A Qualification of 3D Geovisualisation

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Publication date:
2007

Document Version
Publisher's PDF, also known as Version of record

A Qualification of 3D Geovisualisation

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Ph.D. dissertation
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Aalborg University 2007

Abstract

A vision of digital systems that can manage the increasing load of raw data and convert it into flexible, global and multi-dimensional digital systems is shared by many professionals working in geosciences and related fields. For geoscientists it is a more direct relationship between dimensionality and technique that is the draw, for others it is the new and various aspects of utility in science and society that attracts. While important technological and productivity improvements are made these years, the field also lives through years of inertia in public and commercial interests. This contradictionary situation is mainly due to the large expenses needed to reorganise data, software and workflows. These expenses are in 3D systems also to be compared to a low and scattered need for 3D in society. This thesis suggests an increasing focus on usability to meet this situation. Focus on usability is not new in the field, but it is usually directed towards professional use in science and related professional contexts. This thesis argues that 3D systems are also used by wider segments in society today and that these segments represent a potential that can help 3D Geovisualisation forwards and out of commercial inertia. Addressing wider segments involves a communication with non-professional users. To address non-professional users there is a need for communication at a far higher level of quality than what is the case today. In this context, it is here suggested to understand 3D Geovisualisation as a media whose content and means can be explored in order to understand how the media works. Here a categorisation of identified content and means contain four categories; representation, rendering, interface and interaction. In the representational part a convention of visual representation is used where geographic objects are represented on a scale going from realistic and detailed to abstract and more symbolic. In the rendering part, various effects like light and shadow can be used to manipulate the scene and thereby act as means of communication in the media. In the interface part the wide possibilities of accessing the three-dimensional digital representations through the user interface is issued. Finally, it can be interacted with in various ways, for instance through queries or by navigating. For each of the four categories, fields of special interest have been identified and discussed, and usability tests are accomplished to elaborate the field. Results show among others, that non-professional users' preferences are not necesarily the preferences expressed by other stakeholders. In relation to the cases used here, it can be social attachments and control that are more important to the users than expected from other stakeholders. In conclusion, when developing projects it is especially fruitful to consult users on representational and interactive issues, while rendering and interface issues can more likely be used in coordinance with conventions and common expectations that already exist in the field. Working with the test cases and the users it has been possible to categorize all concepts inside the media model that appeared while working on this thesis, and the four categories are therefore generally suitable as an umbrella that describes 3D Geovisualisation being a media addressing non-professional users. It is, however, more a synergic and continuous

system than the linear and discrete media model that constituted the basic model. Still a much more understanding of users, utilities, means and effects is needed to develop a profound theoretical background, especially as more complex systems will be even more widespread in society in the future.

Dansk resume
En kvalificering af 3D Geovisualisering

Visionen om at være i stand til at konvertere den hastigt voksende mængde af indsamlede geodata til fleksible, flerdimentionale digitale systemer, deles af mange professionelle indenfor geofagene. For videnskaben er det etableringen af mere direkte relationer mellem dimensionerne og teknikken der er hovedideen, for andre de mange nye aspekter i forhold til anvendelse i videnskab og i samfund, der driver interessen. Alt imens vigtige teknologiske skridt tages indenfor 3D geoteknologien i disse år, oplever fagområdet samtidig en inerti i offentlig og kommerciel interesse. Denne modsætningsfyldte situation er især opstået på grund af de store udgifter der følger med en omstrukturering af data og organisationer. Dette skal for 3D systemernes vedkommende sættes i forhold til det relativt lave og diffuse behov for 3D som samfundet oplever i dag. Denne afhandling foreslår at øge fokuseringen på usability og anvendelighed for at imødekomme denne situation. Fokusering på usability er ikke ukendt indenfor fagområdet, men den er som regel rettet mod den professionelle anvendelse indenfor forskning eller på ekspert-niveau. Denne afhandling påpeger at 3D systemer også anvendes af bredere segmenter i samfundet idag og at disse segmenter repræsenterer et potentiale der kan hjælpe 3D Geovisualisering fremad og ud af den kommercielle inerti. For at henvende sig til bredere segmenter i samfundet bliver den ikke-professionelle bruger et omdrejningspunkt. I forhold til den ikke-professionelle bruger, er der et behov for at kommunikere på et langt højere niveau end tilfældet er i dag. I denne sammenhæng foreslåes det derfor at betragte 3D Geovisualisering som et medie, hvis indhold og virkemidler skal undersøges for at forstå hvordan mediet fungerer. Der er derfor identificeret fire kategorier der er velegnet til at beskrive mediet på et overordnet plan; repræsentationen, renderingen, interfacet og interaktionen. I repræsentations-kategorien beskrives et system hvor den visuelle repræsentation af de geografiske objekter kan opstilles på en skala der går fra at være højt realistisk og detaljeret til at være abstrakt og mere symbolsk. I renderings-kategorien indgår de forskellige muligheder der teknologisk eksisterer for at manipulere med effekter, så som lys og skygge. I interface-delen indgår det brede spektrum af muligheder for at tilgå digitale 3D systemer gennem skærmmiljøet. Endelig er interaktionsdelen den del der beskriver hvorledes brugeren kan interagere med systemet, for eksempel ved at foretage forespørgsler eller navigere. For hver af de fire kategorier er der identificeret og diskuteret områder af særlig og aktuel interesse og der er derefter gennemført usability tests for at uddybe en forståelse for området. Resultaterne viser blandt andet at de ikke-professionelles præferencer er ikke nødvendigvis de samme præferencer som er udtrykt af professionelle interessenter. I de tilfælde der er arbejdet med her, kan det være den sociale forbundethed samt en oplevelse af kontrol, der er vigtige for brugerne, men som ikke opleves tilsvarenbde interessante for interessenterne. I interface-testen og renderings-testen er der bedre overensstemmelse mellem de ikke-professionelle

brugere og de professionelle, hvor også litteraturen på området viser en vis positiv overensstemmelse med resultaterne her. Det kan derfor konkluderes at det i systemudviklingssituationer er særligt frugtbart at konsultere målgruppen på repræsentations- og interaktions-siden, mens det på renderings- og interface-siden bedre kan forsvares at læne sig op ad de eksisterende konventioner og almindelige forventninger der allerede findes på området. Gennem arbejdet med test cases og brugerne har det været muligt at at kategorisere alle opståede koncepter indenfor de fire overordnede kategorier, og de har derfor været anvendelige til at beskrive 3D Geovisualisering som et medie der er velegnet til at henvende sig til ikke-professionelle brugere. Mediemodellen viser sig dog snarere at være et synergisk og kontinuerligt system end den lineære og diskrete mediemodel som blev beskrevet som udgangspunkt. Der er dog stadig brug for endnu mere forståelse for brugerne, anvendelsesområderne og mediets midler og effekter for at få en større forståelse for emnet og for i sidste ende at udvikle en mere veletableret teoretisk baggrund.

Tabel of Content

Section 1: Introducing 3D Geovisualisation

1. Introduction

A vision of a digital Earth

The world has witnessed the development of several new media throughout history, from printing and production of graphics to the digital invasion of pc's and the internet. Along with the pc, three dimensional virtual worlds have been introduced, as well as 3D Geovisualisation being one of the most contemporary issues in geosciences and geoindustries. The visions connected to 3D Geovisualisation have been expressed comprehensively by Al Gore (Gore 1998) in his speech "Digital Earth" at California Science Center:

"We have an unparalleled opportunity to turn a flood of raw data into understandable information about our society and out planet. This data will include not only high-resolution satellite imagery of the planet, digital maps, and economic, social, and demographic information. If we are successful, it will have broad societal and commercial benefits in areas such as education, decision-making for a sustainable future, land-use planning, agricultural, and crisis management. The Digital Earth project could allow us to respond to manmade or natural disasters - or to collaborate on the long-term environmental challenges we face."

Developments and driving forces

Al Gore's vision is shared by many parties and has persisted more or less in the same form since 1998. Even though visions in the western world in the 80's and 90's included a near future full of virtual technologies, a virtual breakthrough is an ambiguous reality; both a story about success but also about inertia. On one hand, the gaming industry has experienced an enormous development both culturally and technologically, a development that has spread to all other corners of society. A direct consequence of the success in the gaming industry has been much cheaper and much more advanced software being widely available today. This also affected geographical information and cartography, and the impact is especially clear in 3D Geovisualisation. Historically, the development of 3D Geovisualisation is closely related to the technological development that the gaming industry has caused and hence also affects the way 3D Geovisualisation is developing today. This is described by Wood et al 2005, who claims that development in geovisualisation is mainly driven by technology in contrast to driven by theory, because economical interests are far larger within technology (Figure 1.1).

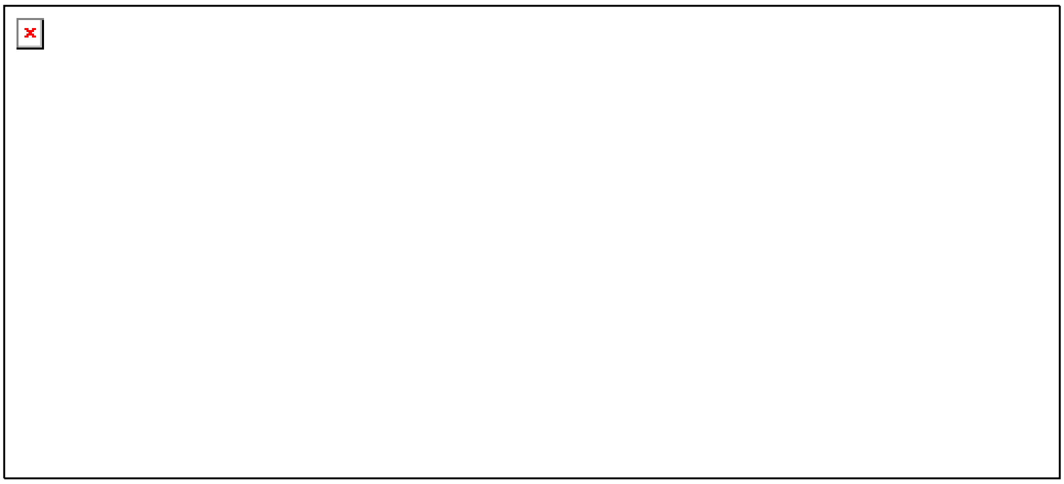


Figure 1.1: Development within geovisualisation is driven mainly by technology as shown by the thick arrow. (Wood et al. 2005).

From an internal geographical research point of view, it is the professional wish of a simple and more direct relationship between dimensionality and technique that drives the academic development of geovisualisation (Wood et al. 2005). This theoretical point of view is less dominant than technological development driven by short-term interests. As a consequence of this, the long-term visions of Al Gore are not supported very strongly. This inertia in the long-term visions exists, but also inertia in commercial success, when it comes to 3D Geovisualisation. It has, in many cases, been difficult to justify the huge expenses for development held up against the practical value in industry and society, despite several successful projects. One reason is that education and time consumption of personnel are important variables in organizations when new strategies and software are chosen. In 3D, more complex technological issues exist, where data management, storage and interaction are fundamentally different from traditional systems, and hence decisions sometimes favour traditional systems both in industry and in governments. It is possible to link the inertia in commercial interests and long-term-visionary systems together and argue that as soon as we have an optimal system it will also sell better. But as (Dykes et al. 2005) point out, contemporary geoinformation technology is dominated by approaches that can be characterized as “build and they will come” – an approach that is not very useful in commercial and competition-dependent geoindustries.

The “build and they will come” approach is challenged here by suggesting that there might be a lesson to be learned from the immense technological development in the gaming industry. This lesson is not about technology, stakeholder cooperation or theory, but the simple force of human attention which started the “goldrush” of the gaming industry. Consumer demand in the entertainment industry is a convincing story of success, underlining the well-known principle that usability and technological development needs to go hand in hand. The work associated with this thesis has been performed in the spirit of this idea. It is the hope that a close connection to end users can benefit future development in technology and theory in geovisualisation and especially the subset of 3D Geovisualisation that is the central issue here.

Defining geovisualisation

As it is discussed above, the field of geography and cartography has been influenced by the vast technological development that occurred over the past 10-20 years, just like almost all other fields have been influenced. As a response to a development going from traditional cartographic paper productions to modern digital and interactive media, the concept of geovisualisation is introduced and defined by (MacEachren and Kraak 2001) as;

"Geovisualisation integrates approaches from visualisation in scientific computing, cartography, image analysis, information visualisation, exploratory data analysis, and geographic information systems to provide theory, methods and tools for visual exploration, analysis (concept operationalization), synthesis (concept construction) and presentation of geospatial data (any data having geospatial referencing)."

This is a terminology and a definition that seems to be accepted widely by actors in the field. Geovisualisation introduces new aspects and possibilities that influence the way to work and make it fundamentally different from traditional cartography. The most important aspects are individualisation and iterative workflows, the support of explorative inductions, multi-sensoral systems, multi-user access and also 3D data management and visualisation.

Some disagreement exists among practitioners in the field whether geovisualisation actually is a field of itself. The definition is rather wide and since most information is geographical and most geographical tasks end up creating some kind of a visualisation, the result could therefore easily be that ”everything is geovisualisation”. The original intention was rather just to mark the change into digital geographical media containing many aspects and possibilities that did not exist during the centuries of paper maps. To fully discuss the details of the subject it is here accepted to understand geovisualisation as a field and 3D Geovisualisation as a subset of this field.

Geovisualisation as a terminology and as a field is mainly used in scientific and professional spheres, but products and results are also presented in wider spheres - maybe even whole societies. Interdisciplinarity is a fundamental part of geovisualisation where many scientists working with geovisualisation have come from another field of expertise. These fields are mainly Information Visualisation and various aspects of computer sciences. Interdisciplinary scientists contribute to geovisualisation by introducing new or analogical analytical tools in a geographical context and by suggesting new ways of managing access to these features. Interdisciplinarity is also prominent when it comes to the application of products and results; geovisualisation is mainly used to solve problems in other disciplines.

Though central issues in geovisualisation are non-discrete by nature, it is possible to accentuate a number of contemporary focus themes in geovisualisation (Dykes et al. 2005);

- representation; limits and advantageous uses of both traditional and novel representation methods and the creation of meaningful graphics to represent very large, multi-variate spatio-temporal data sets and the development, use and continual evaluation of innovative tools.
- visualisation-computation integration; The design, development and testing of software and hardware solutions that support the kinds of graphical interactivity that are specifically required by geovisualisation are key requirements.
- interfaces; Facilitating progress in the real world use of geospatial information and technology may require the adaptation of existing interface design and the development of new paradigms to provide high levels of interaction with advanced forms of (possibly novel) representation.
- cognitive/usability issues; it is essential to develop knowledge of whether the geovisualisation techniques, tools and solutions that are produced actually work and under what circumstances this is the case. We must also be able to explain and even predict such outcomes.

Of all the projects and issues that exist within geovisualisation, 3D issues constitute a minority. Nonetheless, it is a quite important minority since it is due to its' inherent nature that forces the field to experiment with fundamentally new ways of understanding and accessing geoinformation. These new ways influence all of the four geovisualisation issues accentuated above, for instance by discussing object-oriented representations, 3D graphics, immersive interfaces and also the outcome and its relation to users and workflows.

The development of geovisualisation is illustrated well by the "map use cube" by (MacEachren 1994) (Figure 1.2). Paper maps are placed in the upper right corner, where they are printed for large public groups (public axis in Figure 1.2). It incoorporates no interaction (low human-map interaction axis) and it is the known factors that are used (the "presenting knowns" axis). With digital development, maps move towards the lower right corner of the cube, where its' individual design includes many possibilities of interaction and where unknown factors can be studied. These two contradicting situations MacEachren calls communication contra visualisation. Visualisation is used to describe the modern situation of users acting as their own map producers in modern digital media. Communication is in this geographical context the traditional cartographical situation, where a professional expresses representations and conventions through a set of symbols that is more or less intuitive to the observer. The situation of pure visualisation is the consequence of the new digital media at its most extreme, but it is not necessarily a goal in itself. Pure visualisation and full interaction of large data sets would probably not help citizens searching for demographic information for instance, though maybe a professional geographer is able to interpret relevant data sets and explore unknowns. The task of choosing and sorting data sets for presentations should, however, still be an important task in a digital system much like a traditional cartographer's job. So the goal is rather to understand the spectra of the cube than to advocate for pure visualisations in the lower left corner of the cube.

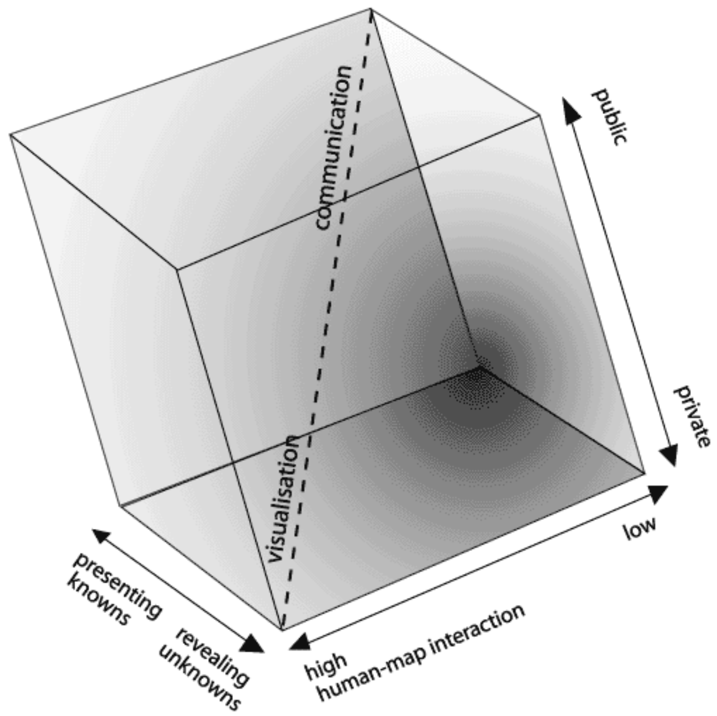


Figure 1.2: The map use cube. Geographic information has changed from being public communication with low interaction and the ability to present knowns, into a visualisation tool with high private purposes through interaction and an ability to reveal unknowns (MacEachren 1994)

Working with this thesis at a practical level, a wide spectre of possibilities of interaction and attributes were, however, not available (as for instance visualisation at its most extreme) due to technological limits within the timeframe of the thesis. Therefore several of the practical test cases issue 3D Geovisualisation as a presentation tool, placing the cases of this thesis towards the middle.

Virtual Reality

The definition of geovisualisation has its background within cartography and geographic information. But 3D Geovisualisation is also related to Virtual Worlds – as games are as well. Especially Virtual Reality (VR) when it comes to the use of depth cues, scenes, interaction paradigms and rendering techniques. Sherman & Craig defines VR as:

"a medium composed of interactive computer simulations that sense the participant's position and actions and replace or augment the feedback to one or more senses, giving the feeling of being mentally immersed or present in the simulation (a virtual world)."

Immersion refers to a hardware-generated experience of being present in the virtual reality as the racing driver does in Figure 1.3, while interacting in the fully immersive CAVE Automatic Virtual Environment (CAVE) at Aalborg University.

Figure 1.3: Immersive simulation of a car in the CAVE at VR Media Lab, Aalborg University.

VR includes expectations of real-time feedback (feedback is given without noticable breaks occurring) (Whyte 2002; Heudin 1999). Not all definitions wish to incorporate elements of immersion, because unnecessary associations of highly specialized equipment or expensive hardware easily appear. Since VR has developed in many directions, (Fisher and Unwin 2002) suggest to use a very general definition, without addressing immersion:

Virtual Reality is the ability of the user of a constructed view of a limited digitally-encoded information domain to change their view in three dimensions causing update of the view presented to any viewer, especially the user.

This definition basically addresses virtual, digitized, three-dimensional, interactive and real-time concepts, and does not specify whether these views reflect a real or an imagined world. A set of geographical objects can be combined to construct a Virtual Environment (VE), by defining the relations between the objects. These relations concern the topography, geometry, the physical extend and relations also including the interaction between them (Slater et al. 2002). VEs can be observed through a camera and controlled by the user (Bowman et al. 2005). In this way, VR is often regarded as form, while VEs is content (Heudin 1999). Many experiments take place in different branches of VR research bringing inspiration among others to 3D Geovisualisation, though it does not fall into the definition of 3D Geovisualisation. Digital enhancements of the reality as in augmented reality, introducing artificial physical laws or modelling life simulations and dynamics (as in Figure 1.4) can be major sources of inspiration (Sherman and Craig 2002; Heudin 1999); (Slater et al. 2002; Verna and Grumbach 1998; Krueger 1991; Heudin 1999).

