

# 3D MULTIMEDIA PRESENTATIONS - INTEGRATING REMOTE SENSING, PHOTOGRAMMETRIC MODELLING AND CARTOGRAPHIC VISUALISATION

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## ABSTRACT:

Recent developments in computer science have influenced the use of Geo-imagery by expert groups and the general public. The processing methods of remote sensing results and photogrammetric recording have become more accurate, effective and the work flow is accelerated. The results, in general, are often used for engineering, documentation purposes and for the communication of environmental systems. By this, it is meant that the understanding of the system plus its internal coherence is improved by the use of new digital presentation methods.

Cartography, as the communication interface of different user groups, tries to find and use more effectively methods for communicating spatial information, by integrating the results of remote sensing and photogrammetry. With the use of multimedia, in the field of multimedia cartography, a new integrative communication form that uses interactivity, multitasking and different ways of coding information, can be explored. It has created a new paradigm for the visualisation of natural and cultural information related to topography.

Within the cartographic communication process 3D multimedia cartography uses both symbolisation and generalisation to build communication models. In addition, for very large scales, elements of the data management model, like photogrammetric models of objects, may be directly included in these types of cartographic presentations. The focus is to understand relationships between spatial objects using the techniques of Geo-communication.

This paper results from the integration of Geo-imagery and products from photogrammetry into the cartographic communication process using 3D multimedia cartography. It shows the effects on common understanding in terms of information and highlights the possibilities of software implementation methods.

## 1. INTRODUCTION

The introduction of digital technologies and thus the use of multimedia components within cartographic information processing has extended one of the main tasks of cartography, the sustainable communication of spatially related information. Applications in cartography range from navigation to geo-visualisation. Navigation tasks follow the primary goal of finding and moving to a particular location. Therefore the main focus of this research is to understand how people navigate through the environment. Oppositely, the purposes of Geo-visualisation are to assist a user in understanding the Earth's environment, and thus to support the construction of knowledge. This target-oriented aspect, for providing a sustainable communication system would be adequate for cultural heritage applications.

Geo-visualisation using multimedia 3D cartography appears to provide serious support for knowledge acquisition. Depending on the grade of immersion, an intuitive understanding of the visualisation is possible. This may be used to establish a common basis within the "islands" of the reality, the mapmaker and the user.

In order to enable an effective communication, so as to avoid information-overload, and understanding, the virtual environment in a cartographic application has to be simplified, interpreted according to user needs and augmented with multimedial components. In a large-scale view digital models from photogrammetry may be useful. This is because overviews of an area or a region require some simplification due to the perception of information and semiotics.

Cultural heritage has the intent to identify, protect, conserve, present and transmit cultural and natural objects, including landscapes, for future generations (World Heritage Convention 1972). This is the focus of this research project, to build a geo-visualisation product to assist the understanding of the environment. Using multimedia cartography with photogrammetry and remote sensing appears to be a useful "toolbox" to support the work of cultural heritage and its function of bridging "cultural continents".

This paper describes the need for an environmental overview and knowledge acquisition tool, applied to cultural heritage. Advanced offerings of precision photogrammetry and multimedia 3D have to be combined to empower a precise working and presentation environment. Selected examples illustrated are first steps of prototype realisation and related cartographic research.

## 2. DEFINING AN APPLICATION AREA

Geo-imagery assists a wide range of application areas in spatial related topics. Its functional qualities and characteristics enable the bridging of "continents" in economic, natural and cultural aspects. Hence it is also an elementary tool for understanding and accepting cultural diversity and the resultant work of cultural heritage.

In 1992 the World Heritage Centre was established. Its function is to enhance the effective implementation and promotion of the "World Heritage Convention 1972". Therefore it serves as a management and coordination platform with the tasks to support the World Heritage governing bodies, whose task is to

protect the world's cultural diversity and support the development process through the 1972 Convention.

