiar with etc. The difficulty in identifying a unique association between the symbol and its intended function makes the design of self-explaining info-graphics, i.e. graphic symbols with integrated complementing text information, necessary. Although icon-text combinations have been widely adopted as a feasible approach of symbolising interactive functions, their design essentials and usability have not been systematically analysed. Many available combinations do not really help much because they are either inconsistent within the same system or very much dependent of the designer (Figure 3). In many cases, the text offers only an equivalent message in verbal form and does not add complementing information to the icon. Moreover, the instructions guiding an operation can hardly be embedded in a compact icon-text combination, therefore, users cannot immediately understanding the whole meaning until they have tried around or consulted with a lengthy manual. Other unanswered design questions include how to place the interactive functions so that they can be easily found and error-free activated, how to standardise them so that they can be used in other platforms, and how to categorise them in folders so that they can be better accommodated according to the principle of “jack-knife” required by the limited display surface.

Figure 3. An interface with inconsistent and hidden interactive functions

2.3 Map as thinking instrument of explorative GIS

An explorative GIS usually has a very large geo-database in the sense that neither the cartographer nor the GI specialist has an overview of its size and structure. Moreover, the database contents are regenerative during interactive sessions with diversified and networked users. Due to insufficient understanding of such a dynamically changing geo-database and inadequate domain-specific knowledge, cartographers are no longer able to predefine a suitable presentation style to bring the information into view. Instead, they have to leave the decision open to users. This means, users are allowed not only to view and analyse the database, but also to change its contents by means of manipulations such as clipping, adding, moving, deformation, generalisation etc. Maps in an explorative GIS work as thinking instrument that visually supports users to confirm known facts, detect unknowns and finally value-add the geo-database either by inserting the new knowledge into it or removing the redundancy from it. In fact, the explorative interaction is a process of dual information gain that can lead to a mutual understanding between users and the system.

Recent years, cartographers have been developing and spreading numerous explorative mapping tools with the intention to express a database in multiple different ways instead of one possibly optimal way. However, a comparative study on the characteristics of these tools is missing, which makes a visual exploration a more or less blind business. The users' capability of handling explorative mapping tools does not necessarily result in good maps and successful knowledge discovery. Being untrained with cartographic principles, domain specialists do not know how to select a suitable tool for his application from multiple possibilities. Therefore, they can hardly be convinced by their own map products yielded from an arbitrary choice. On the other hand, due to the insufficient development of advanced analytical functions and spatial data mining methods, many explorative efforts have to end up with visual hypotheses instead of statistically confident statements and many unknowns still remain hidden in the database. Finally, getting lost in the flood of data still occurs frequently as the consequence of unavailable navigation guide, a service that must be offered by cartographers.

3. CHANGING CONTEXTS OF MAP USE

Map use as the reverse process to mapmaking aims at mentally reconstructing the real world based on the understanding of the graphic presentation. In this sense, a map that serves its intended purpose has little to do with its users, hence the usability. “Usability is being able to do the things you want to, not the things you have to”[6]. The best way to ensure usability is to involve users in the design procedure instead of merely letting them evaluate prototypes.

While paper maps are usually intended for intensive use by many users, therefore elaborately designed and seldom printed as a single piece, screen maps, whether pre-calculated or real-time generated, are often displayed on-demand as the result of opening a graphic file or activating a view function. The temporary nature of screen display along with the possibility of network connection has forced the dramatic change on mapmaking which in turn yields new contexts for map use. On the other hand, the changed user behaviour of screen reading defines new design constraints. One of the greatest potentials of screen maps is that they can be made adaptive. Not only the presentation style, but also the contents and interactive functions of a screen map can be dynamically tailored to suit the dynamically changing user demands. Different adaptations are intended to match different aspects of usability. Depending on the actual usability, digital screen maps can be designed to be seen, to be admired, to communicate information and construct knowledge, and to support user tasks [14].

3.1 Map to be seen

A map in this category serves the purpose of drawing the attention of first-time or one-time users. In fact, not every potential map user is aware of a certain map or intrinsically motivated to read just this map. Many Internet maps, for instance, are discovered by users not as the result of a purposeful searching, rather by chance during a casual browsing. Similarly, screen maps in information kiosks that are located in public places are intended to reach any people moving around. Whether the user will decide to skip over the map graphic or become attentive to it depends largely on the first impression he gets from the map. A good first impression is only possible when the overall graphic is sufficiently visible, has an inviting appearance and implies something meaningful. For this reason, the major concern for its design is to embed suitable eye-catchers in a known consistent reference. Unfortunately, many of current mapping systems seem to have either ignored the perceptual characteristics of first-time and one-time users or disregarded the limited short-term human memory.

3.2 Map to be admired

A map in this category aims at engaging its intended users who are either intrinsically curious or have been extrinsically motivated upon seeing the map. It is either view-only or interactive. In addition to satisfying all the requirements applied to a map to be seen, it should try to hold the attention of its users till they gained what they have expected. Due to the relatively low concentration in screen reading, hence limited reading time, users often desire to catch the meanings of some essential aspects instead of the fine details in the presentation. For this reason, maps intended for admiration must be particularly aesthetic, legible and strongly generalised, at the same time, they should keep attracting their users with design means such as incremental revealing of contents that are arranged in a shallow and narrow structure, successive rendering from coarse to fine resolution or from diffuse to sharp image that helps to compensate the possible delay caused by limited rendering speed, and infotainment that tries to create a tongue-in-cheek way of expression and playful atmosphere for map understanding. Finally, if the map is interactive, it should also allow its users to enter and quit the interaction session wherever and whenever they want. Unfortunately, very few available screen maps really deserve admirations. The majority of maps circulating in the Internet are either visually overloaded or emotionlessly designed. Therefore, they can hardly entertain their target users.