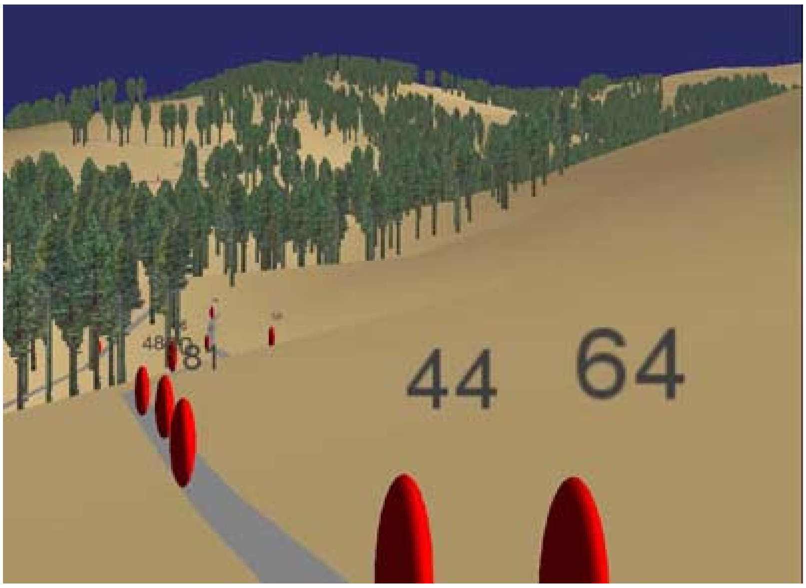


Figure 1.4: A 3D model of tourism in the Austrian Alps.The red columns are agents representing mountain walkers and their movements in the landscape.

Defining 3D Geovisualisation

We have now found a definition of geovisualisation being:

> *"Geovisualisation integrates approaches from visualisation in scientific computing, cartography, image analysis, information visualisation, exploratory data analysis, and geographic information systems to provide theory, methods and tools for visual exploration, analysis (concept operationalization), synthesis (concept construction) and presentation of geospatial data (any data having geospatial referencing)."*

We have also seen that 3D management and visualisation is only a small, but distinct, part of geovisualisation. This part we call 3D Geovisualisation, and this part will be compared to VR in the following. 3D Geovisualisation has from the beginning been strongly influenced by the already then established VR development, technically but also conceptually. Metaphors like "jumping", "flying", "camera" and "scene" originate from VR. In Figure 1.5, Virtual Worlds and Geoinformation are two separate realms while Virtual Reality and Geovisualisation profit from some of the same concepts. The line between these is therefore dashed in Figure 1.5. Virtual Environments reflect usually an imagined world though they also contain real worlds. Likewise 3D Geovisualisations usually contains real worlds, though some authors visualize 3D geoinformation that does not reflect a real world. Therefore, there is no distinction between VEs and 3D Geovisualisation in Figure 1.5, except that they originate from two different scientific traditions.

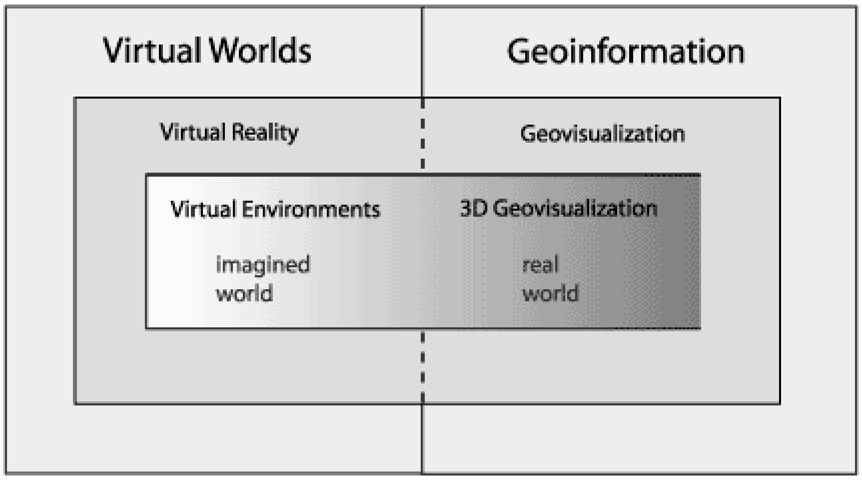


Figure 1.5: Relationship between Virtual Worlds and Geoinformation. Virtual Worlds and Geoinformation are two separate scientific realms while Virtual Reality and Geovisualisation profit from some of the same concepts. The line between these is therefore dashed in the figure. Virtual Environments reflect usually an imagined world though it also contains real worlds. Likewise 3D Geovisualisation usually contains real worlds, though imagined worlds occur.

In authors like (Light 1999; Bingham 1999), the third dimension (height z) is used to represent for instance frequency or temperature. Such models do not represent a real world though they visualize geographic information in three dimensions and as such are 3D Geovisualisation. Another author that still visualizes geoinformation, but does not reflect a real world, is Sara Fabrikant. She visualizes non-spatial attributes, here geographically related density surfaces in 3D (Figure 1.6) and this work satisfies the definition of 3D Geovisualisation, though data does not reflect the real spatial world. Examples of the reverse situation are the game The Getaway (see Figure 6.3) or flight simulations where data reflects the real world but is not explorative, iterative or analytical as expected from 3D Geovisualisation. Because of these examples it is not possible to draw a solid line between 3D Geovisualisation and Virtual Environments, but it is necessary to graduate the border between the two in Figure 1.5.

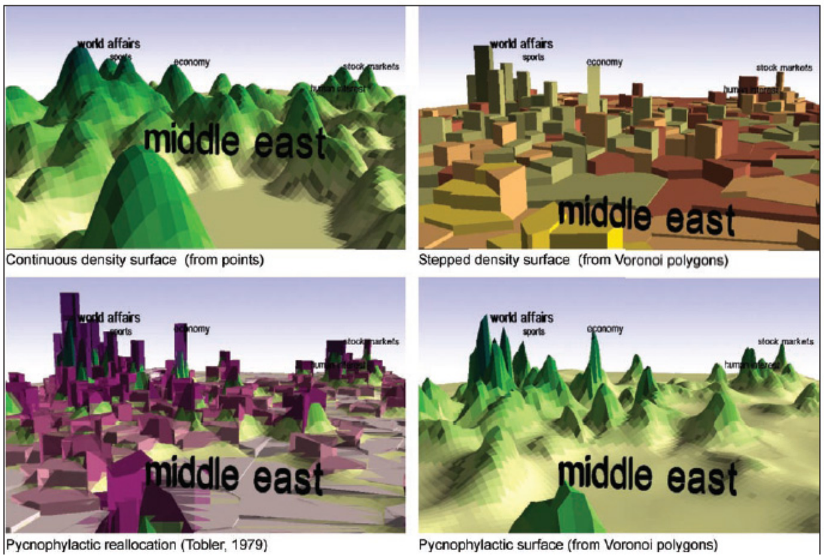


Figure 1.6: Textures and 3D shapes communicating geographically related information (Skupin and Fabrikant 2003).

Some authors use the VE synonymous with 3D Geovisualisation and some add GeoVE or GVE to emphasize the geographic realm. These are nomenclatures that work within the above definitions. Since it has been a priority to relate this thesis to the geographical and cartographic tradition and the work of the ICA Agenda, a nomenclature using geovisualisation rather than Virtual Environments, is used here.

Why 3D Geovisualisation?

All cultures throughout history have dealt with the basic task of understanding and communicating physical space. Historical examples of 2D representations exist in most ancient cultures – and discussion continues as to whether it is because ancient cultures could not or would not choose 3D representations. At least some advantages exist in 2D. In Figure 1.7 this medieval visualisation of the last supper of Jesus has focused on its narrative qualities of telling a story about who was with him. A correct three dimensional visualisation of the same situation would inevitably make some of the participants and the symbolically important equipment less visual. The story about whom and what would then be less clear in a correct 3D visualisation with regard to perspectives.

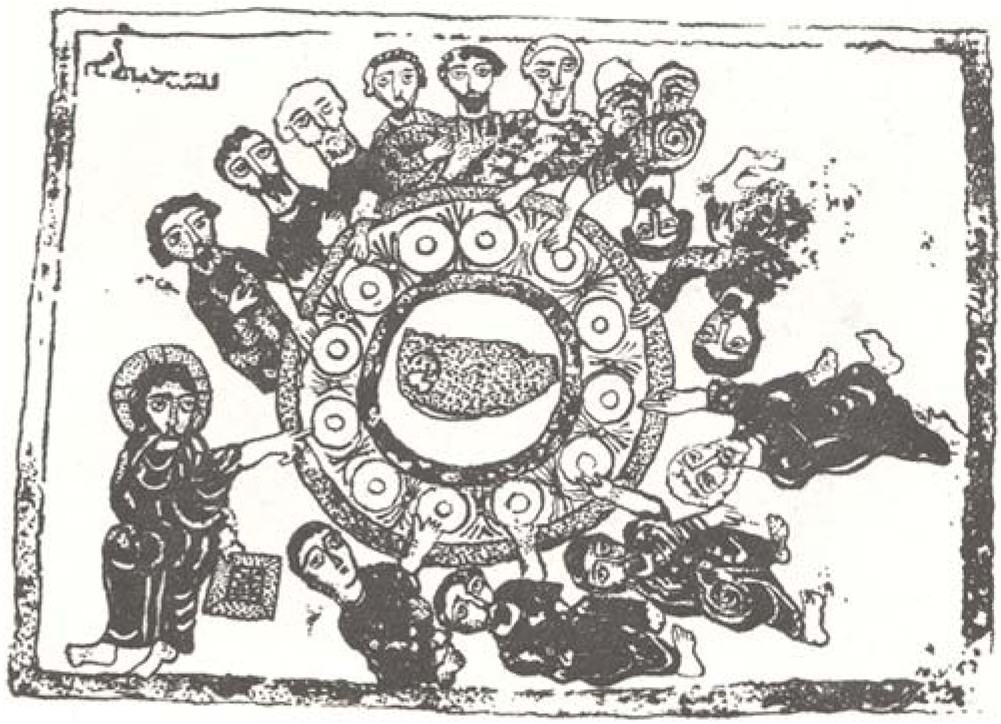


Figure 1.7: Mideval visualisation of the last supper of Jesus.

After the medieval period, the renaissance brought a revival of natural sciences that included the study of mathematically correct perspectives in art and science. In modern western culture, mathematician Abbots "Flatland" (Abbott 1992) writes a popular prosa where geometry lives a more or less rich life in different dimensions of space. A modern interpretation of two dimensions, the flatlands, and three dimensions is explaind by information visualisation expert Edward Tufte (Tufte 1990) like this:

„Escaping this flatland is the essential task of envisioning information – for all the interesting worlds (physical, biological, imaginary, human) that we seek to understand are inevitably and happily multivariate in nature. Not flatlands."

When it comes to visualizing scientifically correct visualisations like in geovisualisation, arguments for escaping these flatlands and the use of 3D are many:

- Simple transformations between model, data and reality.
- Presentation: 3D models are natural and cognitively easier to interpret and are thereby suitable to communicate ideas and visions.
- Exploration: the human vision is made to quickly interpret a large amount of content or data in a scene. There are relations in a scene which the human brain percieve, often without being conscious of it. A large amount

of data can therefore be communicated, exemplified by (Granum and Musaeus 2002) in a project using 3D datamining.

- Immersion: The user can be led through hardware interfaces to get the feeling of immersion into the scene and thereby to have a strong sense of being in a physical world. This has been used in adventure oriented models, as well as in product development of for instance engines.
- Documentation: Much geographical information contains height information that are only handled as additional information in 2D. In 3D, a more exact documentation can be performed.
- Simulations and dynamics: temporal simulations of 3D data can give new ways of studying complex processes in nature and society. In 3D they become more realistic simulation than in 2D (Gloor et al. 2003) (see Figure 1.4).

These advantages of 3D are strong compared to 2D and a major change when it comes to managing, representing and presenting data. But as the number of attributes rise in 3D, complexity rises as well. A fourth dimension expressing for instance income of the citizens by a colour code will probably be readable, but expressing much more dimensions like age, health and the like, will demand high visualisation skills, that at a point will be so complex that it is unreadable. The growing complexity can be described as a function of growing dimensionality, nD, resulting in an exponential curve (Figure 1.8).

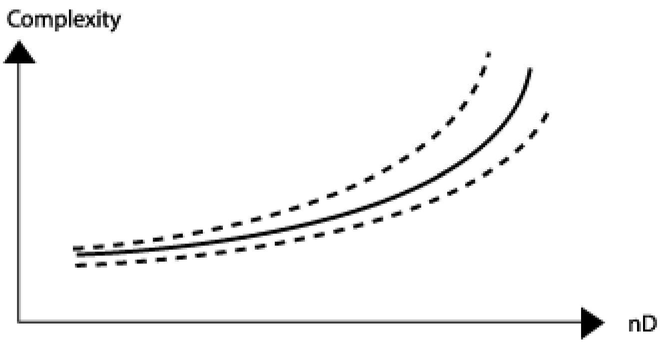


Figure 1.8: The growing complexity as a function of growing dimensionality, nD. Several possible curve patterns are shown. The exact curve development depends on spatial awareness of the user and the actual situation. Common for them is that the curve pattern at some point grows exponentially into an infinite complexity.

Because of this 3D complexity phenomenology and usability becomes even more important fields to deal with, and therefore (Kraak and Ormeling 1996) states that geovisualisation strongly depends on a parallel user-focused development through Human-Computer Interaction (HCI). Because of the rapidly increasing complexity, 3D is not necessarily the ultimate solution seen from a communicative point of view, but has to be used with careful consideration. Most people in western culture are familiar with a 2D representation in for instance ordinary drawings or maps and would probably be able to understand and interpret 3D representations intuitively as well. So there might be strong visual, interactive and documentative advantages in 3D but it is also a complex process that demands a lot, both at a technological and a phenomenological level – no matter whether 2D maps can be understood as a presentation of one or many ”slices” of a 3D mass and thereby a selection or a simplification that in some cases can be enough or even a stronger presentation of the actual problem. Hence, it is not expected that 3D will or should replace 2D systems in the future.

Use of 3D Geovisualisation today

The most common use of 3D Geovisualisation today is within public planning and architecture. Most municipalities in for instance Denmark have thus bought 3D models for planning and stills, videos or realtime visualisations derived from these are often publicly available. Within administration of water supplies in Denmark, an association of actors consisting of private companies and municipalities are working on developing 3D software specialized for public ground water exploitation (Figure 1.9). Some museums focus on 3D information for presentations, using its unique ability for landscape visualisation and for visualising temporal changes. Tourism plays an increasing role, while the gaming industry keeps geovisualisation under surveillance.

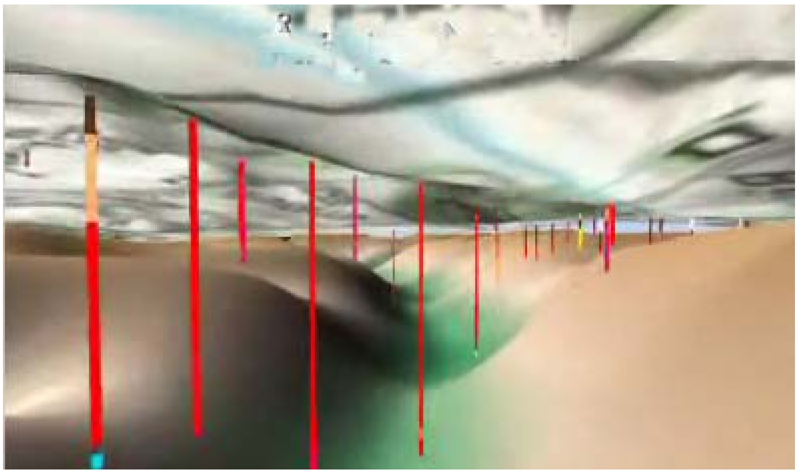


Figure 1.9: Underground visualisation of ground water ressources in Århus Amt, Denmark. The red “tubes” represent drillings. The texture draped above is a surface map, and the texture draped below represent the pre-tertiary surface in the area.

An interesting development is that 3D Geovisualisation seems to be most widespread within public administration in Denmark. A possible explanation for this relates to the concept of the media, by reflecting a need in western societies for a further understanding of the still more complex and democratic society. Media plays a special role here, having the task of sorting streams of local and global information. Thereby it aids societies in creating shared images of the world that cultures or subcultures need to understand and communicate about in a complex world that always seems to change. Globalisation and cohesive forces in society are headlines in present political discussions of welfare and future development. It is also interesting to see that communication and democracy are buzzwords in 3D Geovisualisation both in the field in general and in public administration. As a media that can handle this complexity applying it its own expression, 3D Geovisualisation has potentially a place in modern societies around the world.

Future applications

In a new field, like 3D Geovisualisation, a theoretical background can cause the development of more efficient systems. In practice, it is only when initial technological development has slowed down, that theoretical development takes place (Wood et al. 2005). This happened in the gaming industry, and in many ways it seems that 3D Geovisualisation is about to reach this stage as well. Technological development is reaching a halt, giving room for other thoughts and discussing more critically quality and needs in a larger perspective. A future challenge is therefore the development of a theory, involving for instance ideas of the way collaboration and interaction should be performed and the way society should store, handle and visualize public information. An example of an ideologically driven project is the multivariate system, Grifinor, developed at the Centre for 3D Geoinformation at Aalborg University (described in chapter 2). Multivariate systems are commonly considered to be a major and very present issue in positivistic 3D Geovisualisation and a breakthrough here can cause a breakthrough in the utility of 3D Geovisualisation. With multivariate systems professional application is much more attractive; skilled personnel analysing geographical information within for instance planning, environment or disaster management. A future where online visualisations are connected to administrative tasks like storage and editing is a technological possibility, but requires cooperation at many levels of society. This cooperation probably constitutes an even larger obstacle to overcome than the technological obstacle, since requirements and expectations are different and the economy and inertia are an existing part of society as well.

Theoretical development not only includes the above data model's perspectives, but also phenomenologically based theory. An interesting analogy is the development of the web. Today, designers have access to large statistically based guidelines that phenomenologically have taken the concept of the web to a totally different situation today than in 1990s when the graphically based web was at an initial stage. 3D Geovisualisation is still at a rather immature stage phenomenomically. Some steps are, however, being taken to generate a superior understanding of the utility both from a user's perspective, but also by understanding this new media in the context of society and organization. A clear sign of this is that the number of speakers at relevant conferences and workshops addressing user-centered 3D Geovisualisation issues has grown from almost zero in 2002 to one or two at each event today.

At present, many developers, producers and customers are hesitating these days; which data types or software products are serving their goals best? Many organizations, hence, experience that expert knowledge is needed in order to deal with 3D. In planning societies in Denmark, this need is met by employing young personnel trained at their places of education in 3D. This rise in public education adds to the strengthening of development as well.

A field that has the potential of a large-scale break through – or maybe already does have in 2D at least – is car navigation systems. This field has a potential of huge user groups, just like games, and can make large differences in their daily lives. The car navigation products are examples of a cartographical/geographical product made for non-professional, non-geopraphical focus groups, but are also partly made by producers outside cartography. An example is the car navigation from Sony (Figure 1.10).

Figure 1.10: Sony's 3D map navigation technology for cars. The 3D mapping interface shows actual buildings, and knows street addresses, enabling it to identify destination addresses.

Some are developed as "ad-hoc" applications due to the fast development needed to compete in the market. These applications are created without being true 3D systems and without being based on a theoretical background; strongly driven by economical interests in technology (being an example of a product where "technology" justifies a thicker arrow than "theory" in Figure 1.1). These ad-hoc developments open up economic profits that allow for more sophisticated systems to be developed in the future.

A possible fusion of 3D Geovisualisation and games is discussed at times. Though 3D Geovisualisation has many things in common with the gaming industry, aims and goals in 3D Geovisualisation are much more focused on multivariability and accuracy. The gaming industry rather focuses on narrative issues like personalities and atmosphere. A combination of these is not easy (Rhyne 2002), though it might be an interesting development in the future. The work on characters/avatars, motion, avatar interaction - atmospheres that appear in the gaming industry, could influence commercial application in 3D Geovisualisation as well. Commercial industry today is strongly dependent on branding, for instance through narration, where the geographic realm has no experience or traditions at all. Virtual shops and shopping streets combined with e-commerce, avatars and cookies acting as personal shoppers and guides are technologically possible outcomes, interesting in commercial business that also has the economical conditions to carry it out.

A way to challenge the inertia in 3D Geovisualisation could be to increase cooperation with the entertainment industry. In the gaming industry strategic and social games are already an established field, having a potential in the context of geosciences as well. ActiveWorlds, SimCity and TheSims are examples of "serious" games containing social interactions and strategic development. A Danish example (though not an example of 3D Geovisualisation) is the "The Debate Game" (Løssing et al. 2003) where creative stages of an urban planning project are supported by a public game (Figure 1.11).

Figure 1.11: Scenes from the urban planning game "The Debate Game",where local political personalities are invited for a game about the future of an urban area. The game is based upon pattern recognition in pieces and video recordings.