The World Heritage Convention makes a significant contribution to global natural and cultural heritage conservation. It has 175 signatory States Parties. Currently the World Heritage list consists of 730 properties and it is growing yearly.

The main endeavour of the 1972 Convention is to ensure the assistance for the member States for the identification, protection, conservation, presentation and transmission of cultural and natural heritage to future generations. [<http://www.unesco.org/culture/heritage>] The achievement of these goals is, in general, supported by two disciplines – photogrammetry and cartography.

Research in photogrammetric methods, the development of new techniques of recording and analysis and the management of data are fundamental parts for the protection and conservation of cultural objects. Results of this work – using geo-imagery, photogrammetric images, orthographic textures and digital data – are further used for the presentation and identification of the relevant objects.

The main tasks of cartography may be fundamentally differed in the class of “way finding” and “geo-visualisation”. The objective of way finding research is the understanding on how users navigate through an environment and how they learn about it. The primary goal is to find and move to a particular location, which is also relevant in virtual environments. The results of this work are restricted to applicable themes of cultural heritage – e.g. when thinking about finding properties. In the context of presentation, the transmission and sustainable communication elements of geo-visualisation seem to be more important. The main objective is to assist in understanding the Earth's environment with the help of new methods and thus to support searches for the unknown and the construction of knowledge. [Slocum et al 2000]

In a more traditional way, the main task of cartography would be the visual documentation, archiving and communication of spatially related topics. Therefore geometrical and semiotic mapping rules were developed over the last centuries. [Kretschmer 1986]

Asking for a sustainable communication methodology calls for a definition of “sustainable”. According to the definition of the Brundland commission (World commission on Environment and Development, *Our Common Future*, Oxford University Press, 1987) it is defined as: “to meet the needs of the present without compromising the ability of future generations to meet their own needs”. The author's understanding of this definition, in context with cultural heritage and the work of photogrammetry and cartography, means that the original natural and cultural objects on one hand and models, recorded data, cartographic applications and spatial connected knowledge – including maps for reconstruction and cartographic interpretations of real objects – on the other hand should be “archivable” and usable for future generations.

From this point of view photogrammetric models and products require open data standards. It can be expected that proprietary formats will not be readable in near future. [<http://www.rlg.org>] For the cartography point of view, the knowledge presented with the help of maps should be available in the future. In addition to seminal programming standards of an application, maps need to be readable and understandable, independently from its semiotics.

Knowing of the demands of sustainability and the differences between cartographic tasks, the idea and vision to develop a sustainable multimedia 3D presentation that integrates remote sensing, photogrammetric modelling and cartographic visualisation, should be encouraged and defined. Basically this proposes an open standard cartographic application using multimedia components to support an intuitive communication process combined with an automated, or semi-automated, placement of symbology, which is dependent on the scale, beginning at the drafts of remote sensing, photogrammetry and GIS.

### 3. 3D CARTOGRAPHY IN CONTEXT WITH KNOWLEDGE ACQUISITION

Over the last decades the introduction of digital technologies within the reproduction, archiving and presentation techniques have expanded the flexibility of cartography. Independent combinations of media, the use of different modalities, interactivity and multitasking has enabled user-specific presentations and created a new topic within this working field: multimedia cartography [Cartwright et al 1999].

The new possibilities and different forms of presentation provide new communication methods for spatially related information, which can be seen as the main task in this new technological era of cartography [Gartner 2002]. Thus the usage of multimedia forms an effective adjunct to the cartographic communication process [Cartwright et al 1999].

The addition of three dimensional visualisations within multimedia cartography opens interesting perspectives for the spatial communication process. Topographical information does not have to be read from the map, but can be seen intuitively. Surveys e.g.[Buchroither 2002] have shown that 60% of users of topographical 2D maps have difficulties to extract a three dimensional impression. In addition other polls [Schroth 2003] revealed users preferred camera movements in a height of about two meters (eye height) instead of fly overs. These results seem to be based on physiological and psychological parameters.

