CARTOGRAPHIC DESIGN PRINCIPLES FOR 3D MAPS – A CONTRIBUTION TO CARTOGRAPHIC THEORY

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ABSTRACT

The cartographic design of computer-generated perspective views with cartographic content – so-called 3D maps – follows mostly the preferences of map authors. It is affected by a large number of input variables. Here, all steps of the design process have to be considered (concept, modeling, symbolization, visualization). For classic maps, cartographic design principles were established many decades ago. But for 3D maps, there do not exist any equivalent principles yet. The goal of the described research project was the derivation of new cartographic design principles for 3D maps. Starting from an overview of design aspects and variables, a systematic set of 3D maps examples were generated. The maps, considering different graphic variables and variations, were evaluated by means of expert interviews. As result, 19 propositions of cartographic design principles were postulated. They should assist map authors in their creative work. Also, they could have an impact for the theory in 3D cartography.

1 3D MAPS TODAY

1.1 Modern 3D maps

Today, modern computer-generated perspective views with cartographic content – so-called 3D maps – are widely spread for very different purposes. The development of software technology as well as the availability of different types of geo-data facilitates the generation of such cartographic representations not only for experts in geomatics, but also for an interested public. The perspective perception of a generalized and symbolized geographic space offers often a better understanding of spatial coherences. 3D maps could be seen as a supporting complement of classic orthogonal maps. Additionally, 3D maps exert a high fascination to most of people because of their similarity to natural landscape observations, e.g., from terrestrial viewpoints or from planes (Haeberling 2002).

1.2 Variety of 3D maps

3D maps can be presented on a large variety of display media. Until these days, the presentation of static perspective views on print media like atlases, magazines, journals or posters is ongoing (fig. 1).

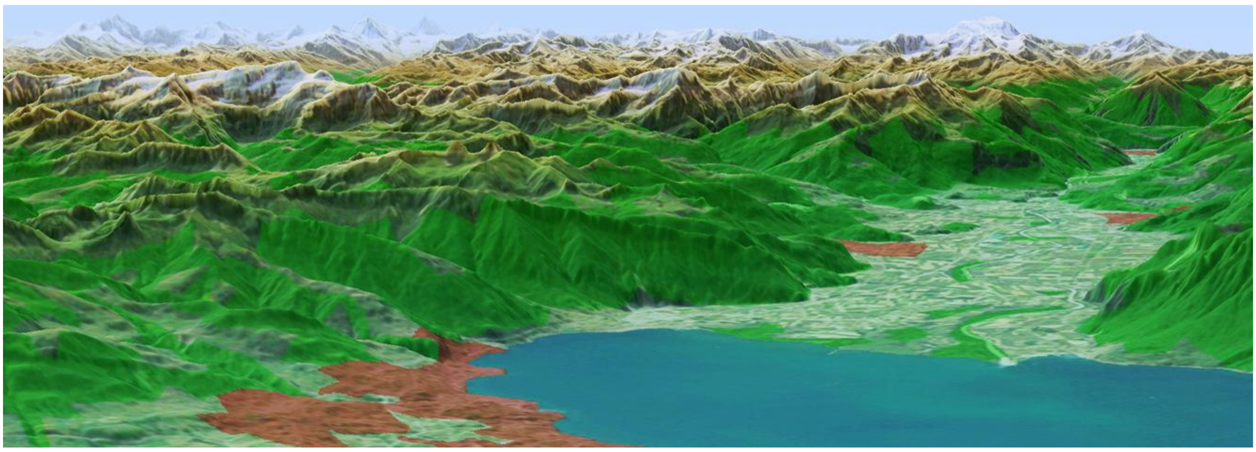

Figure 1: 3D map within an interactive atlas on CD-ROM, with topographic content, draped semi-transparent satellite image and hypsographic coloring (Atlas of Switzerland 2004).

