
3D DISPLAY TECHNIQUES FOR CARTOGRAPHIC PURPOSES: SEMIOTIC ASPECTS

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ABSTRACT

The variety of the cartographic 3D-visualisation is constantly increasing and thereby more and more fields of application are being developed. These facts require that the coherence of technical, perceptive-psychological and cartographic-theoretical aspects has to be subdivided and classified. Through these formulations of interdependence of the single parameters shall be pointed out. The consideration of communication-theoretical and perceptive-theoretical aspects shall lead to a purpose-oriented realisation of the 3D-visualisation techniques according to the user's necessities.

KURZFASSUNG

Das thematische Gebiet "Kartographische 3D-Visualisierung", dessen Vielfältigkeit ständig zunimmt und dem immer mehr Anwendungsbereiche erschlossen werden, erfordert, daß die Zusammenhänge von technischer-verfahrensspezifischen, wahrnehmungspsychologischen und kartographisch-theoretischen Faktoren aufgeschlüsselt und klassifiziert werden. Hierdurch sollen Ansätze einer Interdependanz der einzelnen Parameter aufgezeigt werden. Die Berücksichtigung kommunikationstheoretischer und wahrnehmungstheoretischer Aspekte soll zu einer anwendergerechten und verwendungszweckorientierten Umsetzung der 3D-Visualisierungstechniken führen.

1 INTRODUCTION

1.1 Scientific Application Fields of 3D-Display Techniques

For GIS and remote sensing environments, common as well as new innovative techniques are applied to 3D data sets, virtual reality or volumetric models.

The advantages of 3D representations assumed in the higher validity of the special visualisation form are also more and more used in different kinds of atlases (for example the Swiss National Atlas) as in large-scale (virtual) representation forms.

1.2 Activities in Theory of Cartography

At the Institute for Cartography of the Dresden University of Technology research is, i.a., especially focussed on the development and application of theory of cartography. This research field is strengthened by the role of the Institute as one of the international centres of cartographic semiotics also within the scope of ICA (Koch cum. lit. 1999/2000; Wolodtschenko cum. lit. 1999).

1.3 Consideration of Theoretical and Cognitive Aspects

In cartographic sciences the cognitive aspects especially have never been so popular like the perception-psychological ones. This is mainly due to the complex data material which is comparatively difficult to interpret.

Only the establishment of digital techniques, which opens new possibilities for the visualisation, directed the tension also to the cognitive factors and, subsequently, they were better taken into account for the understanding of the communication process and, last but not least, the map design (Peterson, 1994).

Hence, in the scope of this paper some of the cartographic, theoretical and also cognitive aspects will be discussed in the context of 3D-display techniques, as the authors want to stress the importance of cartographic theory. Systematic analysis is at least a basis to avoid sensationalism and aimless application of the 3D-techniques.

2 PURPOSES OF 3D TECHNIQUES

3D-techniques have received considerable attention in the past. Research in this issue is motivated by the wide potential areas of application. Besides the application in the various scientific fields, 3D-display techniques are going to be adapted in the so-called user-oriented field of application including mainly those outdoor activities where the third dimension plays a particular role (hiking, biking, climbing, skiing, ski mountaineering, hanggliding, paragliding, etc.).

3 CARTOGRAPHIC COMMUNICATION PROCESS

For this user-oriented purpose different techniques are used according to their individual features.

The concepts of a special rating system have to be connected to the communication process.

The cartographic communication process (Figure 1) showing just the mainpart of the whole process represents the postulation of W. Witt (Witt 1979) as well as (as a result of it) the position of the cartographer in the process: Witt postulated for the interdisciplinary view of the cartographic communication process that the analytical-researchlogistic aspects have to be concerted with the social-psychological requirements, for a noise-free communication process. This allows the closing of the cartographic communication process. An optimised cartographic information transmission can only take place if the cartographer understands the behaviour of his/her target groups, which he/she wants to reach with his/her products, and if he/she bases his/her work on this understanding.