#### 3.1 Spatial perception

The main definition of 3D cartography is still geometrically based and thus it is adapted from position of the projection plane in space, excluding the horizontal or upright projection [Hake et al 2002]. This definition only takes account of analogue and geometrical visualisations, but it is not applicable to the new presentation forms in multimedia 3D cartography. Therefore one initial point may be the cartographic communication process, where the type of user interface – the computer to human being connection [Dransch 2002] – is appropriate for the definition.

For the most part of visual presentation forms it is possible to differ between “pseudo3D”, “p3D” and “real3D”.

Most computer based 3D applications use the pseudo3D form. A two dimensional surface visualises the presentation of a three dimensional application. Here, apart from a screen, no additional hardware is needed. Pseudo 3D provides perspective monoscopic visualisations on flat devices – paper or screen – and only uses psychological depth cues.

P3D stands for “Parallax 3D”, which employs selected bi- and monocular physiological and psychological depth cues. It mainly includes the technologies of chromostereoscopy, Pulfrich effect, stereoscopy and multistereoscopy (e.g. lenticular lenses on a paper medium). In most cases additions to the screen are needed to enable P3D (e.g. shutter glasses).

Real 3D presentations use all available bi- and monocular physiological and psychological depth cues. Within these images of space, continuous effects of parallax occur in all directions. The main technologies for production of these images are volumetric imaging, light emitting volume, rotating helix mirror and processes of holography. [Bollmann et al 2002]

Basically these three different kinds of visual presentation are dominated by the theory of spatial perception, the physical parameters of the display and the graphical semiotic. The parameters for the visual perception of depth are classified in physiological and psychological terms. The physiological parameters describe the technique of the human visual system and include retinal parallax, accommodation, convergence and the parallax of movement. The psychological class is independent from the technical condition, supporting relations between the real and perceived world and strengthens the spatial impression. It consists of the size of the retinal picture, linear-perspective, air-perspective, overlay and hiding, shading and gradients of texture. [Albertz 1997]

Due to the fact that multimedia 3D cartography not only consists of visual presentation, but which forms a substantial focusing point, a more common classification may be added.

Based upon the work of Heim [1998] four "I" factors are important for creating a multimedia 3D cartographic application – immersion, interactivity, information intensity and intelligence of objects [MacEachren et al 1999].

The intelligence of objects specifies the possibilities for supporting users in interpreting a cartographic environment, the information intensity is a formalisation for the "level of detail" – in this sense the amount of information presented – , interactivity assist users in orientation finding and information extraction. Immersion names the submersion of a user in the virtual cartographic environment.

The factor of immersion is strongly connected to the parameters of visual perception. The definition "...a psychological state characterised by perceiving oneself to be enveloped by, included in, and interacting with an environment..." [Witmer and Singer 1998, p.227] assumes the existence of psychological and physiological parameters for spatial perception. The more parameters – depth cues – used by a visual user interface, the more an user will be immersed into the virtual environment.

### 3.2 Knowledge acquisition

The assimilation of information within a multimedia 3D environment does not only depend on depth cues but also on processes of memorising and learning. Therefore a 3D environment may be a helpful tool when thinking about active knowledge acquisition.

Following the principle of Zimbardo [1995], knowledge acquisition is supported by the grouping of information and the usage of individual rules of organisation and order. In cartographic tasks this means that criteria for similarities of body structure and temporal behaviors, common meaning and organisational structures according to semantical classification and hierarchical structuring are being made [Buziek 2000].

In addition the learning theory of Bandura reverts to a dual coding. It says that the establishing of knowledge is based upon learning of direct experience and representative experience. Therefore imitating and evaluating sequences of imitation [Bandura 1987].