Concerning their content, 3D maps could be either very detailed for thematic analysis or elementary for a quick overview. Aside this trend, the interest in 3D maps on screen is increasing constantly. This is due to the potential of the implemented interactivity and dynamic use. Many commercial map products and scientific approaches have been developed in the last few years. They are often of an outstanding graphic and technical quality. But unfortunately there must be also noticed a great number of negative examples with a poor graphic appearance. Especially a great number of fly-through applications – modeled with a digital terrain model (DTM) and a raster-based texture like an orthophoto or a digital raster map – were published on the Internet or on CD-ROM. This modern kind of 3D maps is frequently implemented in application for tourist or entertaining purposes. However, the potential use for planning tasks or scientific presentation is still increasing as well (Haeberling 2004).

1.3 Technical design process of 3D maps

Before emphasizing the graphic quality of the 3D map segment, we should have a look on the technical design process. This is necessary because all input cues in the four process steps *concept*, *modeling*, *symbolization* and *visualization* have an impact on the final appearance. The process steps are running through iteratively.

In the conceptual phase of every cartographic product, the user context must be identified (Reichenbacher 2004). Also the product specifications had to be defined. Thus, the knowledge and experience of users as well as their objective using situation with its circumstances (e.g., tasks, site, time) must be considered. In this step, the regard on the future users, the use situations and the integrated thematic content influence more indirectly the appearance by choosing the map type.

Second, the modeling step contains the handling, converting and merging of different topographic or thematic data sets and image data (DTM, vector-based data, raster-based textures). Out of the original raw data, there will be often result a complex structured 3D landscape model, especially when implementing dynamic and interactive functionalities in the 3D map (which is not focused in this contribution).

In the symbolization step graphic attributes are added to the single objects of the 3D landscape model. They are changed in shape, size, color, brightness, texture and other graphic features (sharpness, transparency). Also the original position could be altered due of a necessary generalization. There, the graphic appearance of each object class is defined as in the legend construction for classic maps, and cartographic generalization rules must be considered. This legend building does not affect the graphic appearance of the objects at the moment when they are attributed graphically. Thus, the landscape model is transferred into a cartographic 3D model.

Finally in the visualization step, the cartographic 3D model is displayed perspective on the designated media. Only now the cartographic objects appear in front of the user because of the projection parameters and the inevitable interaction of lighting and shading effects (Terribilini 2001). For this, the final rendering process needs also input cues of camera settings and the parameters for the aimed file format.

2 INVENTORY OF GRAPHIC ASPECTS AND GRAPHIC VARIABLES

2.1 Problems in the design process of 3D maps

Today, the design of 3D maps follows mostly the preferences of map authors. But often, they are not aware of all the possibilities of settings they could manipulate. In the entire design process of 3D maps, it is essential to know which graphic cues are involved in each step. Even map authors know some of these possibilities (by handling the software), they do not take into account of useful or unfavorable setting values. Actually, there has been neither an overview of such graphic aspects nor any of the concrete single design variables with their useful variations (Haeberling 2004, Hake et al. 2002).

2.2 Graphic aspects, design variables and their variations

Thus, the cartographic design of 3D maps is affected by a large number of design variables. Design variables – grouped in design aspects, which characterize specific fields in the design process (e.g., modeling of digital terrain model objects, appearance of objects, perspective, atmospheric effects and natural phenomena) – have an effect on the graphic appearance in the visualized 3D map. They are acting quasi in a unidimensional way. And the specific variation of the design variable is a concrete value or option of a limited or unlimited setting.

A first trial for an inventory of design variables relevant for map concepts and production has been assembled in Haeberling (2004). The list is structured along the design process of 3D maps with the steps of *modelling*, *symbolisation* and *visualisation.* It is structured in 13 design aspects relevant for the 3D map image and its content (fig. 2). At the same time, a 3D map is always affected by two basic aspects of design, the degree of *abstraction* and *dimension*, that is the proportions of map objects.

Modelling

Modelling of digital terrain model objects
Modelling of (topographic) map objects
Modelling of orientating map objects

Symbolization

Graphic appearance
Special graphic aspects
Textures
Text objects
Object animation

Visualization

Perspective (projection)
Camera (viewing)
Lighting
Shading and shadow
Atmospheric effects and natural phenomenon

Figure 2: Design aspects of modeling, symbolization and visualization.