Computer games are characterized by the shifting between a fictive world and a group of rules defining the game (Juul 1999). In 3D Geovisualisation, the world is more representative than fictive, but interaction possibilities still form rules that have to be followed. In games focus is of course directed towards social or humanistic dimensions and compared with the tests performed in this thesis it is interesting to see that during interviews, life and atmosphere have several times been mentioned by the subjects. This underlines the expectation that there are many convergent interests and possibilities and a future fusion seems obvious.

One of the large trends in Denmark, as in the rest of the western world, is a focus on creative industries' economy. This field is based on entertainment and adventures that is increasingly becoming an important economical part of western societies. Demands on exhibitions and arrangements are not anymore mere showing but rather felt and experienced personally. This development coincides with a development within HCI where digital design, as well as general design, focuses on the strength of emotions. Donald Norman is the major advocate for this new trend in usability (Norman 2004) that also to some extent cause changes in HCI methodology. New methodologies need to capture and express these emotions in a product and since the nature of emotions is flowing, methods tend to be less and less formal.

The main activity human beings focus their attention on is its relationship to itself, its close human relations and its surrounding social contacts. With this in mind it is not surprising that any item that allows human beings to play with social contacts becomes a success in wider circles. The entertainment industry lives from this and so does commerce. Commerce in a social context helps human beings to identify themselves and to communicate this identity to others. Activities connected to this process, mainly shopping and purchasing, are also becoming an activity in 3D. Second Life is a platform where users can login, interact and perform e-commerce with the virtual environment and the avatars of the other users. Along with the gaming industry, e-commerce is also a field that could be relevant in 3D Geovisualisation, especially in relation to systems that adress non-professional users.

Figure 1.12. A: Screen-dump from Second Life.

Outside Denmark, research in agent-based modelling, simulations and cellular automata provide very powerful tools, and for some purposes, 3D is definitely a development that will strengthen these fields further. Usually projects are carried out in 2D, but some work is in 3D as well (see Figure 1.4) where a mountaineering agent-based model is made by (Gloor et al. 2003). Researchers behind this project also made a large scale traffic modelling system consisting of millions of intelligent cars simulating realistic environment and traffic patterns (Michael Balmer 2004). Simulations and agent-based models are not objects of the same attention in Denmark, probably because population density is rather low, so controlling traffic, settlements and pollution are less pressing. Recently the city of Copenhagen has, however, just entered into an agreement with MIT on tracking citizens' movements through cell phones and over a longer term visualise these to plan traffic in the city. A few Danish researchers have addressed agent-based modelling: Hans Skov-Petersen (Skov-Petersen et al. 2004) and Thomas Balstrøm (Balstrøm 2002), on projects for recreational landscape exploitation and on determining beneficial trekking routes in mountainous terrain.

Commercial interests are, as described earlier, not experiencing high activity in the field and seem to be waiting for expanded possibilities. Department manager Poul Nørgård from engineering company COWI elaborates:

"What could really change the situation is if some kind of political change occurs – if a public driver could initiate further development. New laws coming up, new demands on noise modelling or maybe if new requirements on architecture force more complex analytical processes to be available. As it is today there is no well-defined need for 3D in society. "

Decisions on standards, data storage, modelling and updates could turn out to be politically and organizationally important tools. Today no extensive political interference is present, causing a situation where all producers create, maintain and store their own data sets, not necessarily compatibly with the rest of the market. If some kind of political change will occur, the need for complex systems in Denmark will probably change the whole situation, both regarding simulations other analytical features and presentations.

Qualification of 3D Geovisualisation

In 1987 visualisation in computer science was publicly mentioned for the first time in a report to the U.S. National Science Foundation and was described as

"methods and products that integrate the power of digital computers and human vision and directs the results toward facilitating scientific insight."

This description specifically points at science being the focus group (MacEachren 1998). Supporting scientists both in geosciences and related fields is still a primary activity in technological development and in usability in both 2D and 3D. An example is the self-organising maps that organise information through a neural network meant to structure large spatial datasets for exploration and determination of derived structures. As an example, relations between Dutch municipalities is represented by size, position and colour (Figure 1.13). The author group then suggests a strategy for determining and supporting the user's comprehension of the structures and representations, focusing on three issues: effectiveness, usefulness and user's subjective views and preferences (Koua and Kraak 2005).

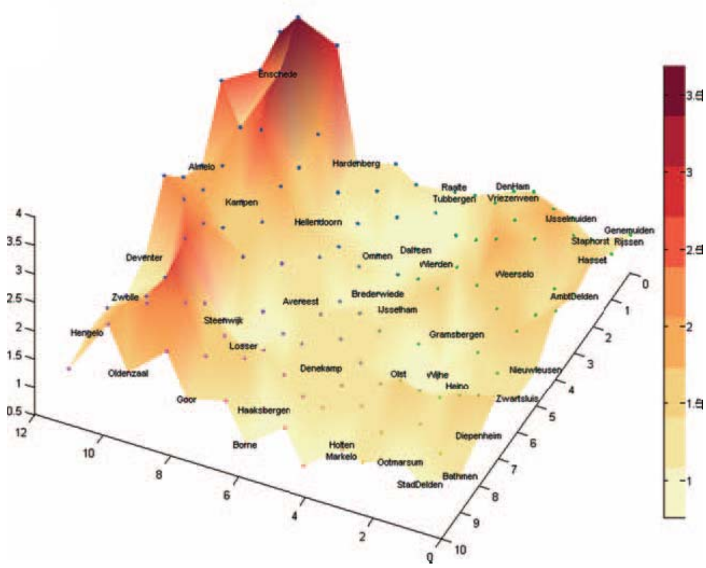


Figure 1.13: Size, position and colour of multivariate clusters representing a 3D relation matrix of Dutch municipalities. It is of cause absolutely necessary that technology and tools is developed as a basic scientific activity in research centres as a fundamental activity in the field.

What has happened since 1987 and 1997 is that several of the products are also meant to be used by average citizens and consumers, expanding the issues of interaction significantly. But working with 3D Geovisualisation meant for larger audiences is less common in scientific spheres. This is actually a pity since some of the economy related to geovisualisation is related to a large audience, because many products and presentations are available for instance through the internet. Especially in 3D Geovisualisation it is a pity, since the 3D media provides strong means for human attention and attraction interpretable for the average citizen. These are means that we actually do not know very well, but they could change the "build and they will come"-approach into a more deliberate approach. This would first of all benefit the present commercial inertia and over a longer term also benefit theoretical development.

To address the various relevant focus groups, Plaisant (Plaisant 2005) recommends usability and goes even further. She uses Information Visualisation as an analogy and incorporates a wide range of usability issues in geovisualisation called Universal Usability. Universal Usability addresses user diversity (age, language, disabilities, etc.) the variety of technology used (screen size, network speed, etc.) and the gaps in users' knowledge (general knowledge, knowledge of the application domain, of the interface syntax or semantic). The concepts of Universal Usability is something to strive for in the long run, but in this context it seems to be too ambitious at the moment. One of the most significant projects that addresses non-professionals and novel users in 3D Geovisualisation is the TellMaris project. The scientists connected to the project explore the use of mobile displays in tourism for navigation/information and their efforts are specially accentuated here for supporting their studies with usability tests (Coors et al. 2003).

Using the word quality in the title of this thesis leads to accepting subjectivity and to understanding a dependency of human utility, contexts and focus. To elaborate this dependency on focus groups further, Figure 1.14 shows the various points of view where 3D Geovisualisation influences. Firstly there is the individual experience of the end user. Subsequently 3D Geovisualisation plays a role in society as a mass media communicating cultural and public information, while geovisualisation also plays a role in organizations and for commercial interests. Technology is provided by a group of developers and producers, and from a geographer's point of view geographical information like geodata and georeferences are important professional aspects (Figure 1.11).

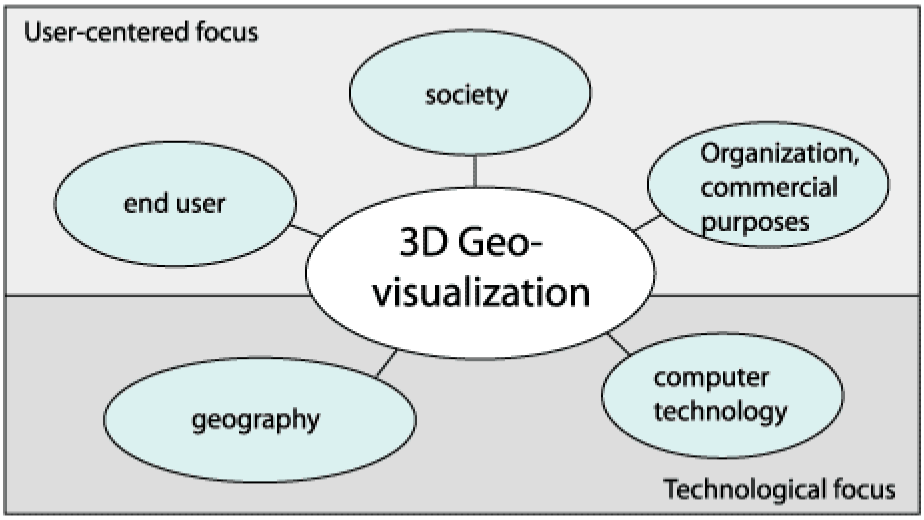


Figure 1.14: Geovisualisation seen from five different points of view; the end user's individual outcome, the role of society, the organizational/commercial role, the geographical context and finally the technological development.

In this thesis 3D Geovisualisation is mainly discussed in relation to the end user. Secondarily, it is discussed in relation to society and commercial areas, while geographic and computer technical perspectives are only peripherically issued in this thesis. Taking this end user-centered approach, it has become reasonable to consider 3D Geovisualisation as a media, since non-professionals presumably do not have other backgrounds in common than a contemporary cultural experience. Another advantage of the media analogy is that media is in communication studies usually understood as a mass media, that communicate with large segments in a society, meaning that it is useful to communicate with non-professional users. In communication studies a media is a system or an artifact that establishes communication by sending a message from a sender to a receiver. In natural sciences the computer is the media that supports communication by the transportation of digits of 1 and 0 in bits. On a phenomenological level, a media likewise delivers a conceptual message from sender to receiver and the representation of the message can be, for instance, visual or audio. Communication through a media is either one-way communication or a controlled response system where for instance a system or a robot can learn to respond in various ways, but probably never as complex as two-way human communication (Watson 2003). It can, however, be argued that it is not 3D Geovisualisation that is a media but the computer as a physical artifact which is the media, like it is the television or the radio that in traditional sense is a media. (Bechmann Petersen 2006) has studied digital media and suggests that in the case of digital media physical barriers do not exist, so for instance a pc can appear both as a television, a telephone and an internet connection. This leads to a new and not artifact-dependent definition of a media that allows 3D Geovisualisation to be a subset of the computer. In this sense, 3D Geovisualisation can be a specification of a media. Using a media analogy it is possible to provide a method to work with the elements in 3D Geovisualisation that a user percieve directly. The media analogy also automatically incoorporates the concept of mass media – having the specific interest in adressing large segments or whole societies. 3D Geovisualisation and the content of this media are further elaborated in Section 2.

Why qualify 3D Geovisualisation?

The original idea behind this thesis was to learn how to become better in making more usable and more communicative products, especially products directed at non-professional users and average citizens where novel users will constitute an important part. To do this there was a need to know more about how end users actually use and understand 3D Geovisualisation. One main idea therefore stands above; a wish to meet the users for whom 3D Geovisualisation would be unknown territory and to observe them interact with 3D Geovisualisation. If 3D Geovisualisation should experience a development that is (also) driven by end users' attention and preferences, it is crucial that scientific and professional spheres using 3D Geovisualisation are open to the often fundamentally different understanding and preferences that non-professionals have. Some pre-studies of un-experienced and non-professional users revealed serious difficulties performing basic tasks, and suggests serious obstacles in an attempt to commercialise and distribute 3D Geovisualisation even more. In relevant literature "media", "communication" and "user-friendly systems" seems to be buzz-words. As an example in the latest version of SketchUp provided with the latest version 4 of GoogleEarth, it is stated that communication is an important parameter in 3D media. But what does this communication in 3D consist of and what is exactly meant by that is not specified. Likewise many new products and features claim to be user-friendly, but taking a closer look often reveals that only poor, or no, usability tests are performed to support such claims.

As a relatively new and small media there is no existing theory of how to use 3D Geovisualisation, nor any consistent nomenclature to support this, and it is therefore left over to each developer to base their work on their own experience and their own abilities to understand the quality of their own work. Though building up theories probably will be a long process, and is hence not the short-termed aim of this thesis, some considerations made in this direction would make development less dependent on each developer's singular experience. Many possibilities do, however, exist to rely on analogies from other fields of far more well consolidated areas like psychology (cognition/perception), Information Visualisation, architecture, landscape and planning, traditional cartography, art and aesthetics. Though analogies from the above mentioned research fields are used as much as possible, still something unique exists in 3D Geovisualisation. It is for instance not possible to compare 3D directly with traditional stills of landscapes or architecture that are planned in detail according to angles and height above a surface. In 3D, dynamics, immersion and interactivity change the whole configuration of the visualisation and the use of analogies is inadequate.

For private companies, aspects of communication are also important features to control. The development of still better technology increases dimensionality and complexity and hence the interpretation demands a higher level of spatial skills and trained spatial awareness. At the same time, 3D Geovisualisation is becoming more popular and commercial, leading to focus groups that diverge. A combination of these two situations also requires some concentration on communication skills. Communication is even a crucial parameter of competition, today and in future projects. Intense competition already exists in many geographically related commercial communities and visualisations and communicative aspects become increasingly more important to each provider as the 3D field grows. Developing a theoretical user-focused background is the modern answer to increasing competition.

Relation to the ICA Research agenda

The ICA's commission of Visualisation and Virtual Environments is the central organization working on definitions and research directions. It has via four multidisciplinary work groups created a suggestion of a coordinated development within geovisualisation (MacEachren and Kraak 2001). The four work groups are; a) Representation, b) Visualisation-Computation integration, c) Interfaces and d) Cognitive/Usability Issues, and e) a group of interdisciplinary challenges are finally issued. This thesis explores issues c), d) and e), where especially the following statement within e) has a superior importance;

> *1: "To develop a human-centered approach to geovisualisation"; aiming at the development of more usable tools through cognition and the visual potential to support thinking, learning, problem-solving and decision-making.*
>
> *From work group c), the Interfaces workgroup, and d), the Cognitive/Usability Issues workgroup, the following statements are addressed:*

2: "To develop a comprehensive user-centered design approach to geovisualisation usability"

3: "To determine the contexts within which geovisualisation is successsful"

The Cognitive/Usability Issues work group has furthermore made their work more precise in a publication by (Slocum et al. 2001) where several points are relevant in this thesis;

1: "Determine the situations in which (and how) immersive technologies can assist users in understanding geospatial environments"

2: "Develop methods to assist users in navigating and maintaining orientation in GeoVEs"

3: "Determine ways in which we can mix realism and abstraction in representations to influence cognitive processes involved in knowledge construction"

4: "Determine the relative advantages of animated and static maps"

The newly released book "Exploring Geovisualisation" (2005) addresses much of the work group issues, and the latest developments within these, as a follow through of the research agenda. In rough terms, focus areas and research challenges follow the original work of 2001, so that 3D, HCI, cognition and usability are still of special interest. Within Cognition/Usability, the goal is described like this;

"By drawing upon knowledge of the perceptual and cognitive processes involved, we may be able to generate a body of knowledge and associated theory relating task, technique and user type that establishes best practice " (Dykes et al. 2005).

To build such a "body of knowledge" is a process of maturation that takes a long time to create a coordinated and commonly useful experience. In addressing 3D Geovisualisation as a niche of geovisualisation in general, this building of a "body of knowledge" seems to be challenged by a constantly changing technological framework. Maturation should thereby not be the result of a singular process but a multi-directional development that is able to contain all utility segments that the future might bring. Nonetheless the spirit of this thesis is very well described by the above citation.

2. Data models and software

GIS Data models

Application of geographic information today is mainly performed through Geographic Information Systems (GIS). GIS developed through the 1990s, can be described partly as a digital map producer, partly as a complex tool for problem solving, registration, unit of storage and partly as a piece of software. From a superior point of view, a combination of general information (maps) and specific information (attributes) is GIS. Many other definitions of GIS have been suggested depending on shape, function, dynamic processes and depending upon how it is used. Geographic systems are built upon a data model. A data model is the mechanism used to represent real-world objects and processes digitally in the computer system. In this way data models are closely related to the topic of data representation (which is mentioned in chapter 5) – but usually data models are used as a formalisation of representations. In a general GIS system, real-world objects are described and represented digitally, allowing for the user to see and analyze the results (Figure 2.1).

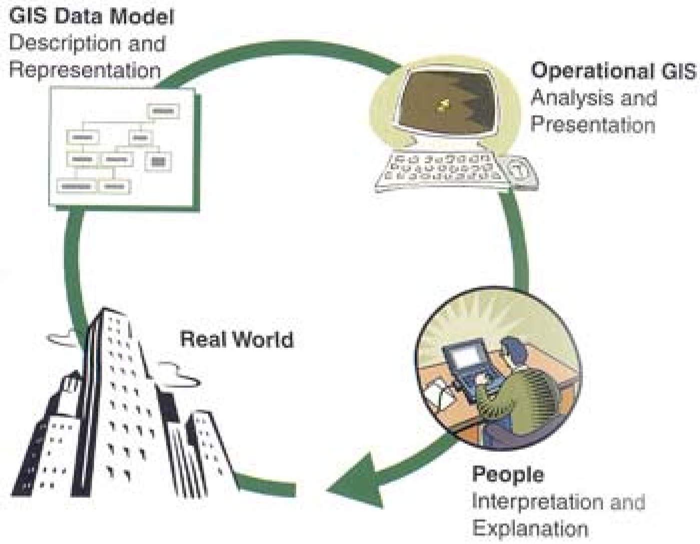


Figure 2.1: Data model in GIS. Real-world objects are described and represented digitally, allowing for analysis to construct a meaning in a phenomenological context (Longley et al. 2001).

Since digital systems are finite entities, it has to make use of simplifications in order to deal with the complexity and infiniteness of the real world. The choice of data model performing these simplifications decides the possible operations, and the layered and non-layered structures. Hence the choice of data model varies depending on utility. Both in GIS and 3D Geovisualisation data models can be based on raster, vector, topology, TINs, object information or combinations of these.

3D visualisation technique

In visualizing 3D geographical data, the overall process can be described as in Figure 2.2:

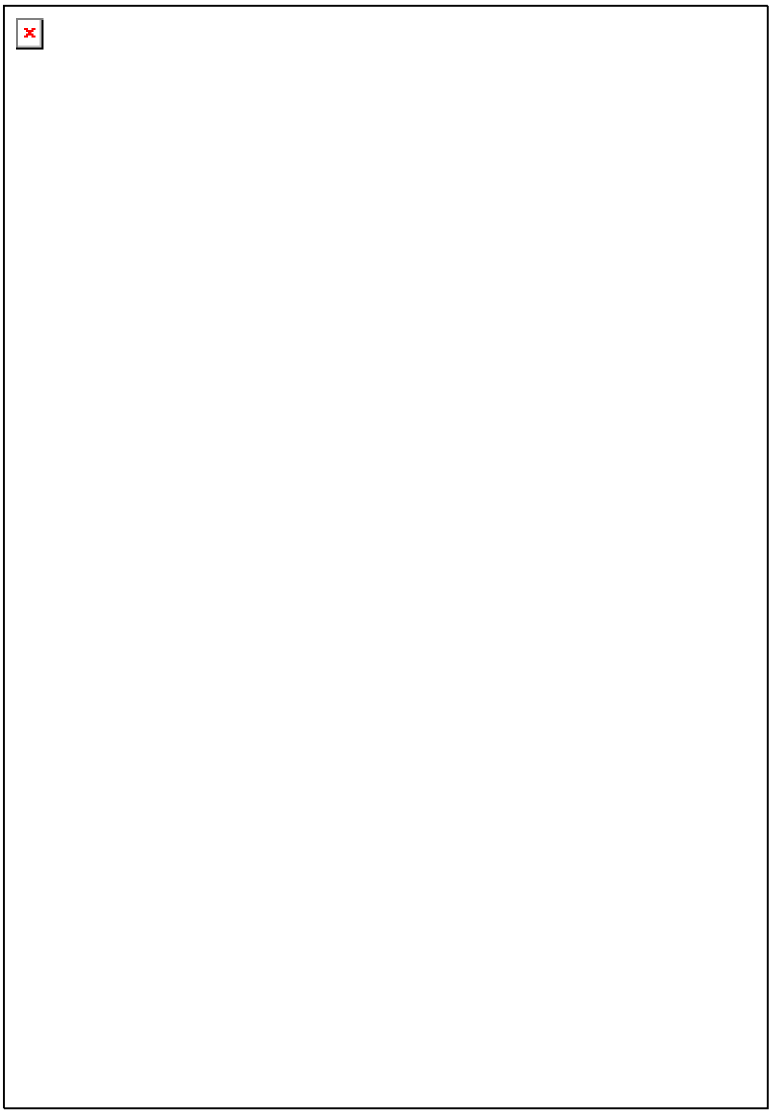


Figure 2.2: General process of visualsing 3D geographical data (Wood et al. 2005).