3.3 Map to communicate information and construct new knowledge

A map in this category is interactive and intended for intensive and extensive use by highly motivated users. In this context, it serves as an information carrier, a window of geo-database as well as thinking instrument. However, this functional distinction does not matter so much from the point of view of map use. Users of such a map usually have strong and dynamic information needs, i.e., they are eager to acquire the information through or with the map. Therefore, it is important to impress the user that an informative map is not a flat and thin surface, rather represents a multidimensional, networked and smartly responsive information source. Viewing, searching, browsing and visualising operations should be supported by intelligent orientation and navigation services. The designer must be able to "distil the information into brief, descriptive nodes. Each node has to contain a list of the ingredients, and instructions on how the ingredients are mixed together to the greatest advantage"[11]. In designing interactive functions, hyperlinks and layers, the prior computer knowledge and habits of users should be taken into consideration so that the re-learning can be avoided. Moreover, extensive techniques such as online questionnaire, recognition of eye-movement patterns [4], study of calling frequencies of interactive functions and/or interaction modes [15], autonomous agents etc. can be applied to model the behaviours of each individual user, thus identify his actual information needs and expectations. Furthermore, the users should be allowed to store, transmit or print out their acquired information [8]. The interactive functions should be ergonomically placed so that they can be intuitively found and comfortably activated [17]. Unfortunately, these user characteristics and their requirements remain largely untouched in current cartographic systems, although there is a growing awareness of their impacts on usability issues. Developer-centred approach is still dominating the design of maps in this category. In fact, "design problems typically have rather unclear starting conditions and a rather large number of moves from the unclear starting state to the equally unclear goal state"[7]. One of the bottlenecks that hamper a more user-centred approach is caused by inadequate methods to formalise diversified user requirements and reduce the large number of constraints to a manageable set.

3.4 Map to support user tasks

The information needs of a user are not always, but often connected to his tasks. The user needs information in order to perform a task or he needs to perform a task because of the acquired information. In either case, maps are supposed to help the user. Two representative user tasks to which maps provide useful support are spatial planning and mobile activity.

Spatial planning as a decision making process is typically based on a teamwork that takes place in a collaborative communication system. In such a system, human-computer interaction, human-human interaction, geo-database, network, domain knowledge and experiences of planners should harmonically work together with maps as working language, thinking instrument and presentation medium. The smooth and constructive exchange between the map and various planners at the same or different places requires a common visual literacy, a consistent interface, a typology of collaborative actions, the communication rules and a generative team memory.

In mobile contexts, the user's interaction with both the virtual reality on small displays and the reality in his surroundings tends to be more personal and constrained by other factors. Apart from technical limitations, the time-critical mobile tasks and the constantly changing mobile contexts allow only very limited interactivity and very short time for map reading [18]. The small display held in user's hand or mounted in his mobile vehicles can accommodate only a limited number of points of interest and a "skeletonised" visualisation. Moreover, the relevant information must be rendered just in time and should be immediately understandable. Keeping these limitations in mind, aesthetic considerations should give way to the functionality.

Modelling of user tasks is considered as a feasible approach that helps to reduce the great diversity of user characteristics influencing the usability of maps [3], [9], [12]. However, many investigations so far have either ended up with an enumeration of general rules that can hardly be converted to precise machine language [5] or created a plethora of atomized model facets. What needs to be studied is the modelling of the user tasks at their different granularity levels for two major purposes: finding reusable design components, one the one hand, and establishing patterns that characterize the re-occurring user tasks, their constraints on map design and their already successful design solutions, on the other hand.

4. CONCLUSION

Maps that are fit for purpose are not necessarily fit for use. This paper has brought together the constraints for purpose-driven and user-centred map design, thus revealed the mismatch between the function and the usability of available maps or cartographic information systems. The consequences of technique-orientation in cartography have been analysed with the intention to raise the awareness of missing theories and methods. With a number of open questions and possible answers the author appeals to cartographers for more attention to usability study and more effort towards the design of geo-services.

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Meng, L.

Department of Cartography, Technical University of Munich,
Arcisstr. 21, D-80333 Munich, Germany.
E-mail: meng@bv.tum.de. Website: http://www.carto-tum.de.

Biography

Professor, Dr. Liqiu Meng, is the head of the Department of Cartography, Technical University of Munich, Germany, since January 1999. She completed M.Sc. in 1985 at Institute of Surveying and Mapping (Zhengzhou, China), PhD in 1993 at University of Hanover (Germany), and Qualification for Professorship in 1998 at Royal Institute of Technology, Stockholm (Sweden). She acted as research & teaching assistant for cartography in China (1985-1988) and Germany (1993-1994), senior lecturer for cartography and geoinformatics at University of Gävle, Sweden (1994-1996), specialist consultant for geoinformatics at SWECO, Stockholm (1996-1998). Her teach and research interests are cartographic pattern recognition, automatic map generalisation, adaptive visualisation, spatial data mining.