3 DERIVATION OF CARTOGRAPHIC DESIGN PRINCIPLES FOR 3D MAPS

3.1 Cartographic design principles in general

For classic topographic or thematic maps, cartographic design principles were established many decades ago. (For the term "cartographic design principles" we could also use synonymous terms like "cartographic rules" (MacEachran 1995), "principles of cartographic representation" or "cartographic convention" (Neumann 1997).) Such cartographic design principles are guidelines how to represent cartographic objects by attributing with Bertin's visual variables (Bertin 1974) or by dealing with minimum threshold and size or by generalizing map objects.

3.2 Cartographic design principles for 3D maps and derivation method

For 3D maps, however, equivalent principles do not exist in cartographic theory yet. No guidelines could be applied in the design process for this kind of representation. Map authors adopt usually the cartographic principles out of their experience with classic maps. But, 3D maps with their 3D data model include some additional aspects, which are relevant for their depiction. Different subtasks like choosing a perspective view, setting lighting and shading variables, structuring the three-dimensional space and the background with atmospheric effects have to be fulfilled. The design variables should be used consciously. And for all these variables, guidance in terms of a limited range of favorable variations must be provided.

In a research project at the Institute of Cartography, ETH Zurich, some design variables for 3D maps were evaluated (Haeberling 2004). The variables were namely: the *inclination angle* of the viewing direction and the *viewing distance* (*zoom factor*) (both of the *camera aspects*), the *horizontal lighting direction* (from the *lighting aspects*) and the *sky structure* and *haze density* (both from the aspects of *atmospheric effects and natural phenomenon)*. Three variations from every variable were selected out of an applicable range of values or options. Then a systematic set of examples of 3D maps, depicting a topographic situation of a typical Swiss mixed urban-rural landscape, was created. Therefore, a section of the digital landscape model *Vector200* together and the corresponding *DTM25* (Swisstopo 2005/1, 2005/2) were symbolized and visualized with the commercial 3D landscape visualization software *World Construction Set 4* (Questar Productions 1998). Additional orientating objects like labels for localities and a graphic coordinate lines were integrated in the cartographic 3D model (fig. 3). Within each set of nine maps, the maps were varied in three abstraction degrees of symbolization and three dimension degrees of symbol size. The aspects abstraction and symbol size of map objects are inherent in every cartographic representation.

The fifteen series of 3D maps examples were rated and evaluated by 27 experts in geomatics and cartography. Also the degrees of abstraction and symbol size as well as the variations of the design variables were discussed concerning their efficiency and usefulness for specific use situations.

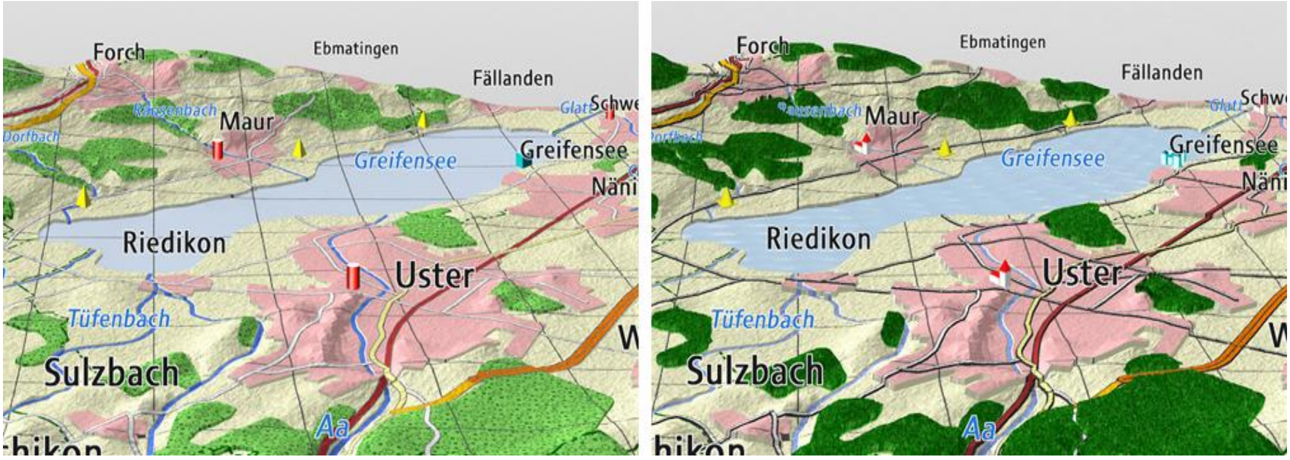

Figure 3: Examples of a topographic 3D maps, computed with symbolized vector data. Left: cartographic symbolization with a high abstraction degree; right: cartographic symbolization with a moderate abstraction degree (Haeberling 2004).