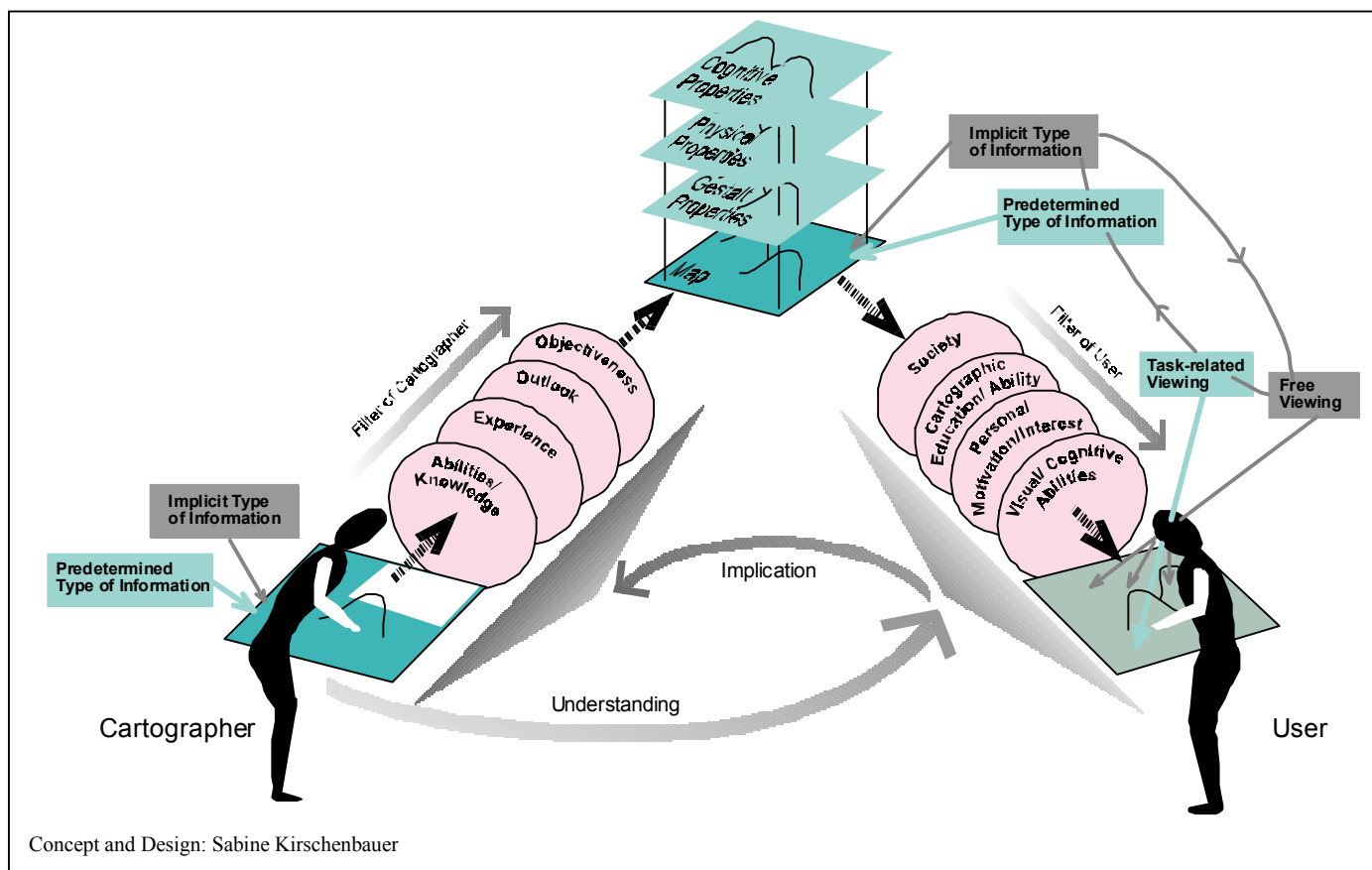


Figure 1. Cartographic Communication Process

4 PERCEPTION CUES

The complex process of human spatial perception and cognition is based on physiological, psychological and other parameters. The human brain interprets information about spatial relations of the environment encoded in the attractions from visual, acoustic and tactile "sensors". From these the visual attractions are most important in this process.

For the visual spatial perception the parameters termed depth cues are basic. One has to distinguish between physiological and psychological cues.

The physiological cues: retinal disparity, convergence, accommodation, motion parallax and chromostereopsis are mainly affected by the structure of the human vision system and the relations between observer and object. Psychological cues are more affected by viewing experience and image contents. They include: retinal image size, linear perspective, aerial perspective, overlapping, shading and texture gradient.

Although their exact coaction is quite unknown, skilful combinations of selected cues facilitate the creation of artificial spatial perception. Only two of them - the retinal disparity and the convergence - are pure binocular cues. The other above mentioned cues can be summarised as monocular cues. Using only monocular cues, the spatial perception is possible from two-dimensional visualisations and monocular viewing, but in general this will cause a weaker depth sensation.