The construction of patterns and the adoption of categorical behaviors is activated by processes of enhancement and motivation, which may be evoked by the usage of different modalities of the same information – e.g. changing of color and sound to express one information [Dransch 1997]. With the help of individual memory-structures, changing knowledge of an environment is a process of building, storing and realisation (essentially as patterns). New experiences, interactions and situational activities change stored knowledge and reshape it. Perception and knowledge acquisition is a continuous activity that may be depicted as cycle of perception [Neisser 1979].

Spatial perception and knowledge acquisition are the two main aspects in the transmission of spatially related information. Both may be combined as the notion communication. At a very common approach communication consists of a sender-acceptor model, which describes the coding- decoding and interpretation of information. During the interpretation part errors may occur depending on the user's experiences.

This observation supports the system's theoretical description of communication. It says that each individual builds-up their own island – truth or understanding – of the real world depending on their experiences and knowledge. Communication can only exist, if these islands of understanding overlap. In the end "truth" will be what the acceptor understood and interpreted, but not what the sender said (system theoretical description – Birkenbiehl).

The knowledge transfer within a 3D multimedia presentation underlies these theories and observations. It consists of three islands – reality, the mapmaker and the user – where the number of user islands is infinite. Overlapping within the user groups takes place according to similarities of knowledge and experience. For the author the hypothesis that the elaborated usage of 3D presentation and metaphors may support the cartographic communication process exists. It is based on keeping up habits of perception and a familiar environment and thus combining and overlapping the individual islands.

## 4. IMPLEMENTATION FOR A 3D MULTIMEDIA PRESENTATION

The aim of a multimedia 3D cartographic application for cultural heritage would be a reasonable and sustainable product for experts and equally for educational purposes for the public. Therefore the aspects of communication – psychological and physiological parameters of spatial perception and knowledge acquisition – as well as technical requirements – concerning data quality, data description, data formats, programming techniques and semiotic issues – have to be considered. In addition the lifetime and durability of digital media and long-term archival concepts must not be disregarded.

Results of photogrammetrically recorded objects, remote sensing and GIS should be combined in this cartographic application. Before, a common description of data and formats are needed. Of course the rules of cartographic generalisation and symbolisation also have to be borne in mind and applied dependent on the scale or "level of detail" required.

### 4.1 Graphical elements in a cartographic 3D application

A 3D multimedia presentation combines visual, aural and, depending on the user interface, tactile components with the characteristics of "multimedia", computer-based, multi-modal, interactivity, multi-coding.

The most used interface for computer based applications is the

screen, the visual component. Thus graphical elements obtain an important part of information and knowledge transfer.

Within a cartographic 3D application the graphical component consists of terrain, primitives, complex models, texture, light and camera-view and movement. These main elements are fundamental in computer graphics and may now be adapted for a 3D cartographic information system. Here, the most important needs are the allocation of coordinates, the transformation to a common geographical projection and the implementation of a semiotic and communication model.

The *light*, *texture* and *camera-view* are elementary to obtain a spatial impression and to enable depth cues. Including *camera-movement*, these elements prevent and mitigate the main disadvantages in a 3D environment, hiding information, usage of an infinite number of scales in one view and the impossibility to compare geometrics [Kroak 1988]. An interactive camera movement makes information more read- and understandable.

*Complex models* of real objects may deliver fine details depending on the recording method and the subsequent data structuring and modelling. The photogrammetric recording of fine details is important for an overall documentation and may be taken into consideration for a very large scale of visualisation. In many cases and for the needs of LOD (Level Of Detail) a simplification and generalisation of this provides details to a general model would be helpful in order to save memory and processing power during the rendering process.

In general the format of these specific photogrammetric modelling applications is convertible to a common understood structure – like VRML, XML. Assuming the existence of a geographical reference these models may be used in a cartographic application [Dorninger 2003].

*Primitives* name simple geometric objects like a plane, box, sphere, cylinder and particle systems. These are build within the application and so the process of creation only needs some processing time. No download time has to be considered, which is important for WWW applications and for performance optimisation. The formal description for the composition of cartographic 3D symbols out of primitives is a powerful tool and useful for presenting simplified objects in smaller scales (bigger distances to the camera).