3.3 Propositions of cartographic design principles for 3D maps

The quantitative ratings and the qualitative statements of the experts about the options and value ranges for the design variables were analyzed and interpreted. With these results and as final target of the research project, 19 propositions of cartographic design principles for 3D maps were postulated (fig. 4).

For the abstraction degree in 3D maps

(1) *A map-like symbolization of area and linear map objects allows a familiar and well interpretable 3D map.*
(2) *Volumetric 3D map symbols improve the perspective perception of a 3D map.*
(3) *3D symbols for point map objects are well suited for image-like representations.*
(4) *Image-like 3D symbols may consist of simple geometric shapes.*
(5) *Topographic map objects can have a natural-realistic appearance, but they must not be photo-realistic.*
(6) *Structural patterns could be useful textures for area map objects.*
(7) *Structural patterns must not be designed too dense and fine.*
(8) *Structural patterns must exhibit a good color contrast to the terrain.*

For the dimension degree in 3D maps

(9) *The character of the terrain is emphasized when exaggerating of the digital elevation model.*
(10) *The size of topographic map objects must be chosen so that they can be clearly identified in the foreground as well as in the background.*
(11) *Sizes of linear and point map objects must be chosen so much that they do not cover too much of the terrain.*
(12) *The size of map objects must be defined so that they do not hide too much of each other.*
(13) *Point map objects could be sized larger than linear or area map objects.*
(14) *The appearance of point map objects must not be too dominant.*

For camera aspect in 3D maps

(15) *To look at a 3D cartographic landscape model, an inclination angle of 45° in average is preferable.*

For lighting aspect in 3D maps

(16) *The lighting of the cartographic landscape model must mainly come laterally or slightly from ahead.*

For atmospheric effects in 3D maps

(17) *A neutrally colored model background without sky structure fits generally well to perspective view of a cartographic 3D landscape model.*
(18) *Even without haze effects, a 3D map is recognized perspectively.*
(19) *The addition of slight haze improves the depth perception in a perspective view.*

Figure 4: Propositions of design principles for 3D maps (Haeberling 2004).

4 VALUE OF DERIVED CARTOGRAPHIC DESIGN PRINCIPLES

4.1 Usability and practical assistance

Because the proposed cartographic design principles were phrased in general terms, they could be applied for most design processes of 3D maps. They are not only valid for concrete use for specific purposes. Another important target of the project was also to sensitize map authors for their creative work. When applying some of the derived propositions they become aware of the appliance of other input values or new design possibilities. Even the list of the is limited and totally uncompleted – there could be formulated many others propositions for applying all the different design variables –, the cartographic design principles for 3D maps will assist an efficient generation of these representations. In the future many combinations of variables and their advantageous variations must be tested in 3D map examples. Moreover they have to be evaluated in usability tests and user studies (Haeberling 2004).

4.2 Contribution for an enhanced theory in 3D cartography

The continuation of the cartographic theory is an ongoing process. Many cartographic domains progressed in the last decade rapidly, also the branch of 3D cartography. But we must not only focus the technical approaches for modeling data for 3D representations. We are also obliged to consider the graphic appearance and supply the practical use of the created 3D map products (Haeberling 2004). Especially for the enhancement of cartographic theory, the described propositions of cartographic design principles for 3D maps give surely an impact.

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AUTHOR'S CURRICULUM

Dr. CHRISTIAN HÄBERLING, born 1961, has been employed at the Institute of Cartography since 1995. He received a diploma in Business Administration, and a second diploma in Geography from the University of Zurich. 3D visualization has been his passion and expertise for a long time. He obtained a PhD from ETH Zurich, researching design principles for topographic 3D maps, one of the first research contribution in the area of 3D map production.

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