Retinal disparity is caused by slightly different perspectives between the retinal images of the two eyes. Similar to the 3D measurement in stereoscopic photogrammetric models the spatial relations are obtained from the disparities of retinal images.

Convergence is the angle between the viewing axes of the eyes when focusing a point or object. The muscular tension for the rotation of eyeballs gives for distances less than 10 meters (Okoshi 1976) information about the distance of the focused object.

Accommodation is the change of focal length of the crystalline lens in order to focus a point or object. The spent muscular tension for focused distances less than 2 meters is a cue for depth perception. Accommodation is closely connected to the convergence and effective only in combination with binocular cues.

Motion parallax is a depth cue caused by the movement of the observer who is viewing a static scene. Objects, which are closer to the observer seem to move faster than those objects, which have a larger distance to the viewpoint. This cue has a high significance for the spatial perception of the environment (Alberty 1997).

Retinal image size of an object is beneficial if the real object size is known or similar objects in different distances are viewed. The image size has a reciprocal relation to the object distance.

Linear perspective in retinal images is determined by the optical parameter of the eye. Parallel and convergent lines are straightened to one far point and effect a stringently spatial perception (Kraak 1988). Only if the object is known or contextual knowledge about the scene is available, the foreshortening caused by the perspective is non-ambiguous.

Aerial perspective is a cue resulting from the diffuse scattering of light on atmospheric particles. The viewing experience shows sharp objects with high contrast seem to be closer than unsharp objects with lower contrast. This cue is also partially responsible for the psychological effect, that red seems to be closer to the viewer as blue (Imhof 1965). The cue mainly intensifies other depth cues (Sieber 1996).

Overlapping has a high importance for the spatial structuring of the retinal image. An object with a closer outline is perceived more closely to the viewer than another. Absolute distances are not derivable (Vlahos 1965).

Because of the "Gesetz der guten Gestalt" (Law of the Good Form) (Alberty 1997) the cue is clear without ambiguity if the object is known or additional cues are available.

Shading (illumination) summarises three illumination effects: reduced brightness by increasing distance for point sources (Vlahos 1965), shadows, cast shadows and chiaroscuro (Sieber 1996). Shading is an ambiguous cue. If the position of the light source is unknown, for proper depth perception the form of the object has to be known (or vice versa).

Texture gradient is a quantum for the variation of the texture density depending on the distance. The cue is stronger with increasing homogeneity of texture structure. Due to the compression (depending on distance), a homogenous texture contribute the depth perception with larger amount as inhomogenous textures. More detailed and exhaustive descriptions and image examples concerning depth cues can be found e.g. in Vlahos 1965, Okoshi 1976, Kraak 1988, Albers 1998, Sieber 1996.

5 GRAPHIC SEMIOLOGY

For the map production, respectively the cartographic communication process, an encoding of geoinformation in graphical, acoustic or tactile information is essential. The publication of the *graphique semiologie* by Jaques Bertin (Bertin 1974) was a initial impulse for wider research in map semiotics. Since that time the system of Bertin has been tried to be expanded trough umpteen scientists and adapted for new technologies (e.g. Spiess 1978, Freitag 1980 & 1996, MacEachren 1995, Dransch 1995, Böhm 1998).

W.G.Koch (Koch 2000) proposed a system of variables for multimedial cartography based on an extensive review of literature. Especially the graphical variables have to be taken into account for 3D hardcopy. Koch distinguished in 2D static, 2D dynamic and 3D dynamic graphical variables. The in Koch (Koch 2000) mentioned seven static variables are the basis for 2D and 3D dynamic variables in a hierarchical system and described as basic variables. Due to the existing strong interaction between the depth cues and the 2D and 3D dynamic variables mentioned in Koch (Koch 2000), for sytematisation of 3D hardcopy technologies these variables should be considered carefully.

Kraak (Kraak 1988) proposed a linked system of static variables and depth cues which is useful if the 3rd. dimension is considered as thematic dimension. Assuming the third dimension with the same priority than the first and second. dimension (e.g. topographic mapping), the depth cues are needed for the localisation of map information in 3D space or for the spatial structuring. Thematic information located in map space can be encoded in conventional manner by means of static variables.

With respect to the visualisation technology, static variables are (more or less) used for artificial depth perception. The idle variables are available for encoding thematic information: geo object quantity and/or quality. Each of them define a degree of freedom for the 3d-visualisation technology for cartographic purposes.