Raw data is made accessible in "data management" and is processed in "data assembly". Data is transformed into a 3D representation for graphical visualisation in the “visual mapping of data”. Via the rendering process an “image” is created as the resulting 3D frame. This is sent to the user interface – the “display”. The process of rendering is the central process that visualises the geographical objects, by sending information about the geographical objects to the graphics card of the computer and on to the user interface. In this way, software and hardware work together to send each vector polygon of the objects in a scene through a system of pipelines which for instance establishes geometry, and calculates culling effects and projections. Another pipeline fills each polygon with texture and calculates light effects. Each 3D frame is built in this way, and in cases where realtime interaction is expected, a minimum of 20 frames pr. second (fps) is needed. Detailed technological descriptions can be found in (Akenine-Möller and Haines 2002; Slater et al. 2002).

3D Software

The last few years many different systems are being developed and improved at universities and by private initiatives, refined for more and more specialized purposes. The development of laser-scanning has reached a level sufficient for providing data for realistic 3D geovisualisation modelling, that today is the subject of various terrain models and automatic object generation, especially for ubiquitous cover. Among the large GIS companies, ESRI has developed a series of 3D applications, the ArcGIS 3DAnalyst including ArcGlobe (Figure 2.3). MapInfo's Vertical Mapper is the competitive response to this (Figure 2.4).

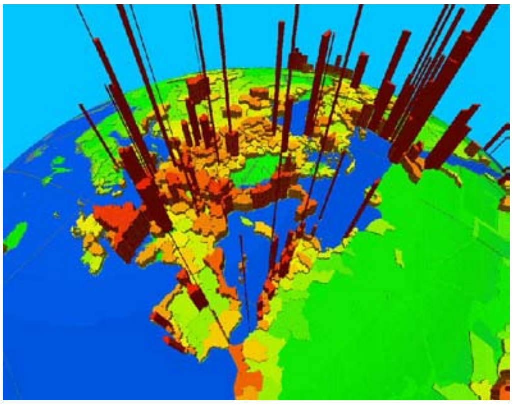


Figure 2.3: ESRIs ArcGIS 3D Analyst.

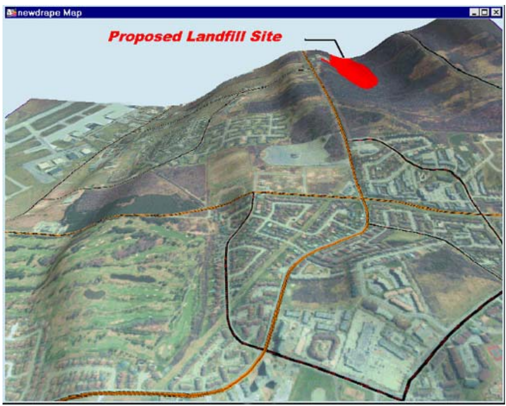


Figure 2.4: MapInfos Vertical Mapper.

Finally, another type of product is the CAD-related programs like 3D Studio Max and SketchUp.

CAD models

In CAD models, 3D objects are represented by vectors as points, lines and polygons in a coordinate system. This representation can be performed in great detail and with a high degree of precision and is therefore suitable for pure visualisation of a limited geographical area, for instance in design or engineering. CAD models are, however, not very useful for storing associated attributes or topological information and therefore are not useful for analytical tasks. It is hence not reckoned as a GIS, though the simple principle of point, line and polygons are sometimes used here. Local coordinates are most common in CAD, but some applications, like 3D Studio Max, are capable of managing geographical coordinates at some level, though not advanced features like the global curvature.

2½D surface models

The 3D system that has the largest commercial influence today is the 2½D system, and has probably gained its popularity due to its fast production rate and efficient internet streaming. Visualisations of large geographical areas can thereby be distributed to a large number of users. The data model is based on Triangular Irregular Network (TIN) models, that form triangular shapes between well-defined points that possess x,y and z coordinates. The numbers of triangles can vary, dependent on the relief, and they are especially useful for analysing terrain features, but not suitable for other geographic analytical tasks. In American literature, these systems are sometimes called ”fly-over-maps” which is very descriptive for their best function. On top of the TIN an orthophoto or a topographical map is draped. Such basic models are called 2½D, in opposition to true 3D systems, because it is not possible for the system to handle more than one z-value. If attributes or objects should be added to the terrain, it has to be organised in geographic entities as layers, like a traditional GIS layering model.

Virtual Globes

Some 2½D systems are designed especially to visualise globes, not just a local surface. Among them are large companies, but non-traditional producers in mapping circles: NASA’s World Wind (Figure 2.5) and Google Earth (Figure 2.6). Google Earth and its various content is maybe one of the most well-known and popular 3D Geovisualisation concepts existing today.

Figure 2.5: NASA's World Wind.

Figure 2.6: Google Earth.

Another group of smaller companies are specializing in 3D products. Among them are the Swiss spin-off company Geonova (Figure 2.7) and the (originally military related) Skyline (Figure 2.8).

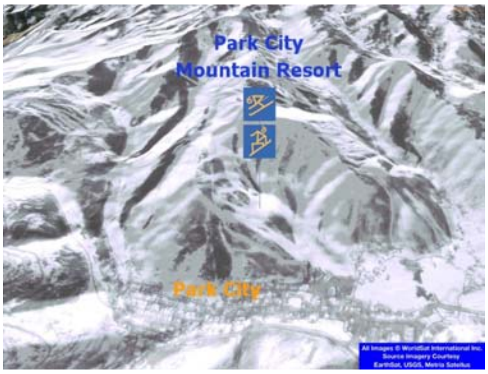


Figure 2.7: Ski resort visualisation, from Geonova.

Figure 2.8: Portuguese landscape visualisation from Skyline.

Multivariate systems

Multivariate systems are also virtual globes but are based on an object data model where objects are organized in classes, not layers, optimal for managing both properties and behaviour of the objects and is more flexible concerning accessible operations. Object orientation furthermore serves a simple and more direct relationship between dimensionality and technique, as it is requested in the ideologically driven development of 3D Geovisualisation. The flexibility and efficiency of such systems can potentially handle large and complex sets of internet streamed geographical objects and attributes. If expectations of these systems under development will be met in the future, the utility of such systems must be much wider than of both CAD and 2½D systems.

The four systems used in this thesis

In part 3 of this thesis, four different software products are used (Figure 2.9). They represent different data models and the first three are among the best and most widespread 3D software at the moment. The two first products, 3D StudioMax and SketchUp are advanced CAD systems. 3D StudioMax is used together with the viewer VR Navigator Pro which delivers a possibility of detailed and precise visualisations, various interaction possibilities and advanced rendering possibilities. The system, however, handles all data in a scene for each frame, and a limited geographical content is therefore necessary. SketchUp is a similar but simpler system. ArcGIS 3D Analyst and the viewer ArcScene is based on 2½D technology. The last product, Grifinor, is based on multivariate data models as a result of research at 3DGI.

	3D Studio Max & VR Navigator Pro (3D CAD)	SketchUp (3D CAD)	ArcScene (2½D)	Grifinor (3D)
representation (test 1)	X	X		
rendering (test 2)	X			
interface (test 1 & 2)	X	X		
interaction (test 3)	X		X	X

Figure 2.9: The use of software products in this thesis.

Grifinor has been created as a research project at 3DGI, in order to exemplify a possible solution of a multivariate data model. In Grifinor, objects are stored in a 3D context which makes it possible to perform flexible analytical tasks outside the context of layers. The flexibility of Grifinor allows new properties to be added, without changing the existing system. Grifinor consist of 4 main parts; GeoDB, ODB, viewer and the applications (Figure 2.10).

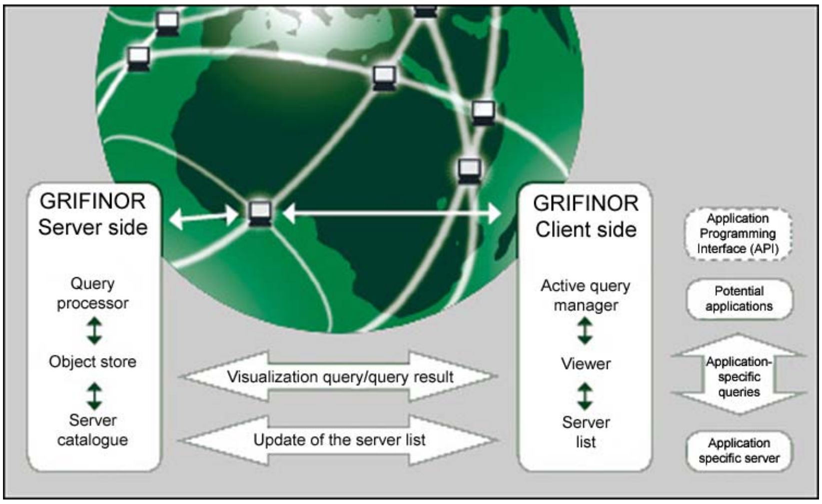


Figure 2.10: The network architecture of Grifinor.

A detailed description of the system can be found in the publications by (Overby et al. 2004; Kolar 2004, 2004; Bodum 2005). The four software systems presented here are used for developing test cases in this thesis.

3. Scientific background and methodology

New trends of multidisciplinarity

Traditionally technology works with natural physical objects, and its relation to phenomenology is regarded as a contrasting field. Phenomenology is interpreted by philosophers in different ways, but here it is used literally, as being the study of phenomena. The study of phenomena is the study of the meaning that physical objects have in human experience. It includes among others cognitive psychology and social constructions. Traditionally, phenomenology evaluated the effects and significance caused by technology, without having a direct influence on the development. With information technology this situation has changed, allowing phenomenology to play a more central and influential part instead of mere post-rationalization. Information technology is characterized by managing man-made symbols and representations, and involving cognitive, interactive and organisational analysis of processes related to physical objects. In this way phenomenology and technology has merged and multidisciplinarity is a large part of modern science and thinking.

This thesis leans against this new understanding of technology. On the phenomenological side, the media model investigates that specific instance of information technology defined as 3D Geovisualisation and its relation to a concept of quality. On the natural scientific side, this thesis relies on traditional natural scientific methods of the construction of a research question and the empirical test of it. To introduce the word quality drops a hint of a humanistic attitude in itself, since a quality involves some level of subjectivity that excludes the possibility of working in a fully natural scientific way. Though human beings are involved in the empirical tests, it is still the software, its significance and qualities that are the object of investigation. The object of investigation is, hence, not human beings in themselves.

Basic science counter to applied sciences

This thesis mainly represents applied science but contain also some elements of basic science within. In applied sciences the goal is to gain new knowledge within an existing field and thereby expand the field itself. Applied sciences are furthermore usually directly applicable in practical situations. In this thesis, research questions in connection to the usability tests are evolved from problems occurring in practical situations. Results and recommandations described here can be directly applied in commercial or scientific products. Some results are recommandations on specific tasks and user preferences, others are directed towards stages of system development. For instance it is suggested to use the media model at different stages in a software development project to double check that the focus on communication and means in relation to the focus group is being kept. Basic science is on the other hand working on expanding the unified amount of knowledge that is accepted as being science. Besides that, basic science is usually not directly applicable in a usable context. In this thesis the long-term goal of introducing a model and to elaborate it, is to contribute to the development of a theoretical frame that is useful to understand the various communicative processes that exist between users, developers and other stakeholders in 3D Geovisualisation. In this way the concept of basic science is secondarily present.

Normal science counter to paradigm shift

As a relatively new field, 3D Geovisualisation is influenced by being under development. It has been suggested that geovisualisation is in the middle of a paradigm shift, because data types, data management and interaction are changing fundamentally going from static maps to interactive maps (MacEachren 1994) and going from 2D to 3D (Bodum 2004). Paradigm shifts are provoked by some kind of crisis as described by Kuhn (Kuhn 1970). Within geovisualisation it is possible to say that this crisis is comprised of by a society developing more and more sophisticatedly and globally so that the recent paradigms (2D) are not enough to solve this crisis. A response from the field of geovisualisation to the crisis is the development of 3D systems. A counter-argument against the idea of paradigm shifts is that Kuhn's original ideas concerned much more basic concepts than the practical implications of data and management. Kuhn argues for instance that two paradigms are incomparable and incompatible – which is not exactly the case going from 2D to 3D or from analogue to digital data. However, it serves two causes to bring a discussion of paradigm shifts into focus:

1. to emphasize the position of 3D Geovisualisation as a field that is not fully established. Therefore some considerations of a basic kind are relevant compared with more well established fields where the same considerations might be implicit.
2. to emphasize that though 3D Geovisualisation often is combined with the word ”development”, this does not imply that 3D is an evolution of 2D. It is rather a parallel development where concepts of geovisualisation can be revised from scratch.

Scientific methodology

The concept of quality in relation to 3D Geovisualisation includes subjective points of view, clarified in Figure 1.14, where it is argued that the point of view that is chosen to be in focus here is a user-centered point of view. Dealing with users and information technology, HCI serves through its usability methods a methodology that is developed for this purpose. Usability methods will hence be used throughout this thesis.

Since no real theory exists within user-centered 3D Geovisualisation, a way to study the media was initially developed. To develop a media analogy, usability tests and a general theoretical development is the best tool available today. This involved setting up a model of the media by identifying its characteristics. Four characteristics were identified and these four characteristics were then examined by investigating their relation to quality in a user-focused context. The methodology in this thesis, hence, involved three steps;

1: initial considerations on quality in 3D Geovisualisation.

2: Development of a model of the media containing categories that makes sense in the phenomenological context they are meant to qualify.

3: Test cases, made to study isolated problem formulations and the empirical testing of these through usability tests. Usability testings took place in year 2003-2005.

These three steps are finalised by evaluations, starting with evaluating the usability tests and the cases used, then evaluating the media model and its categories and finally evaluating the concepts of quality discussed initially (Figure 3.1).

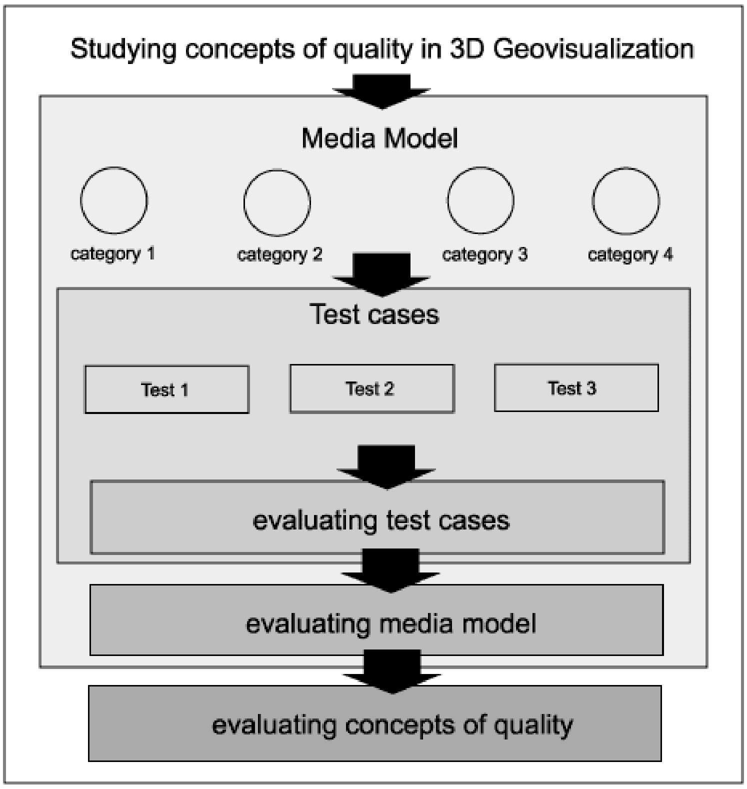


Figure 3.1:Studying concepts of quality leads to the development of a media model, containing four categories. Identifying the characteristics of these four categories leads to further exploration through three test cases studied in this thesis. The test cases, the media model and the concept of quality are finally evaluated and concluded upon.

Each of the 6 steps is treated in a separate section in this thesis as shown in Figure 3.2.

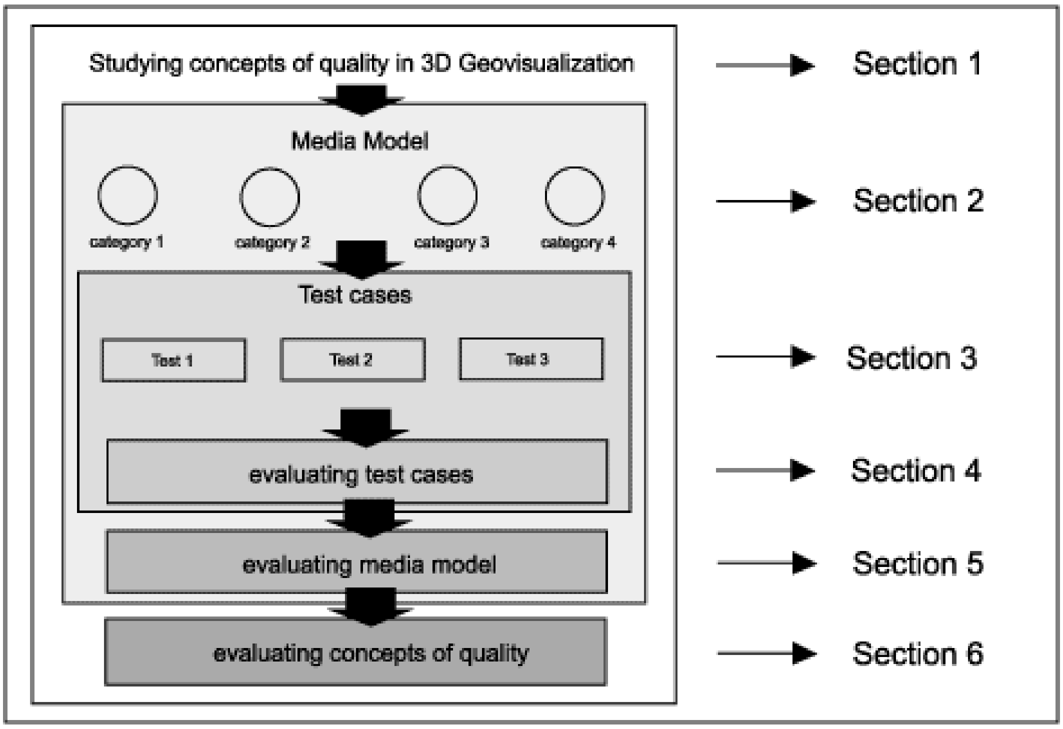


Figure 3.2: The 6 steps in the methodology are treated in each section in this thesis. Introductory in section 1 the concept of quality is the subject of consideration. In section 2 a model of the media is presented and in section 3 this model is the subject of further exploration through usability tests. In section 4 the usability tests are evaluated, in section 5 the media model is evaluated and finally in section 6, the concept of quality in 3D Geovisualisation is revised.

Section 1 presents 3D Geovisualisation, its scientific history and context and its economical and social role in modern and future societies. The qualities of 3D Geovisualisation viewed from various interests, and especially from a human-centered point of view, are discussed. Here it is argued that HCI is an important means to explore a qualification of 3D Geovisualisation.

Section 2 argues that 3D Geovisualisation can be understood as a media; as a way to approach human-centered 3D Geovisualisation. A model of this media and its four-step categorisation is then presented.

Section 3 explores the four categories by performing usability tests within each category, four tests in all, issuing representations, rendering techniques, interactions and interfaces.

Section 4 evaluates these four usability tests and present results, discussions and conclusions on each categoory.

Section 5 discusses and concludes upon the media model used.

Section 6 discusses and concludes upon the initial assumptions on qualification of 3D Geovisualisation and the way they have been treated in this thesis.

Section 2: The Media Model and its Categorization

4. Media model

Media model

As described in the introduction it is a phenomenologically and user-centered approach that is chosen to study the concepts of quality in 3D Geovisualisation. In this way, 3D Geovisualisation is not just a tool, but a media where various possibilities of communication exist. As in any other media it is important for the producer to know the content, means and effects of the media well. Knowing the media well, allows the producer – or developer – to amplify or tone down the various content in order to optimize the message. When identifying characteristics and categories of the media a reductionistic method is used here to conceptualise the structure of the media; and the means of the media is regarded as isolated phenomena. This categorization is meant to be understood in a nominalistic sense, meaning that it is fruitful for the understanding, but not necessarily a realistic model of the true world. In the following, an elaboration of this media model, and its categorization, is described.

The four categories

The categorisation consist of the four groups: representation, rendering, interface and interaction. They are derived from four major topics within VR (Sherman and Craig 2002) and have been introduced into 3D Geovisualisation by (Bodum 2005). The four VR categories reflect a workflow relevant for technological model generation: A suitable, task-specific representation of the real world ranging from verisimilar to abstract must be the first consideration. The object representation is then rendered to be graphically accessible and manageable in a realtime 3D system. The graphical result is accessible to the user through an interface from where the user can interact (Figure 4.1).