Attention should be paid to the similarity of the high detailed model and the very simplified one. Losing these similarities and thus the perceptible connection of objects would lead to misunderstanding and a possible failure of the communication model. Algorithms and rules for an automated generation of symbols may possibly be found with the help of automated aerial photo interpretation techniques or generalisation models [Twaroch 2001].

The *terrain model* is fundamental to communicate topography in context with spatially related information and objects. Depending on the accuracy, estimated download time and existing processing power different strategies have to be considered. For the highest detail a terrain in 3D would be needed to remove discrepancies occurring by the combination of objects – rivers are not flowing downhill, houses flying above ground, etc. In smaller scales a 2.5D generated terrain would be sufficient. Therefore the data source may be a grayscale picture. The values of this bitmap represent the height information, which can then be calculated to a terrain model. The download time and memory usage is directly connected with the resolution of the terrain model, independent from 3D or 2.5D. Sometimes 2.5D offers more possibilities for

performance optimisation. That is why it is often used in 3D gaming applications.

The *texturing of terrain* assists the information visualisation of surface- and line-based objects. It is important to rethink the meaning of information within the texture, particularly because it is so simple to add a texture. Many examples in cartographic 3D applications use ready-made topographical maps, containing labeling, symbols and level curves, without considering that the writings will not be readable from many directions, symbols not perceptible and the level curves will go up and down a hill. Keeping texturing of terrain in perspective it would make more sense to obtain the textural information, elaborating selected and offered according to the application area, from a map-server. The repository of information would then be more flexible, accessible and update able. In addition texturing of objects is a relatively simple method to remove unwanted detail.

## 4.2 Examples – state of the art

Graphical elements point out the possibilities within a visual 3D presentation. Theoretically it seems that the combination of data, provided that meta-data are consistent and the combination of different scales was considered, is nearly unrestricted. In fact discrepancies and limits, that were not thought of before, occur during implementations and cause much additional work.

In this section of paper some selected examples dealing with the combination of cultural objects in a cartographic 3D environment are detailed.

*Carnuntum 3D* started as an example of a master thesis [Jobst 2003] with the idea of being a multimedia 3D cartographic portal providing access to archaeological data and reconstructions in the area Carnuntum, focussing on the ensemble of temples on the Pfaffenberg hill, which does not exist now due to the mining of gravel. The specialties of this application are the extensible model implementation and the terrain texture generation.

*Extensible model implementation* takes care of different archaeological interpretations of objects. Using interactivity (with mouse or keyboard) and explanations, one interpreted reconstruction may easily be exchanged by another. The models are loaded from a database, where it is easy to rebuild, modify and add new models. According to the camera distance models are automatically exchanged following rules from the communication model.

*Terrain texturing* was simplified to the use of ready-made cartographic textures containing surface interpretations. In the near future, depending on the results of archaeological research, it is planned to achieve terrain textures from an UMN Mapserver, where ortho-imagery and different results of GIS queries may be implemented. This product would obey user needs and give more freedom and choice in transmitting individual information [Jobst 2003].

Although the usage of a 3D terrain model for large scale in conjunction with a 2.5D terrain for the smaller scales is a benefit for performance, it results in a small noticeable error: at the border of the two terrains a gap is visible from some points of the camera-view due to different qualities and resolutions.

The second example “*3D-Murale*” comes from an archaeological approach and tries to combine archaeology and Virtual Reality. It is a project led by Brunel University with support from the European Union. The aim is to develop tools to measure, reconstruct and visualise archaeological ruins in

virtual reality using the ancient city of Sagalassos in Turkey as a test case.

The system concept includes several modeling and recording tools, a database to store and retrieve the virtual artefacts and buildings and an outstanding visualisation application.