The degrees of freedom considered for a theoretical comparison of 3D hardcopy with 2D hardcopy (conventional map) are size, brightness, colour, pattern, orientation and shape (Bertin 1974). In Buziek (Buziek 1995) the potential use of these variables for the visualisation of geobjects in 3D space is described.

A systematisation of 3D visualisation technologies can be carried out by rating the visualised image concerning the spatial perception and cognition comfort as well as thematic content. The spatial image is defined as an artificial phenomenon which is spatially observed by the visual perception system; without the physical existence of a real viewing model or scene.

A spatial image can be termed as optimal perceptive, if the visual perception system is working in the same way as viewing a real scene. From the number and type of included depth cues a degree of perception can be estimated. This describes in a broader sense the "nativeness" of the spatial image.

Beside the degrees of freedom and the degree of perception, the quality of the spatial image regarding natural viewing has to be considered. Especially the potential resolution and color depth are parameters which are dependent on the display technology. Quality parameters are summarised by the term degree of immersion. Thereby the amount for spontaneous cognition of thematic content and the authenticity is described. The highest of immersion implies the necessity of additional senses to distinguish between spatial image and reality.

The focus on the above mentioned three parameters of the theoretical spatial image for each technology allows initial assessment for the usability in cartography.

6 THE 3D DISPLAY TECHNIQUES

Buziek (Buziek 1995) points out that the term visualisation is used with different meanings. Therefore it should be noted that in the frame of this paper visualisation is used in the sense of the representation of a spatial image. Consequently it has to be distinguished between the visualisation device (e.g. paper) and the visualised image (spatial image). Likewise flat images, spatial images can be represented by softcopy and hardcopy devices.

Softcopy can be summarised as technologies with the necessity of electronical, computer-driven device, which are in general self-illuminating.

Hardcopy use non electronical display devices without the capability of self-illumination. They influence leight fields in different ways to produce the spatial image.

On the basis of the degree of perception of the visualisation technologies the classification into the following major groups is proposed.

The 2D visualisation technology group contains technologies which only use monocular depth cues. The depth perception is based on pure psychological effects, thus the degree of perception is low. A typical example is a photograph, a movie or a rendered 3D scene.

The parallax group (also called pseudo 3D) enfolds visualisation technologies which are based upon psychological and physiological effects. Selected binocular and monocular cues are utilised with different strength. Parallax visualisations are ranked with a medium degree of perception. Parallax stereoscopic images and interlacing technologies belong to this group.

If all binocular and monocular cues are usable with a visualisation technologie, it is classified to 3D. The degree of perception is high, closed to (or like) the natural viewing. Conventional hologrammes or volume displays are examples for this group.

Table 1 shows the proposed group partition and the current state of development. It should be noted, that this partition alone does not allow statements about the resulting quality of a spatial image. For example: the use of a 2D technology with high degree of freedom maybe produce more immersive spatial images than a parallax technology with less degrees of freedom.

Table 1. Division of visualisation technologies for spatial images

degree of perception	group	basis	depth Cues	tech. status
high	3D	psychologic, physiologic	all of binocular and monocular cues are usable	theoretic or experimental
medium	parallax	psychologic, physiologic	selected binocular and monocular cues (with different strength)	experimental or ready to be used
low	2D	psychologic	only monocular cues	experimental or ready to be used

Compilation: Robert Schenkel

3D visualisation can be divided in stereoscopic and autostereoscopic visualisation (Okoshi 1976; McAllister 1993). The difference between them is the need for additional devices (e.g. glasses) to view the spatial image. Technologies without additional devices will be referred to as free viewing in the following while the remaining will be denoted as aided viewing. The problem of free or aided viewing is considered to be less important for the usability of spatial images for cartographic purposes. For example: the wearing of glasses has an influence on the degree of immersion, but neither on the degree of perception nor on the degrees of freedom.

Table 2 renders the result of a review of literature and patents dealing with 3d visualisation devices. Due to of the variety of technologies their function will not be explained. For further reading the publications (Buchroithner & Schenkel 1999; Okoshi 1976; MacAllister 1993; Hariharan 1996) can be recommended. Buchroithner 1999 has described potential 3D visualisation technologies for cartographic purposes.