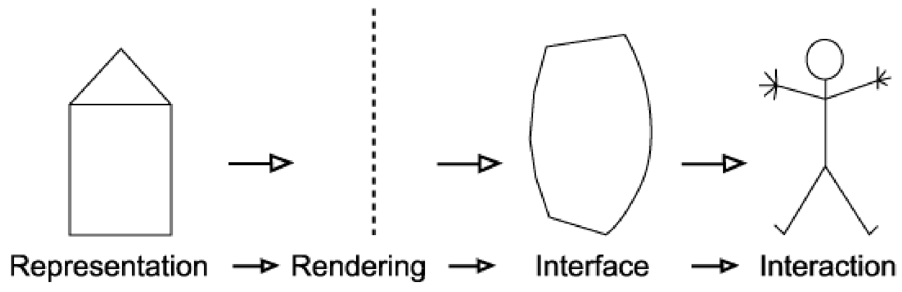


Figure 4.1: The four categories; representation, rendering, interface and interaction.

The developer that produces 3D Geovisualisation models works from a positivistic technological point of view. Focusing on the user, a phenomenological point of view is adopted. The relationship between technological and user-centered 3D Geovisualisation is illustrated in Figure 4.2.

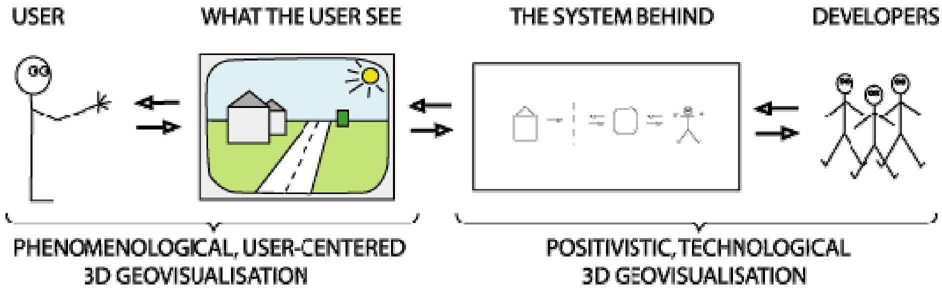


Figure 4.2: The relation between technological and user-centered 3D Geovisualisation. The technological approach develops and studies digital systems, while the user-centered approach studies the relation between the user and what the user experiences in relation to the system.

This thesis suggests using the four issues derived from the technological description as a categorisation of user-centered 3D Geovisualisation as well (Figure 4.3). A phenomenological approach to the representation contains a discussion about the chosen realism and abstractions (Chapter 5). In this thesis the rendering is a discussion about the use of effects like light or color tones; so that a visual ”refinement” or ”improvement” of the scene can take place (Chapter 6). In this way, the category rendering focuses here on optimization, more than the original positivistic meaning, as being the process of visualizing the scene in 3D, and in realtime. The Interface is the physical frame that the environment of the monitor constitutes, and through where the visualisation is visualized (Chapter 7). The Interaction is the users’ possibility to navigate, manipulate and in other ways interact with the model (Chapter 8).

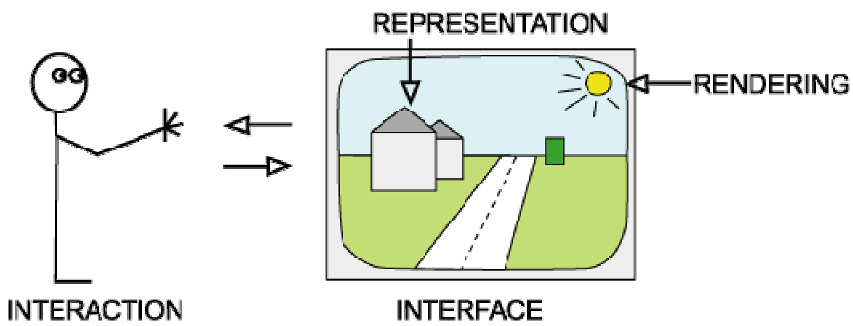


Figure 4.3: The four technological issues, representation, rendering, interface and interaction, can be used as a categorisation of user-centered 3D Geovisualisation as well.

In the media model, the main characteristics of the media are identified, derived through the description of a model of 3D Geovisualisation. This model consist of 4 categories; representation, rendering, interface and interaction (Figure 4.4).

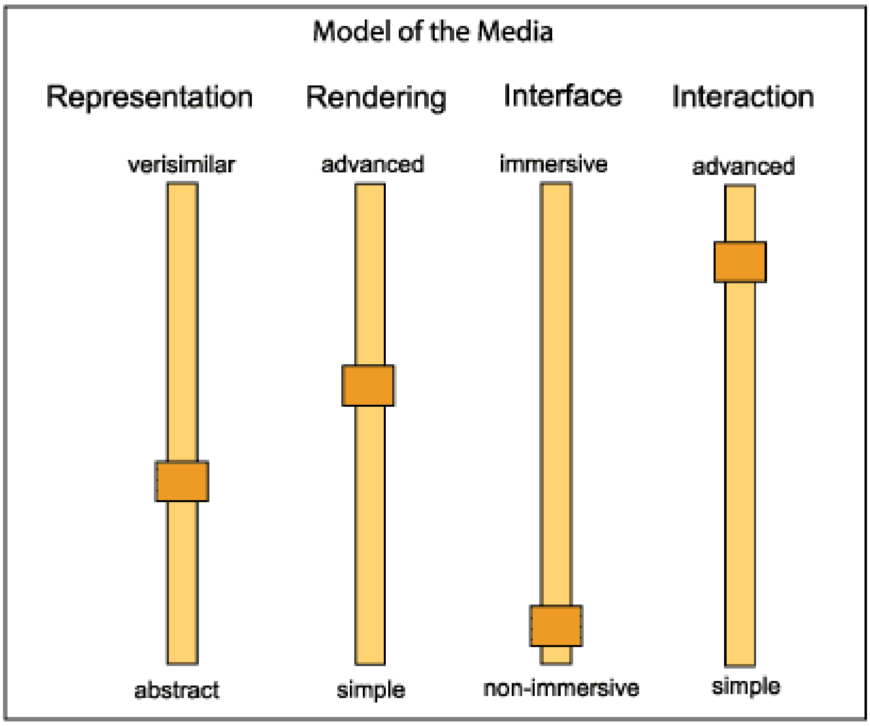


Figure 4.4: The four categories constituting a model of 3D Geovisualisation . Content and means can be turned up or down – and thereby an optimised result can be achieved. Position of adjustment knobs is arbitrary.

Software context

Software development can be described at different levels of abstraction (Figure 4.5). The software is supposed to work in a practical situation in the real world, and is therefore meant to reflect a model of the real world. The world is however almost infinitely complex so this model of reality needs to focus on and simplify phenomena that are interesting seen from a certain point of view – the "Universe of discourse". In for instance a road construction project it is the road and its attributes which are in focus, but focus can vary in discourse model 1 and model 2. The conceptual level describes reality and the simplification of reality in order to make sure that needs and expectations of the software can be fulfilled. If the approach is to be taken to the logical/physical level a system architectoral sketch, like UML or ER diagrams is useful and usually also necessary. In the logical level structures of objects are modelled, and at the physical level they are implemented and exist physically on the harddisk.

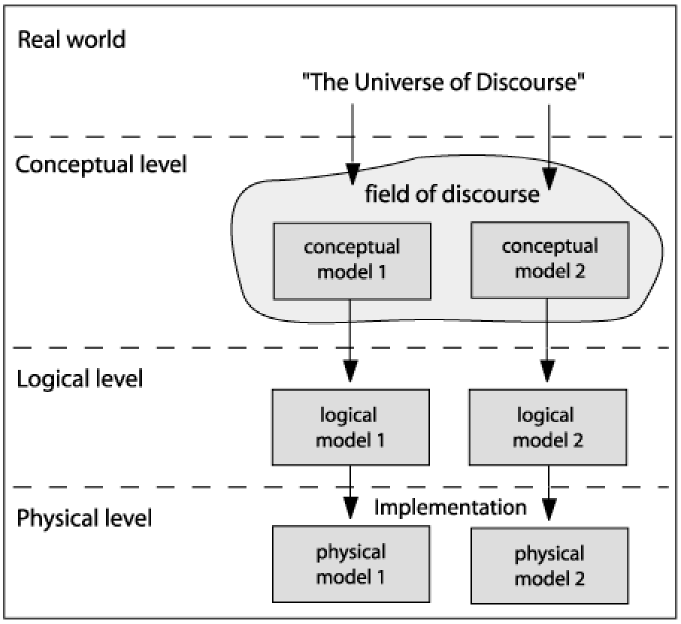


Figure 4.5: From reality to digital model. Reproduced with permission from Lars Bodum.

The conceptual level

At the conceptual level a pure humanistic approach is possible. An example in the geographical and geovisualisation area is (Johansson 2003): who has, with a background from semiotics, studied the picture surface in the new internet based geographical media. The methods used to achieve an epistemological understanding of the new media are critical discussions of Public Participation planning discourse within urban planning. In this thesis the conceptual work is descriptive and based on a model of the content space of 3D Geovisualisation and inferiorly at a number of usability tests built up upon this model and formulated as a preliminary study of a software product. This thesis then only works at the conceptual level of abstraction of datamodelling leading to points of interest. Considerations about realising the results at the logical and physical level are avoided, since technology continously changes. (Fuhrmann et al. 2005) describes it like this:

"Geovisualisation tools should be based on context of use rather than what is technically possible".

In this way technology should not control utility and ideas. The results of this thesis are rather to understand possibilities and explorations of the media that hopefully can inspire realizable compromises today or in the future. Finally, it should be mentioned that the test cases used in this thesis only focus on parts of a final product. In a situation where a final product is to be made a workflow could look like Figure 4.6; where the starting point is investigation and categorisation of a data set, the building of a model, and the generation of an analysis ending up with a presentation of the results.

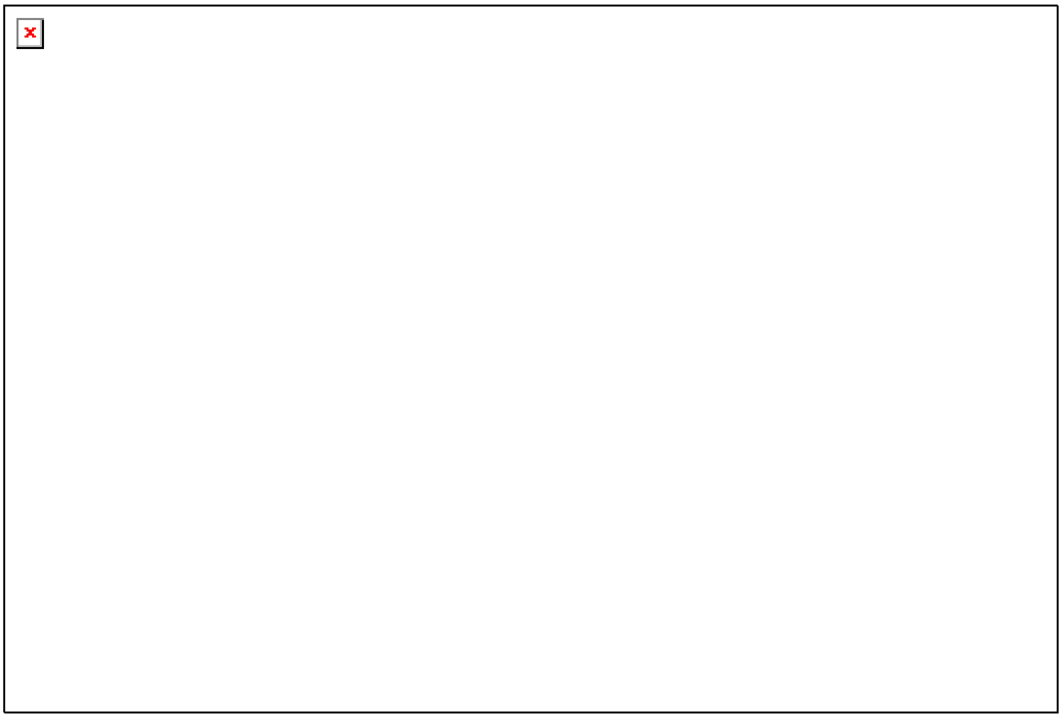


Figure 4.6: Central activities in a geovisualisation workflow (Gahegan 2005).

The process described by Figure 4.6 describes the whole process around the visualisation of geovisualisation. It being the basis of the definition of 3D Geovisualisation as presented by (MacEachren and Kraak 2001), issuing synthesis, analysis, evaluation and presentation. In this thesis, the presentation part is dominant.

Other ways of exploring the conceptual space

(Batty 1997) has likewise worked on a conceptual space. He has suggested a categorisation of what he calls a ”virtual geography” to use for exploration of new digital media in urban planning and architecture. Virtual Geography is the traditional geography mixed with the possibilities of the new media, first of all the internet and the virtual worlds. As an architect, concepts of place and space are important features to address. He defines two levels: A macro level that reflect the geography itself, eventually as a physical reality, and a micro level, which reflects how the physical reality and the virtual reality influence the individual and the society. At a macro level, four different points of view on place and space exist, these being developed in continuancy and in dependency of each other:

- place/space: the original domain of geography, abstracting place into space using traditional methods.

- cspace: c(omputer)space, the space within computers and their networks – here for communication purposes.
- cyberspace: the use of computers to communicate, emerging from cspace
- cyberplace: the impact of the infrastructure of cyberspace on the infrastructure of traditional place. Or the creation of a sense of space – for instance as in 3D Geovisualisation models or in artificial geographies in games etc..

The categorisation by Batty illustrates well how comprehensive a revolution the digital media is in relation to the traditional understanding of geography by introducing new ideas of communication, social frames and space. Batty does however not work in the context of 3D Geovisualisation. It is therefore not directly applicable in 3D Geovisualisation though some of his categories can very well be contained in 3D Geovisualisation. The micro level that Batty introduces is closer to the interest of this thesis; how individuals and society are affected. A study using the categories is made by (Hudson-Smith 2003). The methodology Hudson-Smith uses is similar to the one presented here, consisting of a two-step process. Firstly, the new media is presented, using Batty's place-space categories. Then they are explored in the context of urban planning in various examples and test situations. A main part of Hudson-Smith's studis are the human settlements and behaviour in an planning context in Active Worlds.

Presentation of the four categories

In the following chapters the four categories, representation, rendering, interface and interaction is presented. Initially a general meaning of the word in general is stated, followed by the concept it represents in 3D Geovisualisation. Each category is finally narrowed down to concentrate on a topic and a specifically formulated problem, chosen for further investigation in test cases.

5. Representation

Representation

The original latin meaning of representation is to "re-appear", "again" or to "appear in stead of". The concept is used both within fields related to a physical reality and to be understood as an abstraction in this way that it is not the positivistic physical reality, but a symbol of it. The concept of representation is also related to a realm of thoughts where for instance a snake eating its own tail represents infinity. The representation makes it then possible to express a thought through the human sensorial system, and thereby create an understanding of the surrounding world in association with rules and conventions developed in a cultural context. Within the geographical world, a representation is then an abstraction that is a re-narration of the Earth and its geography. In this way, the challenge of the modern world is not to explore the physical world as the old explorers of the past centuries did, but to explore the representations of the Earth and its geography (Goodchild 1998).

Data representation

A large part of the geographical field sees representations as a measureable and systematic abstraction. A quantitative measurement and positioning or registration of information related to the phenomenon of the physical world results in a representation being a set of data, the data representation. In a digital media data will be represented in a binary system, in numbers of 0 and 1. This method of representation has become very popular in the modern world, because it has turned out to be the most simple, flexible and cheapest method by suiting an electrical system well, based on on-off modes. In this context, a representation implying three dimensions is implicit, where digital, three dimensional representations can result in various data models, based on rasters, vectors or TINs. Furthermore, they can be organised in various ways in databases, but typically as object-oriented or relational structures.

Visual representation

In 3D systems data is represented visually as vectors (points, lines or rectangles) or as rasters (grids, matricer). Vectorbased data is usually represented as TINs or solids. TINs are lines and corner points that are gathered together in triangles. The shape of triangles has turned out to be able to create various shapes in 3D very efficiently. Solids are 3D boxes. If the solids are to represent an irregular shape, boxes are added or subtracted until the desired shape appears. If the representation only consists of a single physical phenomena or object, the 3D model would typically be a visualisation of a product used in architecture or design. If the representation contains several objects positioned in relation to a terrain, they would typically reflect a virtual world like a 3D Geovisualisation. Such a construction will very soon demand some kind of sorting of data to be able to visualise only relevant information and to be able to effectively handle comprehensive sets of data. This is one of the large tasks in the positivistic development of 3D Geovisualisation, and one of the main methods is to construct a Level Of Detail, LoD. (LoD) algorithms, can deliver a high verisimilitude at a short distance from the camera and more abstract when increasing the distance. In a 3D Magic Lens, users can select areas for high LoD visualisation or selection (Ropinski and Hinrichs 2004) (Figure 5.1 and Figure 5.2).

Figure 5.1: The Eraser Lens by (Ropinski and Hinrichs 2004).

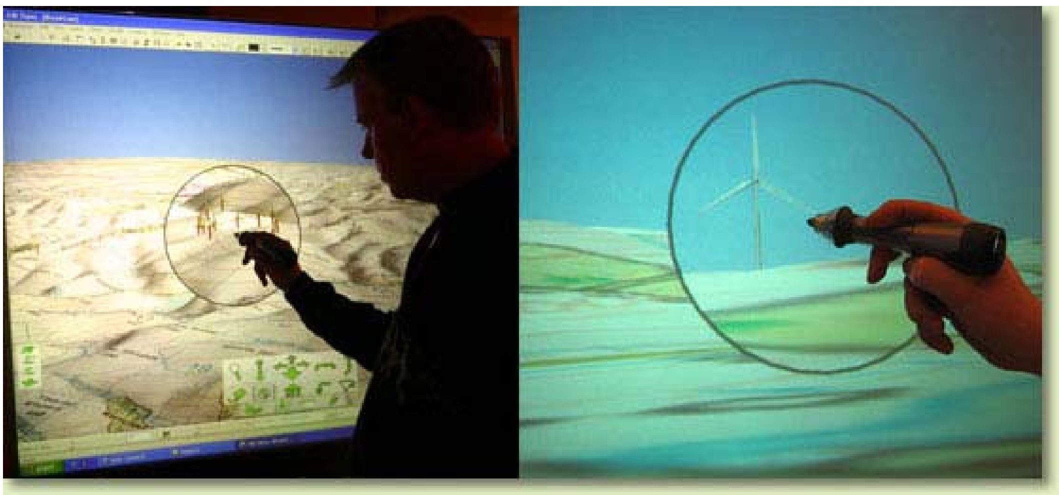


Figure 5.2: A 3D Magic Lens, here developed and illustrated by the Danish spin-off company 43D.

LoD is efficiently supported by an object-oriented data model (Bodum 2005). This means that each vector knows which object it belongs to, and which level of its representation it reflects.

In this thesis the visual representations are however not discussed in positivistic terms, but as the phenomenologic manifestation that the user experiences as the image visualized in the monitor. This visual representation is a product of the choices made in the data representation and in the data model. Through the monitor the 3D system is visually percieved, and if the representation is well-functioning the process of interpretation is normally taken for granted. But on going behind it a complex process of visual communication and perception is taking place. The fact that we understand representations are according to (Mithen 2003) caused by the evolution from animals having isolated functioning groups of intelligence to the modern human being. As Homo Sapiens the groups of intelligence melt together forming a ”cognitive fluidity” (Figure 5.3), making us capable of understanding that a physical thing can be represented by a symbol, as it is commonly used in art, religion, science – in virtually every human activity.

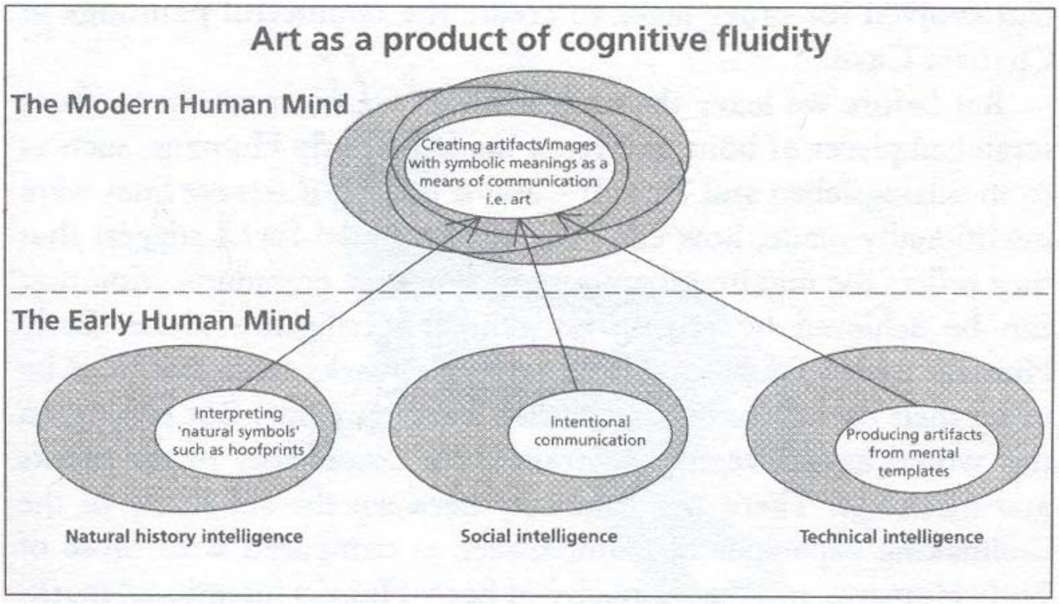


Figure 5.3: In the early human mind of the man-ape the various intelligences are acting in isolated groups, while in the modern human mind, groups of scientific/physical, social and technical intelligences can interact, so that a physical object can be understood as a symbol of for instance social meaning.