The visualisation component takes care of:

- large and complex scenes, so that very fine details of some of the finds may be shown in large scales;
- different user, application and hardware profiles, so that the systems is adaptable for experts as well as for a wide public and
- time-dependent data, so that finds can be presented over a large historical time span, where most of the objects have been moved around and have different dates of creation.

[Hynst et al 2002]

The user of this system can navigate virtually through a standalone high quality site visualisation system noticing level-of-detail selection, predicting the next views and exploiting humans reduced visual resolution while moving. From a cartographic point of view: this system uses – for the most part – large scales and does not give an cartographic interpreted overview of the region and neighbouring sites. It uses a terrain with orthographic imagery as texture to bear some reference to the topography.

The third and last example is taken from the spatial planning community and introduces the “*Digital Landscape Server*” (DILAS) project, a commercial product line from GEONOVA AG and serves as a platform for applied research and development.

The DILAS system architecture relies on commercial database technologies (Oracle 9i DBMS) and consists of a server, manager, 3D modeler and scene generator.

The 3D object data-management model is fully object -oriented for 3D geo-objects and incorporates the capability for multiple levels of detail as well as texture and appearance information.

The 3D object type is supplemented by a number of spatial data types to represent very large mosaics of high resolution terrain and texture data – like raster maps, ortho-imagery, terrain and surface models.

The storage concept for 3D objects is a persistence framework built on top of a DBMS with the representation in Java and XML. Thus it provides an optimum in modelling flexibility in combination with an excellent object query and retrieval performance.

The visualisation module provides a broad range of “standard” GIS functionality and a number of features, which specifically support the visualisation and animation of reality-based 3D models.

[Nebiker 2003]

These three examples represent an non-homogeneous but actual overview of the present state of art. Coming from cartography, archaeology and landscape planning one common goal is noticeable: an easy understandable communication of spatial related information with the help of multimedia and 3D. The different access to maps and the specific understanding of maps results in varying concepts of visualisation and expression of needs within the application.

## 5. RESUME AND FUTURE INTENTIONS

The effect of multimedia 3D cartography on the communication process, knowledge acquisition and common understanding is not well known and controversial at the moment. Some research in the psychological aspect and usability tests have to be done. The usage of existing examples could help to achieve results and to support further intentions.

Based on the technical aspect nearly no limitations are observable. Considering technical requirements, like data quality, data description, data formats, programming techniques and semiotic issues, the combination of data from different derivations, surveying, photogrammetry, remote sensing and GIS, cannot be seen as a problem. In addition the development of new user interfaces enables the utilisation of all depth cues. This results in intuitive and realistic perceptible presentation of information. For this reason semantic issues become more important and have to be further investigated.

The main task of cartography – to communicate spatial related information – may be supported in context with topography with the help of multimedia 3D cartographic applications due to a common understood platform and perception of space. Supporting knowledge acquisition and therefore the understanding of spatial and cultural topics follows educational needs, which may result in bridging the continents and encourage the work of cultural heritage.

The aim of work to create an interpretative tool that combines photogrammetry, cartography and archaeology. A prototype mixed reality, or augmented reality, application will be established in addition to a working cartographic information environment. The main foci are the communication of spatially related archaeological information and on the transition between 2D and 3D.

Applications will provide the tools for the fieldwork related to expert groups or museums installations.