Table 2. Technologies for spatial images

Technology			DF	DI	DP	Vg	Md	Examples
Volumetric imaging	continuous	3D	S, Sz, P, B, O, C	H	H	F	S	light emitting volume
			S, Sz, P, B, O, C	H	H	F	S	rotating helix mirror
			S, Sz, P, B, O	M	H	F	S	rotating matrix display
Holography			S, Sz, P, B, O, C	H	H	F	H	hologramme
Multi-stereoscopy	more than 2	parallax	S, Sz, P, B, O, (C)	H	M	F	S,H	hologr. stereogramme
			S, Sz, P, B, O, C	H	M	F	H	barrier stripes
			S, Sz, P, B, O, C	H	M	F	H	lenticular lenses
Stereo	2	pa	S, Sz, P, B, O, (C)	M	M	A	S,H	anaglyphs

			S, Sz, P, B, O, C	M	M	A	H	vectographs
			S, Sz, P, B, O, C	M	M	A	S	shutter
			S, Sz, P, B, O, C	L	L	F	S,H	image splitter
			S, Sz, P, B, O, C	H	M	A	S	digital stereoscope (HMD)
			S, Sz, P, B, O, C	M	L	A	H	conventional stereoscope
			S, Sz, P, B, O, (C)	L	L	F	S,H	autostereogramme*
Pulfrich Effect	1 image		S, Sz, P, B, O, C	M	L	A	S	SpatialVision™ **
Chromo- stereoscopy	1 image		S, Sz, (P), (B), O, (C)	L	M	A	S,H	Chromadepth™ **
movies	1 image	2D	S, Sz, P, (B), O, (C)	M	L	F	S	fly-by animations
still graphics	1 image	2D	S, Sz, P, (B), O, (C)	L	L	F	S,H	perspective rendering

Compilation: Robert Schenkel

* including parallax & cross eyed stereopairs as well as single image stereograms (SIS, RDS)
 ** stereoscopic effect based on optical filters (none image splitting), thus sharp 2D-image is viewable without glasses

Abbreviations:

viewing (Vg): F-free, A-aided
 method (Md): S-softcopy, H-hardcopy
 Degrees of freedom (DF): S-shape, Sz-Size, P-pattern, B-Brightness, O-orientation, C-color
 Degrees of perception (DP): H-high, M-medium, L-low
 Degrees of immersion (DI): H-high, M-medium, L-low

7 COGNITIVE ASPECTS

The basic idea of the user-oriented 3D-techniques is to supply the user with a more realistic representation which can be perceived as a sort of “real-world-scene”.

Since the human user tends to organise each conception or imagination into a sort of “real-world-scene” it could be assumed that the step from a “real” three-dimensional representation into that virtuality is relatively small compared to one from a rather schematic, two-dimensional representation.

Nevertheless, this advantage must again be materialised with regard to the respective purpose.

The complexity of the derivation of a certain information strongly depends on the context in which it is to be derived and also, in relation to that, on the characteristics of the visual process.

“Recovery of 3D shape is assumed in most object recognition schemes and may be beneficial in specifying the function of an object to the observer (Andersen 1996)”(see also Figure 1 “users’ filters”).

Hence, the coding parameters described in Sections 3-5 have to be organised and used in a proper way, according to the purpose and, first of all, to the capacity of the respective display technique.

Whereas the cues are the more detailed parameters, the three groups of stimuli classes of a display add further complex parameters describing the respective properties of a display

- Physical Properties
- Gestalt Properties
- Cognitive Properties.

Physical Properties

These properties are determined by elements like size, position, colour, contrast e.g.

Gestalt Properties

Similarity, proximity, convergence, e.g. are the more overlapping elements characterising a display.

Cognitive Properties

These properties mean e.g. the visual attraction, figure-ground relation. In general, the intellectual associations coming from a display and influences the viewer as far as it meets the viewer's expectation.

(Castner & Eastman 1984)

These intellectual attributes of a form of representation are frequently overseen, because instead in cartography the processing of physical and Gestalt properties belong to the most significant tasks.

But when it comes to the task-specific viewing as in the scope of the above mentioned outdoor activities the cognitive properties in particular become a strongly influencing component.

The visualisation of the third dimension in a "real" 3D representation causes in a first instance a high visual attraction. In the continuing visual and cognitive process the noiseless communication process is driven by the applied combination of the psychological cues, the technical parameters of a display and of the designing elements.

8 CONCLUSION

The discussion of the single aspects in the background of that the results not completed yet, has indicated that the for cartography adapted 3D technologies largely unnoticed.

This is especially true for the 3D hardcopies. The reasons for that may be couched in the absence of the theoretical foundation. In the connection of 3D representation the cartographic theory of signs cannot meet all the raising requirements at present.

Therefore the connected consideration of the above mentioned parameters should be the basis for a purpose-oriented establishment of 3D visualisations.

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