Though the ability of creating abstractions is inherent within the modern human being, the task of reading a map or visualisation also demands some basic taught skills. In western culture children are often implicitly taught through games and school this basic understanding, though it is a complex task for research in perception to state what exactly is inherent and what is taught. If a design should be efficient it demands a knowledge of principal human visual perception and cognition to be able to create representations that are understandable for each cultural segment that is addressed. Superiorily our visual perception works by firstly registering form, colour and movements. These are added into larger structures which are finally percieved based on the individual memory, experience and attention (Solso 1994; Sturken and Cartwright 2002). A deep knowledge of this process is (or these processes are) used in art and design, where also theories of image, visualisation, cartography and media are related. Within information visualisation particularly especially the work of Edward Tufte is outstanding, while Charles Sanders Peirce developed semiotics, also in a direction that was especially useful for cartography.

Representations in 3D Geovisualisation

Representation is a kind of visual language used to create a meaning in the surrounding physicl world. Each media, being language, film and photography, has its own set of rules and conventions, making representations not only a reflection of a physical reality. It also creates a subjective meaning and an understanding of the world that calls for a responsibility, being more than just neutral simulations (Sturken and Cartwright 2002). Because 3D Geovisualisation is a relatively new field it is still blurred to talk about generally agreed conventions or rules here. But still there are expectations towards details and style, for instance when it comes to photorealism. Some segments of both users and developers expect and prefer photorealism, while others experiment with non-photorealism. An example is (Döllner and Buchholz 2005), who work with abstract styles like sketchy drawings, outlines, strokes, colours and light settings (see Figure 6.1), without striving for photorealism.

(Bodum 2005) suggests a convention of visual representation by introducing the detailed and photorealistic representation as being a verisimilar representation (Figure 5.4). The index is a structured representation in a library of objects. The abstract representations are more simplified and less detailed than the verisimilar, where the icon contains visually recognizable features from its' physical origin. A symbolic representation uses signs and pictograms that usually demand some kind of knowledge or a legend to make it interpretable (Figure 5.4). The symbolic representations are developed based on Peirces semiotic theories and are commonly used when visualizing attributes, but less when visualizing basic elements like buildings, terrain, vegetation and roads.

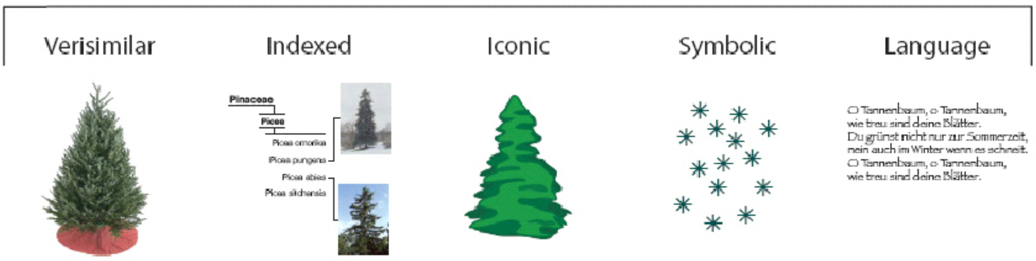


Figure 5.4: Visual representations from verisimilar to more and more abstract. The most abstract representation is the language. (Bodum 2005)

The verisimilar representation expresses a specific, subjective and non-interpretable object contrary to the abstract representation that expresses something general and non-specific. Though this often implies objectivity and impersonality, it can also work as an engaging representation when visualizing, for instance, avatars. An abstract avatar allows the user to identify with it, while a verisimilate avatar would express an exact knowledge of its details, and thereby identifying an exact personality, leaving no possibilities of general identification.

Realism or abstraction?

Creating high realism in whole cities or larger landscapes is costly in terms of data acquisition as well as computationally costly when visualizing. This causes severe limits today, though efficiency is improving on both fields year after year. Methods to collect façade photos from airplanes or trucks are improving (Steidler and Beck 2004), though many solve problems of capacity by simplifying most of the model and only represent landmarks verisimilar to support navigation and orientation (Rakkolainen et al. 2001). In early stages of the development of 3D Geovisualisation, high realism in photorealism seemed to be the ideal (MacEachren 1994). Today representational trends seem to be bifurcated; one direction strives for still higher realism through photorealism and advanced computer graphics, sophisticated to an extreme at for instance www.lenne3d.de (Figure 5.5). Another trend has turned towards simplifications and stylizings.

Figure 5.5: Screendump from Lenne3D. Example of extreme realism.

Non-visuals and multi-representations

The physical world is multi-representational (or multimodal) because most human beings use sound, sensibility, smell and vision to endure it. Studies of virtual environments have shown that combining sound and vision have aided users (Pittarello and Celentano 2001; Rauschert et al. 2002), as well as speech and gestures (Rauschert et al. 2002) to support users in clear and unambigous communication. Adding aural representation in 3D Geovisualisation is based on simple technology and users can rather easily access it. Within VR research haptic representation is under development and not very widely used yet, and not used within geographical information either. Haptic representations involve more complex interfaces, based on gloves or clothes that can transport pressure information to and from the user's body. Though haptic and, maybe especially, aural representations are relevant factors in 3D Geovisualisation, 3D Geovisualisation is, and probably will be dominated by the visual mode in the future as well. In literature multi-representational systems are sometimes defined as systems where an object is described by several visual representations (nD) – equivalent to the systems described as multivariate systems in this thesis.

Introduction to test 1

Visual representations in 3D Geovisualisation have been the issue of (Verbree et al. 1999). The group of authors has developed a system, which supports planning processes by suggesting three types of representations: a 2D colour map (the Plan View), a simple 3D map (the Model View) and a verisimilar 3D map (the World View). This multi-representational three-view-approach has been developed for application at different stages in the process of urban planning, and this approach is a good illustration of the task-specific nature that exists in many workflows. The verisimilar representation created by the content of photo-realism is traditionally recommended for presentation, and recommended by the Verbree author group, but arguments against can be found. In discussing realism contra abstractions are common amongst researchers and developers of 3D Geovisualisation and are therefore the subject of test 1 in this thesis.

6. Rendering

Rendering means "to show", "to recall" or "to re-type" used for instance about the production of photos, video and computer graphics. Within 3D Geovisualisation, depending on computer graphics, rendering is used to describe the positivistic process that visualizes objects in a virtual realm in 3D and usually in realtime as well. Methods of rendering are thus the core techniques of 3D realtime systems (Slater et al. 2002; Akenine-Möller and Haines 2002). Besides the graphical display of images, it is a set of algorithms developed to refine this process in performance and visual quality (light, shadow, colours). Only discussions of visual quality are regarded as phenomenological content and thus an item relevant to discuss with users in relation to this thesis. Performance is a positivistic issue that users expect is just there; like users of television at home will mainly focus on the content of what is broadcast, and not recording and distribution tasks. Another example is culling. Developers use culling to improve performance by letting the system throw away parts in each scene that the users can not see anyway – it may be outside the monitor frame or behind other objects in the scene. Culling can not be seen by the user, hence the user is not visually influenced by culling, though they expect reliable performance in realtime mainly due to the definition of the media. As so, not all rendering issues are carried out as visual means though they are very important rendering methods in a positivistic context.

Rendering issues and discussions are to be found in computer graphics while not many authors in 3D Geovisualisation comment on rendering techniques of a phenomenological origin. One of the few is (Venolia 1993) who uses smoothly shaded and shadowed rendering, to give a better impression and (Kjems 2001) who mentions that shadows are added to improve the visual quality of their 3D models. The computer graphics (Döllner and Buchholz 2005) work within 3D Geovisualisation and regard the following four techniques as the fundamental effects of rendering:

1) Lighting and Shadowing.
2) Colouring and Shading.
3) Edges and Silhouettes.
4) Texturing.

Lighting and shadowing are used in 3D Geovisualisation mainly as a visual depth cue supporting the user to interpret depth, perspectives and object relations. Depth cues are relatively well-known issues based on neuropsycological research of the human cognitive sensorial system. Shadows especially are regarded to be the most important element to enhance the perception of a 3D world (Kjems 2001; Poupyrev 1995). Colours can also enhance depth perception and can act as elements of communication and atmosphere. Furthermore colour cues can be used to express qualitatively or quantitatively content.

Döllner treats edges, silhouettes and textures as well, highlighting them as important rendering issues (Figure 6.1), and using (Isenberg et al. 2003) as a main inspiration in these issues. Döllner uses these styles for denoting a status or a condition. Texturing marks a shape and is useful for image processing, like blending and filtering. To a computer graphic designer as Döllner, these styles clearly belong to a rendering category – while the different levels of realism belong to the representation category. This is mainly because the geographical traditions focus on representations as being a basic feature in the field and therefore needs special attention and a separate understanding, though they are not seperate for computer specialists.

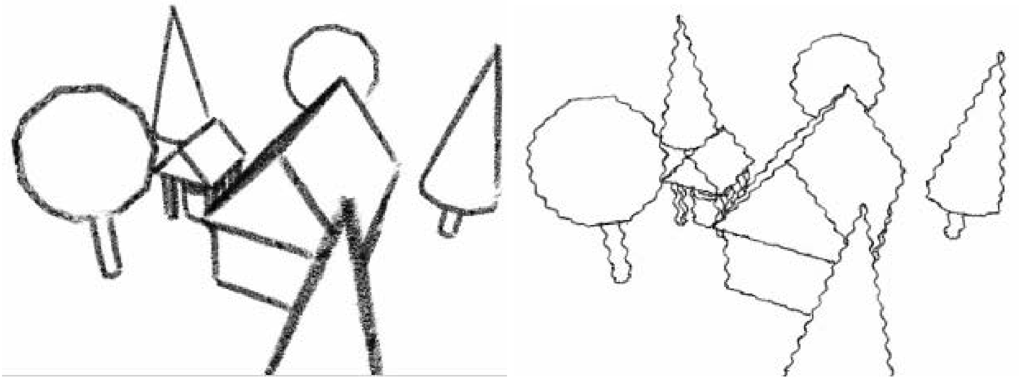


Figure 6.1: Examples of Isenbergs silhouettes (Isenberg et al. 2002).

Aesthetics as the new content

Cartography has always been infulenced by the fact that map products have been produced within their own field, but mainly used outside (Dykes et al. 2005), which has caused special demands on readability and usability. This tendency has enhanced since the development of internet GIS/web cartography, where it became evident that user groups of geographical information again expanded above the traditional group of map readers (Kraak and Brown 2001). With the introduction of 3D systems, this development will probably enhance still (Dykes et al. 2005)). This growing popularisation reveals new questions and makes the producer work in an even more popular awareness. This is very relevant when it comes to regimes of interaction but also relating to other content of the product. A traditional focus in cartography is:

Quality of communication = relevance + utility + accessibility + reliability

These are the four elements necessary to secure that a product contains quality. The quality of the communication depends on its relevance in a real situation, if it is usable and accessible by those involved and finally whether the quality of the data is high enough for the task. Looking at issues of aestethics and communication – being relevant in for instance architecture – the equation is rather like this:

Quality of communication = relevance + utility + accessibility + reliability + aesthetics

A qualification of 3D Geovisualisation is then expected to be able to handle well not only elements but also an aesthetic element. This level can address the end user at a subjective, individual level, for which there exists no tradition within geographical areas. Aesthetics originate from the Greek aisthetikos, which means perceptible to the senses. The traditional understanding of aesthetics is the ”study of the beautiful in art and nature” (Baumgarten 1750-1758) but has developed towards a more bodily and physical understanding like ”the beauty in finding a meaning of a whole” (Kant 1790) and later; ”Beauty is what pleases universally without needing any concept". In this way he combines aesthetics and cognition to a common understanding of human subjective senses. Today this is taken one step further by Donald Norman among others. Aesthetics actually finds it roots in human psychology and Norman argues that communication through emotions is what aesthetics basically is about. Emotions are not just a product of our primitive past but are especially developed within advanced animals and especially within human beings. Emotions affect human behaviour. When a person is stressed and anxious the brain narrows its' view and focuses on very detailed items or subjects. A stressed brain does not solve complex problems easily and tools used in emergency situations need to be much more unambigous than tools for entertainment. When a person feels good, it is relaxed, and the brain works by widening up and focus on broad ideas. This makes the brain suitable for problem solving, judging, learning and supports creativity because the mind is wide and open. Aesthetic things therefore work better, simply because they make the user work better. What makes people feel good can be just small things like candy, art or balanced design (Norman 2004). To address unconcious levels of the human being is a bottom-up approach. A top-down approach is possible as well, when easily usable and unambigous design is available. Users will then automatically regard the design as aesthetic (Nielsen 1993).

Example of visual communication in 3D

In the gaming industry the use of aestethics is extensive. The game Splinter Cell (Figure 6.2) is an example, where a dramatic, dark atmosphere constitutes an important effect throughout the game. As mentioned earlier, many realtime systems and especially internet-based systems are limited by computational power. So, creating stunning scenes in 3D Geovisualisation is maybe not a relevant issue in 2007, but again, branches of future development are moving in that direction.

Figure 6.2: Characteristic scenes from the game Splinter Cell: "Chaos Theory". This realtime game investigates the use of dynamic light settings and shadows as aesthetic narrative means used to create a dramatic atmosphere.

The latest version of The Getaway "Black Monday" takes place in a virtual model of London, where the user gets involved in police scandals and eastern mafias in central London (Figure 6.3).

Figure 6.3: Scenes from The Getaway.

The Getaway is also an example of the budding interest the gaming industry shows in 3D Geovisualisation. Though the first version of The Getaway in 1997 had limited success, a future fusion between the gaming industry and 3D Geovisualisation is still a factor to take into account, and a factor that makes aesthetics relevant in 3D geovisualisation. The industry of entertainment often uses dramatic effects while commercial industry usually works with elements that directly express attraction. Basically, they both rely on cognitive principles common for human beings in general. The tone of the scene, recognition of elements and colour balance is part of an aesthetic, that by working together can create an easily interpretable and attractive scene (Solso 1994). Through knowledge of cultural segments their individual preferences should be achieveable.

Introduction to test 2

Through the technological possibilities in 3D Geovisualisation offers an aesthetic regime where narration or cognitive manipulation of elements can be used as means of visual communication. These means are commonly used in commercial media, architecture, gaming and film industry, fields where 3D Geovisualisation plays or has the potential to play a role in the future. In architecture narration and aesthetics have traditionally been a large part of the field, also after the introduction of new digital media. In test 2 of this thesis, interest is focused on whether aestethics work in 3D Geovisualisation.

7. Interfaces

The user interface

That specific interface where information flows between the system and the user is called the user interface - or in short, the interface as it will be used in the following. The interface can be described more precisely as the user interface that is defined as:

"The user interface is the medium through which the communication between users and computers takes place. The user interface translates a user's actions and state (input) into a representation the computer can understand and act upon, and it translates the computer's actions and state (outputs) into a representation the human user can understand and act upon" (Bowman et al. 2005).

Today, and where graphics are involved, the interface consists of a combination of graphics and text, a representation in a monitor and some manipulation through interaction devices, like a keyboard and a mouse. In this way, the general definition of the user interface involves all of the categories that are used in this thesis. The representation and the rendering is the combination of graphics and texts mentioned 1), the monitor in 2) is the interface and for 3) the manipulation is the interaction. The categorizations introduced in this thesis reflect a need for further separation between representation and rendering, and also to connect to the discussions of representations that have a dominant position in related fields like geography and architecture. Since items 1 and 3 are covered by the representation, rendering and interaction studies in this thesis, item 2, the monitor environment, is therefore the focus of interface study here. The monitor environment is the physical device through which the scene is displayed.

Monitor types

A wealth of different monitors is developed these years, and monitor types have increasing importance in all steps of development. It is possible to identify four major fields of utility and connect them with the interface monitors (Whyte 2002; Sherman and Craig 2002):

1. mobile users using car navigation systems and technicians doing field work preferably use small monitors. 2D is still dominant, but 3D systems exist.
2. web-based systems and single users working at private computers or at the office are meant for mass-use. PC monitors of 19"-23" are common.
3. analytical tools for professionals in special cases use large monitors (for instance in product development) or stereomonitors (in surgery).
4. public presentations work because more users can watch the same monitor, but also because the virtual environment becomes realistic through realistic proportions.

Developing true 3D systems from raw data to the rendering process is possible, but when it comes to the interface the important stereo effects are often neglected, and here, at the final step, breaking the chain of true 3D. Monitor types fall within these groups:

- non-immersive monitors: monographic pc monitors or small monitors.
- semi-immersive monitors: Monographic or stereographic panoramas or projectors.

- immersive monitors: Stereographic CAVEs.

Semi- and non-immersive interfaces

Non-immersive interface is the monographic pc monitor, the small displays of mobile phones or palms without stereo effects (Whyte 2002). Though some challenges exist due to the tiny display, 3D models optimized for mobile devices exist (Rakkolainen et al. 2001; Coors 2002). The horizontal visual range is limitied, usually down to 30%. Semi-immersive monitors support some, but not all, depth cues. This is either the size credibility of the big screens or the small stereo monitors (Figure 7.1).

Figure 7.1: The Semi-Immersive panorama at Aalborg University.

Immersive interfaces

Working in fully immersive interfaces the user is surrounded by stereo images, as in a 6-sided CAVE (Figure 7.2).

Figure 7.2: An immersive interface: the CAVE at Aalborg University.

Immersive interfaces reproduce a credible scale between the physical properties of the user and the virtual representation of the world. Already (Descartes 1641) discovered while searching for the identity of the individual, how easily the senses can be decieved but also how strongly the body relates to its proportions. Besides the scale, immersive systems furthermore support depth cues, and together they can create very efficient sensoral input. The user is conscious of time and place and thereby is conscious of the virtuality, but it is individual how easily the user gets carried away. Experience with using different interface environments mainly comes from researchers in VR, but also some researchers in 3D Geovisualisation have addressed interface issues where both immersive and non-immersive systems are relevant. Generally immersion is found to be a positive experience to most users. (Kjems 2001) concludes that users in a decision-making process in urban planning do feel they benefit from the immersiveness. (Lee and Peng 2003) have registered not only a higher level of presence on big displays compared to small displays, but also a more positive attitude towards the model.

Mono and stereo depth cues

In visualisations, the human ability to process depth cues and transform them into combined spatial perceptions is used. Monocular cues are distinguished from binocular cues. When several depth cues are present, both mono- and stereographic cues, they are added into synergic effects resulting in enhanced depth perception. Monocular cues work when using two eyes as well as one eye and are therefore dominant at a distance where eye bias is minimal. Monocular cues can be reproduced in both 2 and 3D and are based on these effects (Bowman et al. 2005):

- relative size and height compared to horizon
- retinal image size
- interposition or occlusion, when the object in front covers partly the objects behind - continous objects are closer than those interrupted
- motion parallax is a dynamic depth cue (requires moving images)
- aerial perspectives result in fading colours in the horizon due to atmospheric disturbance
- linear perspective
- texture gradients (lines meet in the far distance)
- lighting and shadowing of the scene
- oculomotor (convergence) cues register tension in the eyes, depending on distance to the observed object.

(Okoshi 1976) emphasize the following binocular cues:

- Accomodation: the focal length of the lens.
- Binocular disparity uses the fact the objects in vision are a bit biased by observing with two eyes, and is especially useful in a short distance, within the range of 10 metres.

Stereo effects can be obtained in both pc-monitors and in the large immersive monitors by using stereo methods. There are two main methods to obtain stereo effects: active and passive stereo. In smaller monitors the stereo depth cues create a feeling of depth and contribute to synergic effects when several depth cues are combined. But the limited size of the monitor and the often rather large objects in geovisualisation destroy a real exo-stereo effect, which will allow the objects to "step out of the monitor". Large panoramas or CAVEs are less likely to affect the exo-stereo effect, and will be more suitable for 3D Geovisualisation models in stereo. Some stereo effects do occur at a distance, though, and would especially influence urban models, where objects often are observed at a relatively close distance compared to rural models. If the eye distance and geographical scale of the model resemble real world relationships, the stereo effect of the display will be natural. If eye distance is larger than real world relationships, as is often used in 3D models, the stereo effect is more significant than in the real world.