## 6. REFERENCES

- Albertz J., 1997. Die dritte Dimension – Elemente der räumlichen Wahrnehmung, in Wahrnehmung und Wirklichkeit, Freie Akademie, Berlin.
- Bandura A., 1987. Sozial kognitive Lerntheorie, Klett-Cotta, Stuttgart.
- Bollmann J., Koch G.W., Lipinski A., 2002. Lexikon der Kartografie, Spektrum Akademischer Verlag GmbH, Heidelberg, Berlin.
- Buchroithner M.F., 2002. Autostereoskopische kartografische 3D-Visualisierung, Kartografische Schriften, Band 6, DGfK, Kirschbaum Verlag Bonn.
- Buziek G., 2000. Theoretische Grundlagen der Gestaltung von Animationen und praktische Beispiele, in Dynamische Visualisierung, Springer Verlag, Berlin – New York.
- Cartwright W., Peterson M.P., Gartner G., 1999. Multimedia Cartography, Springer Verlag, Berlin-Heidelberg-NewYork.
- Dorninger P., 2003. XML and Geodata. CORP 2003 - 8<sup>th</sup> International Symposium on Information and Communication Technologies in Urban and Spatial Planning. TU Vienna.

- Dransch D., 1997. Medienpsychologische Aspekte beim Einsatz von Multimedia in GIS, in Kartografische Schriften, Band 2, Kirschbaum Verlag, Bonn.
- Dransch D., 2002. Handlungsorientierte Mensch-Computer-Interaktion für die kartografische Informationsverarbeitung in Geo-Informationssystemen, Habilitationsschrift am Fachbereich Geowissenschaften der Freien Universität Berlin, Berlin.
- Gartner G., 2002. Multimedia und Telekartographie, in den Kartographischen Schriften, Band 6, herausgegeben von der Deutschen Gesellschaft für Kartographie e. V., Kirschbaum Verlag Bonn.
- Hake G., Grünreich D., Meng L., 2002. Kartographie – Visualisierung raum-zeitlicher Information; Walter de Gruyter, Berlin-NewYork.
- Heim M., 1998. Virtual Realism. New York: Oxford.
- Hynst S., Gervautz M., 2002. 3D-Murale – archaeology and virtual reality. Workshop 7 – Archäologie und Computer. Wien
- Jobst M., 2003. Der Einsatz multimedialer Technologien in kartenverwandten Darstellungen am Beispiel Carnuntum. Master thesis. Institute of cartography. Technical University of Vienna.
- Kretschmer I., 1986. Lexikon zur Geschichte der Kartographie. Von den Anfängen bis zum 1. Weltkrieg; 2 Bde, Wien.
- Kroak M.J., 1988. Computer assisted cartographical three dimensional imaging techniques. Delft.
- MacEachren A.M., Edsall R., Haug D., Baxter R., Otto G., Masters R., Fuhrmann S., Qian L., 1999. Exploring the potential of virtual environments for geographic visualization. <http://www.geovista.psu.edu/publications/aag99vr/fullpaper.htm>
- Nebiker S., 2003. Support for visualisation and animation in a scalable 3D GIS environment – motivation, concepts and implementation. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol.XXXIV-5/W10
- Neisser U., 1979. Kognition und Wirklichkeit, Klett-Cotta Verlag, Stuttgart.
- Schroth O., Paar Ph., Wissen U., Lange E., Schmid W.A., 2003. Steckt der Teufel im Detail? Eignung unterschiedlicher Detailgrade von 3D-Landschaftsvisualisierung für Bürgerbeteiligung und Entscheidungsunterstützung. CORP 2004 - 9<sup>th</sup> International Symposium on Information and Communication Technologies in Urban and Spatial Planning. TU Vienna.
- Slocum A.T., Blok C., Jiang B., Koussoulakou A., Montello R.D., Fuhrmann S., Hedley R.N., 2001. Cognitive and usability issues in geovisualisation, Cartography and Geographic Information Science v28 p61-75.
- Twaroch F., 2001. Modellgestützte Rekonstruktion von Gebäuden und deren Verwaltung in einem Topographischen Informationssystem. Master thesis. Institute of Photogrammetry and Remote Sensing. TU Vienna.
- Witmer B.G., Singer M.J., 1998. Measuring presence in virtual environments: a presence questionnaire. Presence 7(3): 225-240.
- Zimbardo P.G., 1995. Psychologie, 6. Auflage, Springer, Heidelberg.