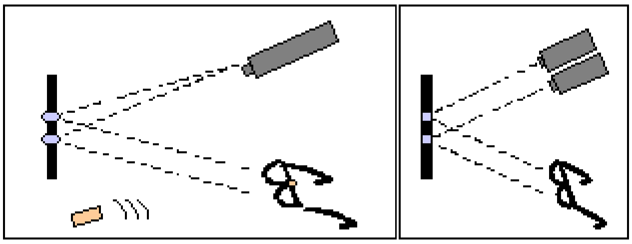


Figure 7.3: Active and passive stereo methods.Graphics from VR Media Lab, Aalborg University.

Introduction to interface studies in test 1 and 2

The spatial feeling is shown to be documented in various ways and argumentations forming its' effects can be found in cognitive studies. What exactly the value added is, is however unclear, and it is the aim of this interface study to see whether it is possible to gain more exact information on this. The study of interfaces is here combined with the study of representation and rendering. It therefore becomes a study of the effect of the interface on the representational study concerning district plans and a study of commercial tourism in the rendering study. For practical reasons it has not been possible to include small monitors or the CAVE, hence the monitor study includes a mono pc monitor, a stereo pc monitor and a panorama.

8. Interaction

Defining interaction

The original meaning of interaction is "exchange" or "mutual influence" and it is used in many different fields of science, for instance in social sciences where interaction happens between humans or cultures. In social science it is being

> *"the most elemental unit of social events where people adapt their behaviour to each other, whether or not they follow mutual expectations or reject them. As coordinated action is not pre-programmed, a minimum of common meaning and linguistic understanding is necessary" (Qvortrup 2000).*

Or from a communication point of view:

> *"interaction may be said to come into being when each of at least two participants is aware of the presence of the other person, and each is has reason to believe the other is similarly aware" (Communications 2006).*

In the field of communication, interaction is not used as an established term, but is sometimes used much in agreement with the sociological understanding of interaction. In media communication, interaction is however not a pre-requisite for communication, though some kind of communication is necessary when interaction is performed. Inspired by the sociological/communicative approach to interaction, the developer can then expect that the user keeps attention focused on the software, ready to try to interpret its behaviour. And in reverse, the user is entitled to expect that the interaction is established in an interpretable way. Using this sociological/communicative approach to interaction one finds that this is more or less the basic concepts of HCI (HCI is further defined in chapt. 10).

Interaction in computer science

Interaction in computer science is closer to the communication interpretation of interaction than to the social interpretation, because the direct contact between the developer and the user is eliminated. Here, interaction is the process that takes place when a human operates a machine (Qvortrup 2000). This system is, however, usually considered as analogical to the system of social interaction, but instead of two people involved one person is replaced by a machine. The term "operate" leads to the notion that there is a physical act involved while performing tasks or retrieving information from the system. This is opposite to the purely visual information that was discussed in the representation and rendering categories in the former chapters of this thesis. Finally, in realtime systems, interaction also plays an important role in giving the systems a realistic stamp, by responding in a natural way to the user's movements, especially when navigating. Other interaction paradigms are relevant, for instance sounds or movements and several authors have found that multimodality supports users in their tasks.

Virtual Reality and Interaction

Virtual interaction refers to the version of the social sciences of interaction, being used in VR (Qvortrup 2000). In this situation, virtual interaction takes places between multiple human users and their machines. The users are not communicating face to face, only their avatars are, resulting in a limited, symbolic behaviour, that intermingles social interaction (human to human – two-way communication) with media communication interaction (human to machine – one-way communication) (Qvortrup 2000). In the geographical world GeoVISTA Research Centre is among the leading developers of virtual interaction, or collaborative environments as they would call them, in geographical systems, though they mainly work in 2D systems. In VR literature, the term 3D interaction is sometimes defined as the 3D spatial context where the user performs tasks. This means that not all interaction taking place in a 3D world is 3D interaction, for instance if the user only observes viewpoints in a 3D world. If the user uses 2D devices, such as a mouse, this is translated into 3D coordinates (Bowman et al. 2005). An advantage of 3D interaction is that it makes use of intuitive senses and can be converted into a 3D system by relying on basic concepts that the user already knows from the real world. Relying on well-known concepts releases cognitive attention to perform other tasks, and in VR it is generally not recommended to work with input-paradigms in the shape of traditional GUI interpretation. The focus on intuitive interaction is however believed to be different in 3D Geovisualisation. This is mainly due to the importance of performing selections and to carry out analysis in 3D Geovisualisation – these complex tasks are not directly convertable in the same way as navigation tasks or simple pick-and-drop-tasks. All in all, intuitive 3D interaction is considered as less important in 3D Geovisualisation and will therefore not be further discussed in this project.

Interaction in 3D Geovisualisation

Interaction between the user and the system is usually considered as the most important user question in 3D Geovisualisation, because it is vital for the utility of digital information. Some usability-experts highlight this by claiming that

"Interaction rules" (Nielsen 1993)

Jacob Nielsen is indeed well-known for his interaction-focused and very usable web-design. In a visualisation-heavy field like 3D Geovisualisation there is a general consensus that

"visualisation alone is not enough" (Verbree et al. 1999; Kraak et al. 1998)

Suggesting that retrieval of accessible information or manipulation is fundamental. Finally, interaction is considered as a major task in 3D Geovisualisation because interaction supports exploration, being one of the strongest advantages of 3D Geovisualisation (Bodum and Kjems 2002; Kjems 2001). Exploring the data sets visually, querying them to extract information and navigating to find patterns in them is essential tasks in information visualisation in general. The interaction category is therefore by far the category where the most usability and development work has been performed within 3D Geovisualisation. The importance of interaction is also reflected in comprehensive litterature within this category and rather much experience made, compared to the other categories introduced here. Focusing on the operational tasks performed by the user while using the software, these tasks basically consists of:

- querying (Longley et al. 2001)
- analysing (Longley et al. 2001; MacEachren and Kraak 2001)
- manipulating (Bowman et al. 2005; Sherman and Craig 2002)
- virtually interacting (Sherman and Craig 2002)
- navigating (travelling and wayfinding) (Sherman and Craig 2002; Bowman et al. 2005)

Querying, analysing and manipulating

Querying is the task of selecting data from large data sets for visualisation in 3D. This could be asking for information about inhabitants in a specific urban area or to assemble environmental data sets in another area. The selected data sets can be analyzed by searching for specific relations, limits or geographic context, for instance. The task of manipulation is usually related to catching objects, repositioning or resizing them, for instance in urban planning. These three interaction tasks all belong to tasks that are essential in 2D GIS systems, and they are generally considered to be so important for geographic information, that they are expected to influence parts of 3D Geovisualisation strongly in the future. Efforts are being done to create systems that are able to manage these large data sets in an efficient way, but only few and limited projects that allow for querying and analysing have succeeded so far. Because of this, interaction studies in this project have been concentrated on navigation instead, and likewise not many studies in literature include these tasks.

Navigation

Navigation is basically a question of selecting geographical objects and "on-top" information from the database of the system and sending it to the user interface. 3D systems are particularly information-heavy, so this process needs to be especially fast and efficient. From the user's point of view, navigation is important in 3D Geovisualisation, as in VR, because it is probably the most basic interaction parameter and the movements being fundamental for the user's first-hand-impression of the system. Navigation can even be regarded as another sensorial impact through which the user endures the system (Heim 2000). Navigation is the task of moving from a starting point to an end point, being relevant both in the physical and in the virtual world. Navigation is composed of a series of partial processes; "travelling" (the motorical process), "locomotion" (positioning) and "wayfinding" (the process of building and understanding a mental model of the relevant landscape in order to be able to get to the destination) (Bowman et al. 2005; Sherman and Craig 2002). Besides being fundamental implication of space, navigation will often be the first task the user has to manage in order to solve following tasks of a more analytical context. For the untrained user, navigation is a serious obstacle, while the skilled user is much better-off, regarding all of the partial processes of navigation.

Travelling

In realtime systems the travel constitutes an important way to explore space, and the act of motion is performed through the interface. In the physical world the individual learns to walk, drivers learn to drive a car and pilots learn how to interact with a plane. Human beings are thus used to learning new ways of performing motion. In VR a set of different methods of travelling exist, where fly/walk-modes are commonly used in 3D Geovisualisation. In everyday talk, navigation refers to game-navigation meaning combinations of arrow keys, mouse and/or joystick that allows the avatars to act. Flight simulator navigation is another term being an interaction that imitates the motion of a plane in the air, for instance turning is performed by changing the camera angle.

Wayfinding

Wayfinding takes it as a read that locomotion has succeeded allowing for the establishment of a path leading from the current position to destination which is desired. The process of space cognition that establishes and memorises this path is based upon the building of a mental model of the landscape and the path. These mental models are typically patterns that are build upon a method of ”divide and conquer” which is the most common and usually the most efficient method. The method of ”divide and conquer” works through the division of the superior area of interest into smaller parts. Characteristics of each area are known or under acquirement, and finally they are brought together (Sherman and Craig 2002). In VR supplementary methods to support wayfinding have been developed; by following predefined paths, ”bread crumbs” (showing former routes), grids, landmarks, compass, position (coordinates, heights), and exocentric views (Sherman and Craig 2002), are also commonly used in 3D Geovisualisation.

Existing projects

Studies of space cognition in real world situations are a research field in itself, often combined with the modelling of navigation in virtual worlds. In 3D Geovisualisation similar studies takes place, in many cases combined with other overall objectives. In this way a project worked on improving mountaineers' navigation skills in real world mountains through the use of 3D scenes. Initially 70% of the landmarks they used consisted of trees, parking lots and other surface elements. After a period of training the mountaineers instead started building mental models based on the topography, being a more secure navigation paramenter in natural areas (Purves 1998). The use of exocentric views is efficient wayfinding support (Fuhrmann 2002), commonly used as a small 2D map in the 3D model. (Rakkolainen et al. 2001) found this combination of egocentric and exocentric views generally preferred by the users. In TellMaris project 3D maps were popular as well, though 2D maps were considered as being sufficient for navigation purposes (Coors 2003). Though navigation in virtual environments is a common issue in research, it is an unclear issue, both regarding usability and paradigms (Pittarello and Celentano 2001; Fuhrmann 2002).

Introduction to test 3

Fundamental difficulties of navigation in virtual environments appear because the visual angle is limited (at least in non- and semi-immersive systems) and also because motion happens in discrete steps where direction and visual angle is coupled in an unnatural motion (Ruddle and Jones 2001). To control motion in space the user must not only control the two dimensions (or four degrees of freedom) of forwards and backwards, left and right being the natural motion in a real world, but also two extra degrees of freedom of up and down. This is difficult for the developer to facilitate through the design of interaction and for the user to learn, both when only standard keyboard and mouse is in focus but also through VR devices. Six degrees of freedom involves extensive “cognitive costs” (Cockburn and McKenzie 2002), which makes some developers work with prefixed flying heights (Dias et al. 2003), or prefixed video recordings. Only four degrees of freedom are much easier to design and learn being very close to natural motion. Others suggest that navigation is not necessary at all, and prefer a kind of 3D Google, where the prime goal is queries and results that are not delivered in realtime. The most common solution is however to add links or bookmarks to prefixed positions. Though six degrees of freedom in navigation involves a lot of troubles for user and developer, it also serves freedom and an unique possibility to explore the environment and in forming rich cognitive maps that increase the likelihood that the user gets what was desired (Elvins et al. 1997; Moore and Gerrard 2002). Some of the users desires can not be foreseen; the county of Northern Jutland asked a few of their citizens how they used the publicly available 3D visualisation of the area. Some, for instance, looked for good fishing spots, an activity that was not included in the original idea. In district plans citizens are mainly interested in views from their own windows while planners/politicians focus on overall lines in the area. The planners are therefore more likely to be satisfied with few strategic bookmarks, in opposition to the citizen. So many situations profit from the six degrees of freedom, and looking at different ways of serving these 6 degrees some seems to serve them more successfull than others. In the last test, test 3, this is the issue.

Section 3: Usability Test Cases

9. Usability

Usability methods

In Section 1 the study of relevant test cases has been emphasized as a preferred methodology in order to study concepts of quality in 3D Geovisualisation. In part 2 relevant problem formulations are based on current discussions in the field. Summing up the problem formulations of the four categories presented in Chapter 5-8 are:

1. Representation: How can different levels of realism be used in presentations?
2. Rendering: Does aesthetics work in 3D Geovisualisation?
3. Interface: What difference do monitors make?
4. Interaction: How can 6 degrees of navigational freedom be supported?

These four problem formulations are discussed in 3 tests. The three tests and their main issue performed here are shown in Table 9.1.

	Test 1	Test 2	Test 3
representation	X		
rendering		X	
interface	X	X	
interaction			X

Table 9.1: The four issues of the three tests performed in this thesis.The interface part is contained in both test 1 and 2.

The methodology suitable for studying test cases is usability methods from the field of HCI. HCI is being defined on the basis of different points of view, but essentially the following phrasing is contained:

"The study of the relationships which exist between human users and the computer systems they use in the performance of their various tasks"(Faulkner 1998).

HCI consists of a theoretical part that uses not only cognitive psycological research, but also computer science and engineering fields. Inspiration also comes from closely related fields like ergonomics, anthropology, linguistics and design, to mention just a few. The methodology of HCI consists of usability, which can be defined as:

”the extent to which a system can be used by specified users to achieve specified goals with effectiveness (the extent to which a goal is reached) efficiency (the effort to reach goals) and satisfaction (the user’s opinion on system performance) in a specified context of use” (Barnum 2002).

Usability consists of methods of both quantitative and qualitative origin. Quantitative methods are based on measurable phenomena statistically operable and unambigous results registered in questionaires or digitally. The results of a qualitative method are not mathematically/statistically managable but independent of occurence and significance. Rather they are based on subjective statements about a product or a structure the product enters into. As such, they are usually designed to answer questions of abstract origin, like ”understanding information” or ”making decisions” (Freitas et al. 2002). Abstract problem formulations are common within geovisualisation, where decision support and public participation are central issues in many projects. Another useful method for abstract problems is narration or story-telling, as suggested by (Fuhrmann et al. 2005). Story-telling is an interview mode where the subject is allowed to express whatever comes to mind. The result is a subjective and ambigous point of view, but can still be valuable for explorative design processes, by giving information of abstract and individual needs as an opposition to generalised and more objective results. In iterative product development both methods of qualitative and quantitative origin are used. These cover initial blurred ideas of needs in an organization to the building of workflows ending with evaluation of the final product, for instance through Cognitive Systems Engineering (CSE) and concept mapping (Brewer 2002; Rasmussen et al. 1994). Other alternative methods are methods of etnographical origin designed to study how the product enters into the daily life of a subject (Summerville 2000).

In this test problem formulations include discussions of the utility of realism, aesthetics and monitor environment. The issues are by nature rather abstract formulations as they are related to concepts of subjective assessment. Therefore it has been of high priority to use quantitative methods to elucidate these in tests 1 and 2, issuing representations, renderings and interface. Interviews are the most commonly used qualitative method. In an interview a phenomenon is shown to the the subject, followed by a number of preprepared question asked by the interviewer. The interviewer is usually present through the whole session that must be recorded in video or aurally. Because interviews give the subject a freedom to express themselves in their own words and thereby are capable of containing abstract ideas, interviews are appropriate here. More comprehensive methods of etnographical or organizational origin are not necessary here, since the problem formulations are rather narrow and do not directly include questions of the surrounding environment. Another qualitative method is Expert Evaluations. They are interviews where singled-out experts are invited, and the interview is characterized by professional conventions and terminology that can assure another level of precision in questions and answers. Since this thesis is interested in practically related aspects of it, it is relevant to include experts to discuss the practical relation between users and producers. Expert evaluations are therefore found suitable for that purpose and used here in tests 1 and 2 as well. Finally, it is generally recommended in usability that a combination of methods is used. Therefore the qualitative methods of tests 1 and 2 are combined with a quantitative method, carried out by a questionnaire. A summative evaluation would imply achievement of well-defined goals relevant in a final product (Haug et al. 2001; Gabbard et al. 1999). In test 3, the problem formulation is less abstract since it is not questionning issues of individual character. It is more consistent issues of being able to navigate or not, and this result is directly relevant in a final product. This is expected to be manageable through a simple summative method, and a questionnaire is used in test 3. The chosen methodology for the three tests is shown in Table 9.2:

	Interview	Questionnaire	Expert evaluation	Time measurements
representation, Test 1	X	X	X	
interface, Test 1	X		X	
rendering, Test 2	X	X	X	
interface, Test 2	X	X	X	
interaction, Test 3		X		X

Table 9.2: Methods used in this thesis.

The choice of methods is supported by (Gabbard et al. 1999). Here the authors show, that the traditional methods of usability are not designed to solve problems within media of VR – that are closely related to 3D Geovisualisation– because the complexity is higher in VR. The team of authors recommends therefore an iterative process suitable for the unique needs within VR. The process includes four steps:

1. User task analysis. This analysis maps all necessary tasks.
2. Expert guidelines-based evaluation. Recommendations from experts.
3. Formative user-centered evaluation. Methods where the user is in focus.
4. Summative comparative evaluations. Methods where the software meets well defined goals.

Combining these steps is a rather thorough procedure, and more thorough than usually recommended in HCI, but when a combination of methods is used, a better coverage of usability aspects are expected. The guidelines of Gabbard et al. are followed here, except the first point of user task analysis, because final products are not issued here.

Usability lab at Aalborg Universitet

For all three tests the usability lab at Aalborg Universitet was used (Figure 9.1), equipped with a 21” pc monitor and a stereo monitor (Figure 9.2). Besides the lab, the panorama cinema at Aalborg University was used (Figure 9.3). Video recording was performed in both rooms, mainly for the purpose of aural recording.

Figure 9.1: A) Subject in the usability lab at Aalborg University, using the 21” PC monitor. B) Monitoring and recording of user interactions and interviews is performed from the neighbouring operation space. The operation space and the user space is separated by a window.

Figure 9.2 :The Stereo monitor.

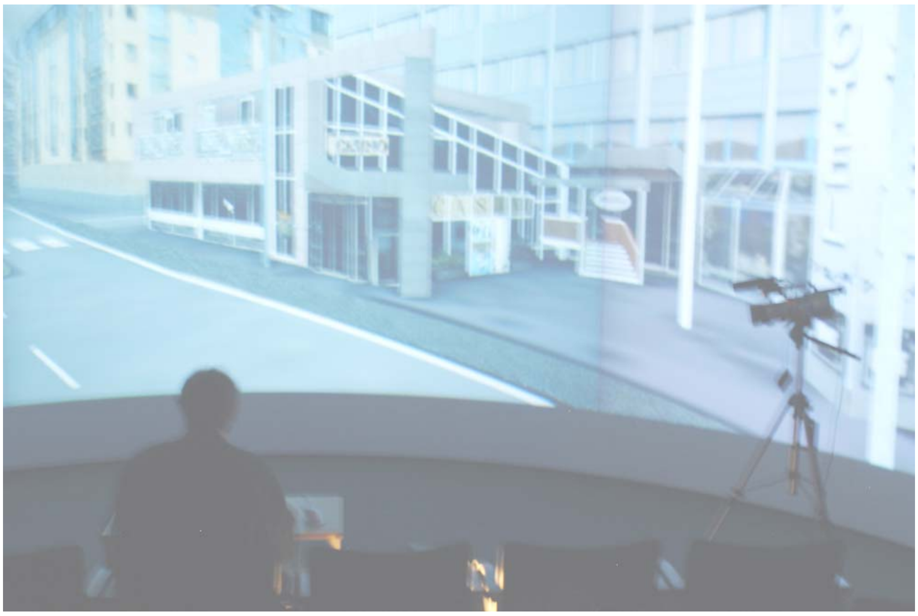


Figure 9.3: A subject in the panorama at Aalborg University. The video recording performed here is mainly for aural recording.

Uncertainties

Though optimal care is taken to ensure reliability of the results, weaknesses are indisputable. The main uncertainties are mentioned here, along with the precautions taken against these uncertainties:

- Can the problem formulation possibly be answered? The problem formulation needs simple formulations to cover the abstract questions and qualitative methods are relevant here.
- Are the interview questions non-ambigous and not guiding? A combination of methods are used here to control the results and in test 1, the same questions are posed in various ways.
- Are the quantitative results statistically significant? At least a minimum of subjects (10) are used in test 1 and 2. In test 3 a larger number is used, raising the reliability of the quantitative tests.
- Are the subjects representative of the focus group? In the first two test cases subjects have been searched among the focus group itself and match these rather well. Since it is very time consuming, the subjects of test 3 are not overlapping the focus group very much.

10. Test 1

Questions to address

Visual representations in 3D Geovisualisation have been the issue of (Verbree et al. 1999). The author group has developed a system, which supports planning processes by suggesting three types of representations: the Plan View, the Model View and the World View (Figure 10.1). This multi-representational three-view-approach has been developed for application at different stages in the process of urban planning, and this approach is a good illustration of the task-specific nature that exists in many workflows. The Plan View (PV) is an ordinary 2D colour map for initial orientation; the Model View (MV) is a simple 3D map for professional volume analysis and the World View (WM), a verisimilar photorealistic map in 3D for public presentations (Figure 10.1).

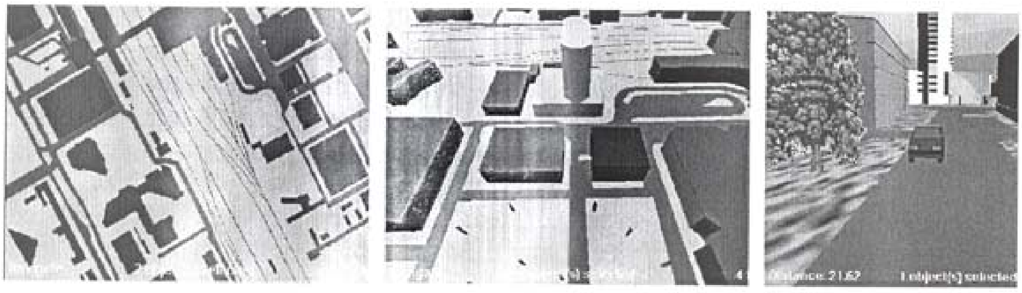


Figure 10.1: The three views of (Verbree et al. 1999) applicable at different stages in urban planning. a) Plan View, b) Model View, and c) World View.

The group of authors suggests using the WV for public presentations of a planning project. The verisimilar representation created by the content of photo-realism is traditionally recommended for presentation, but there are also arguments against:

- Positivistic limits (data collection and handling)
- Risk of over-visualizing. In district planning 3D visualisations can result in detailed representations of future changes that might express details that are not certain.
- Risk of overloading. A detailed scene might call for a high preceptive work load that lowers the reading of a scene.

Verbrees suggestions include, beside from the visual representations, several interactive regimes as well as different interface environments. In this thesis, the study of representation is inspired by (Verbree et al. 1999), but uses exclusively the Model, Visualisation and partly the Analysis Properties in Figure 10.2 as an inspiration for working with representations in Test 1.

Table 1. Properties of the Plan view, Model view and World view.

	Model	Visualization	Navigation	Selection	Manipulation	Analysis
Plan view (2D)	2D geometry attribute values	cartographic	pan and zoom specify position	pointing query distance	create remove translate rotate	buffer overlay network proximity
Model view (2½D)	2D geometry extrusion by attribute values multi-TIN surfaces	extruded 2D geometry cartographic (3D)	view-point centre of interest zoom fly to	pointing query relation	translate rotate scale define relations	line-of-sight volumes proximity (3D)
World view (3D)	3D CAD level-of-detail	realistic textures video	walk-through virtual guide	pointing	scenarios	sound sight shadow

Figure 10.2: The interactive, interface and representational regimes included in the studies by (Verbree et al. 1999).

Discussing realism contra abstractions are common amongst researchers and developers of 3D Geovisualisation and are therefore the subject of test 1 in this thesis. Using high representation for presentations, as it is suggested by (Verbree et al. 1999), does however involve some problems. Partly because high representations are costly both in manhours and in computation power, so if abstractions work as well for presentations technological efforts could be reduced. Furthermore, over-interpretation might be more likely in high representations than in lower, leading to political crisis in public planning. For a VR Media Lab such as the one at Aalborg University, the monitoring of environment and platform plays a large role. Questions regarding the interface is also included in test 1. Questions in test 1 are therefore;

Representation: How can different levels of realism be used in presentations?

Interface: What difference do monitors make?

Following the main idea of bridging the technological aspects and the users as described in Chapter 4, these questions are sought to be answered through usability tests, where a direct meeting with potential users is possible. These questions are usually discussed amongst developers, but at a scientific level rarely between users, and this test is a good opportunity to take a users point of view.

Preparations for Test case 1

District plan 08-061 (Aalborg_Kommune 2003) proposes large changes at the campus of Aalborg University, Denmark. The main landscape change suggested is a new 6 floor high library building, centrally located in the eastern campus area.

Since the existing neighbouring buildings consist of 2-3 floor high mixed private properties and university buildings, the new library building introduces a major change from campus area to city-like area. The district plan include the possibility of adding other buildings, parking lots and recreational areas that support the city-like look, but most are still initial concepts. At the time of the test, the district plan and a spatial version of the library building had just been agreed on. The subjects could thus not use the tests as arguments in the political process. The final design was not decided upon yet at the time of the test, so only the volumetric dimensions including storey partition of the new library building are therefore included in the representations. Campus neighbours/employees and expert evaluators are invited to evaluate the three visualisation views (Figure 10.3 and Figure 10.4). Since this study focuses on visual issues, no interaction is possible except for navigation, and no attributes or informing text are accessible. A final software for full application would involve some textual information and in a complex future system it would also involve way finding, querying and attribute attachment. The subjects were initially informed about the limited possibilities in the test case and of the possibilities a full application could involve.

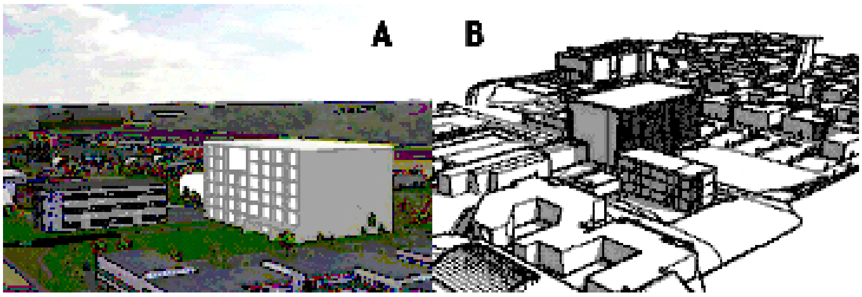


Figure 10.3: The new library building is the large centrally located building in both screen dumps: a) photorealistic WV in VR4Max, and b) simple black-and-white MV in SketchUp.

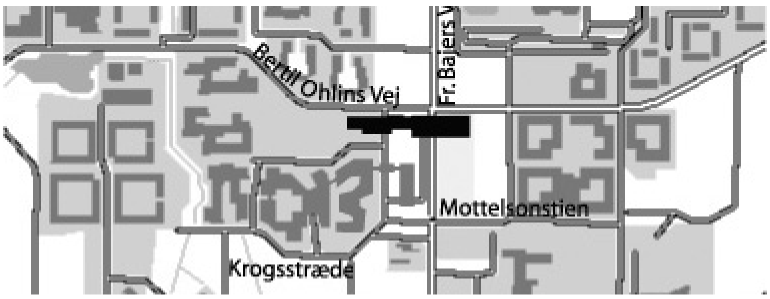


Figure 10.4: The new library building (black area) is placed centrally in the eastern campus area. This paper map constitutes PV in the test case.

The district plans were presented to the subjects in the following types of monitors:

1. PC monitor, 21”

2. Stereo PC monitor, 21”
3. Panorama

The campus area of Aalborg University has been generated in a highly detailed TIN surface representation in 3D Studio Max. The two 3D views were created from this basis, while one view is a paper copy of a digital map (see Figure 10.4). First 3D view was imported for a photorealistic WV presentation of high realism in VR4Max Navigator Pro (Figure 10.3a). The model was then imported to SketchUp and presented in a simple black-and-white realtime model that constitutes the MV (Figure 10.3b).

Focus group

Public presentation of district plans mainly aims at citizens that are directly influenced by the forthcoming changes. That is either people working or living in the area. Wishing to inform locals about the localplans using realtime 3D models, for instance through the internet, requires some computer skills, some hardware capabilities and eventually access to the internet. The focus group is therefore local citizens or employees in the area, having internet access, hardware and some comupter skills. According to Danmarks Statistik, about half of all ages from teenagers to 60 years have internet access from home or from work, and an even larger group have access through other sources than their home or their jobs, for instance at the library. This large group seems to be rather equal, though falls slightly with age (Table 10.1). Comparing access to education, it is clear that students, highly educated and salaried staff have higher access to the internet at home or at work, though they generally all have some kind of possibilities of accessing the internet in some way (Table 10.2).

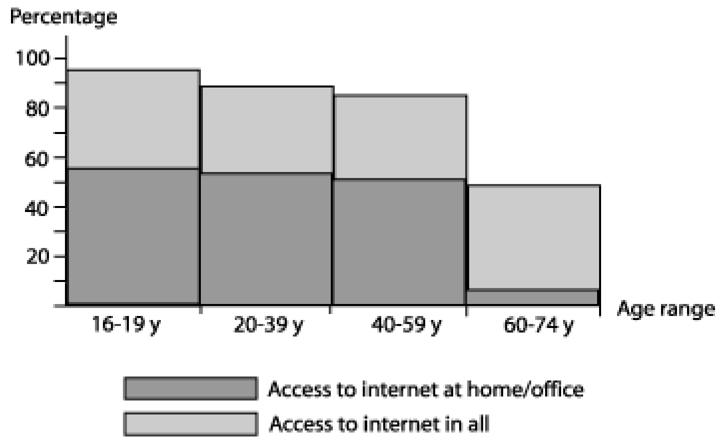


Table 10.1: Percentage of the Danish population having access to internet. Data is sorted by accessibility, type and age: from last quater of 2003. Source: Danmarks Statistik.

Table 10.2

Table 10.2: Percentage of the Danish population having access to internet. Data is sorted by education: from last quater of 2003. Source: Danmarks Statistik.

Since the local population is close to a campus area it is expected that both the focus group and the subjects have a higher education than the mean population of Denmark (Table 10.3).

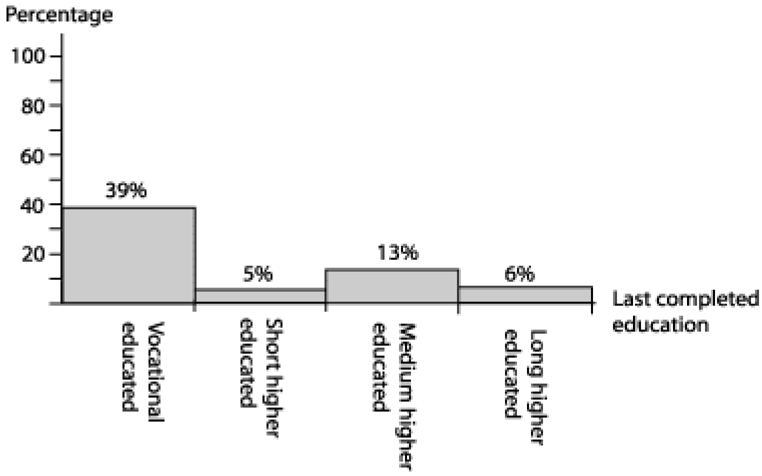


Table 10.3: The highest accomplished education, denoted in percentage of the Danish population. Calculated on the basis of the whole workforce, aged 15-69. Source: Danmarks Statistik.

Subjects

All the subjects participating in the test either work in the area or live in the neighbourhood (or both). Eight out of ten are very familiar with the area and only two do not know the area well since they have only worked there for a short time. They are aged between 31 to 49, and rather well-educated in general – all mean to long educations, educations which are over-represented according to Table 10.3, as expected. They all have access to the internet at home or at their jobs, which is an over representation compared to Table 10.2, but it makes sense due to their high education that also increases their internet access. 50% of the subjects feel they have a good level of understanding of district plans in general, and 60%-70% have looked into some at an earlier occasion, while another 50% find their knowledge not satisfactory, but on the other hand not completely lacking. 30% have never looked into district plans before. 50% claim to have spent time at an earlier stage searching for district plans on the internet; one has regularly been searching for this issue.Their experience with maps seems to be at a high level. Only one, 10%, claims to have only little experience looking at maps. Finally only 10-20% have some deeper understanding or experience with the 3D media, while the rest has none. Their not very experienced relationship to 3D media, and their rather high interest in district plans was expected due to the much discussed changes in the area, but could not be confirmed through statistics. In general, the group of subjects matches the focus group rather well, taking into account that the area is a campus and that the people associated with the area are higher educated that the population in general. The background questionnaire including results can be found in appendix A2.

Expert evaluators

An architect and an urban planner were invited as expert evaluators. The architect works at the university having years of experience as an architect working in private companies. The urban planner works at the municipality and is responsible for the district plan of the campus. The three views of the new library building and the campus surroundings are presented to them and an expert evaluation focusing on the relevance of the three views in their work is performed.

Test procedure

Ten test persons from the local area participated in individual sessions consisting of an interview and a questionnaire. The interviews of around ½-1 hour duration were supplemented with a questionnaire of 32 questions to elaborate and raise the certainty of the results. Finally, interviews with two expert evaluators, an architect and an urban planner, were performed. The test partly took place in the usability laboratory, partly in the panorama situated in the same building, below the lab. On arrival the subjects fill in a questionnaire about themselves and their knowledge of computers and of district plans (Appendix A1). Afterwards they were presented to the district plan, the new library and to the three views in the pc-monitor of the usability lab. A volume, view and shadow analysis (only in MV) are then performed. The view analysis included visiting virtual windows either at their office or at their home to see the landscape changes caused by the forthcoming building (Figure 10.5a). Also the view from the top floor was visited (Figure 10.5b). At the end of the session they were asked to fill in another questionnaire while they are allowed to change between the three views as they wish. A small interview was then performed addressing predefined questions that support the questionnaire. This procedure was repeated using the stereo monitor and the panorama, finalized with a small interview addressing the monitors.

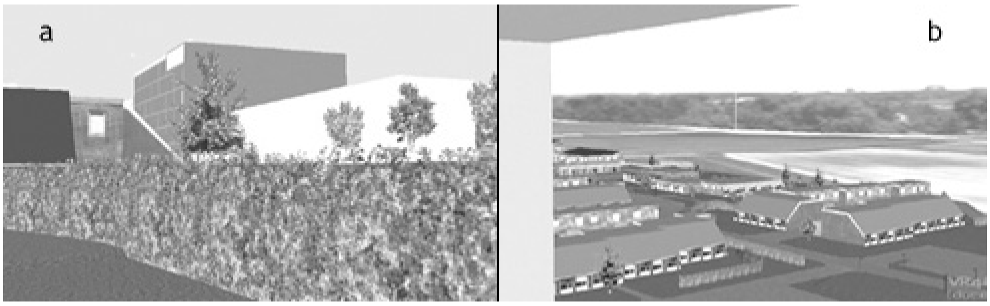


Figure 10.5: A) Example of a view from one of the subject's private garden. The centrally placed white and grey buildings replace the existing lawn and constitute the volumetric dimensions of the new library building. B) View from the top floor window of the new library building looking down at the neighbouring private properties.

Data management

Results from questionnaires and interviews are presented in chapter 14 and 16, starting with the subjects and finalizing with the expert evaluators. All interviews are videofilmed. The interview results are compared and grouped according to the addressed questions. The group of ten subjects is just enough for the results of the questionnaire, being the qualitative method used, to be statistically sound. However the fact that not all subjects answered all questions lowers the amount of data to below the limit of reasonable use of statistics. Hence, the results of the questionnaire are only used to calculate mean value to indicate a trend and not for further statistical analysis. The interview results, being qualitative metods, are on the contrary not sensitive to the low numbers of participants, allowing statements to possess equal value. The interview results do therefore not suffer from the low number of participants. Interview statements are selected for reproduction in the results-chapter (chapter 15 and 16) here, due to either a notable singular statement or to exemplify through on-going statements made by subjects and experts.

11. Test 2

Questions to address

Narration or cognitive manipulation of elements can be used as a means of visual communication through the technological possibilities that 3D Geovisualisation offers. These means are commonly used in commercial media, architecture, gaming and film industry, fields where 3D Geovisualisation play or have the potential to play a role in the future. In architecture narration and aesthetics have traditionally been a large part of the field, also after the introduction of new digital media. In test 2 of this thesis, interest is focused on how aesthetics work in 3D

Geovisualisation, also in relation to the interface, and these questions are sought to be answered;

Rendering: Does aesthetics work in 3D Geovisualisation?

Interface: What difference do monitors make?

As it is suggested in Chapter 4, users of 3D Geovisualisation are in focus and the questions are therefore sought to be answered through usability tests. A test case of commercial interest is build. It consists of a smaller part of a visualisation of a tourism portal in the city of Aalborg. The issue is investigated by the use of interviews and questionnaires for subjects, and by the use of expert evaluations. The methods are designed to cover four aspects in relation to the above questions:

1. Appreciation. Issuing appreciation is a direct way to address user preferences and an important element in commercialism in general.
2. Realism. The level of realism ranges from verisimilar to abstract and can be used as a communication means. High realism, such as photorealism, is desired by many providers, but is often performance demanding to attain and maintain.
3. Depth cognition is a large part of creating a virtual realism. It is therefore a major 3D issue and also differentiates it from other media like 2D maps and web maps.
4. Exploration. Exploration has been proposed to be one of the major advantages of complex systems, allowing for data and information exploration mainly for professional purposes. Here focus is on the user's visual exploration of the virtual world.

As in test 1, a monitor study is included in test 2 to see whether monitor type has an influence on interpretation. The three types of monitors used in the tests are:

- PC monitor, 21"
- Stereo PC monitor, 21"
- Panorama

Preparations for test case 2

Rendering weather effects are commonly used, especially in models of high realism. In test 2 a tourism theme is used and four different light and weather conditions are visualized, as shown in Figure 11.1.

Figure 11.1: The same realtime 3D scene visualised with a) sunshine, blue sky and shadows, b) neutral, c) dark, rainy weather and d) fog.

A visualisation of an area in central Aalborg was made in 3D Studio Max and viewed in VR4Max Navigator Pro (Figure 11.2A) and used for a usability study. Subjects and expert evaluators were then invited to test the model covering an area around the Casino in Aalborg, Denmark. An additional overview model makes it possible to zoom out and see the town from above (Figure 11.2B). The model is created in four different photorealistic versions: a sunny, a neutral, a rainy and a foggy version (Figure 11.2). Users can virtually walk up and down the road restricted to a length of approximately 100 m in the real world to each side of Aalborg Casino but are able to see the 3D model continuing further down the road.

Figure 11.2: A) The Casino and a view down the road. B) The overview model.

Focus group

The focus group is made up of people using digital media and internet technology searching for tourist information. In Denmark, large parts of the population have access to internet technologies and about half of the population has access from home or from their job. This is especially applicable amongst the highest educated and the younger half of the population (Table 10.1 and 10.2). Though they have good internet skills and experience, they are not expected to be experienced users at a high technological level, not experienced in 3D/stereo applications. Tourists mainly visit sites by car, and as families with children. The parents (aged 30-50 years) decide the destination and plan the trip. In Aalborg, tourists are mainly from the local county, secondarily from the rest of Denmark (source: personal information from Dafolo and Aalborg Tourist Bureau).

Subjects

Through the local tourist office in Aalborg four subjects were initially retrieved. To reach the number of subjects as anticipated, the additional 6 subjects were found amongst academic university personnel (2), administrative university personnel (2) and personal contacts (2), selected to match the focus group as well as possible. The subjects are mainly aged 30-40, one is aged 40-50 and one is aged 50-60. The subjects are diligent tourists both nationally and internationally during weekends and holidays, and they use the sightseeing facilities that are accessible at the destination. They mainly travel by car together with the rest of their family. During the planning stage, travel guides, maps and pamphlets are used and 60% mention the internet as an additional source. Of these 60%, they almost all claim to use the internet to search for tourist attractions frequently. 60% of the subjects know the city “well” or “very well”, while only 40% know the area around the casino, being the area in focus, “well” or “very well”. The subjects do not have much experience with stereo, VR or other 3D systems. 40% of the subjects possess a long or medium long education, which is by far, more than the average population (table 10.3). Combining this with expectations regarding the focus group being internet users, this might raise the precentage, but there are no general statistics available on this. The high percentage of subjects possessing a long or medium long education is partly due to the fact that subjects had to be found through the university. All in all, the subjects match the focus group rather well concerning age, internet use, habits of tourism and experience in 3D. The matching was less successful concerning educational background, which could give rise to uncertainties.

Expert evaluators

Beside the 10 subjects, two expert evaluators were invited. The development coordinator at Aalborg Tourist Bureau was invited as one, and the other being a graphic designer, having many years of experience from different visual media including VR.

Test procedure

The user study was performed using interviews and questionnaires of 95 questions in total, with ten subjects. Finally, interviews with two expert evaluators were performed. The subjects were invited to the 1½ hour test at Aalborg University, partly taking place in the usability laboratory and partly in the panorama. On arrival the subjects filled in a questionnaire about themselves and their vacation and recreational habits including their knowledge of computers (Appendix B1). Afterwards they were presented to the projects and the four versions in the pc monitor in the usability lab. A questionnaire was filled in; while they were allowed to switch between the four versions themselves. The test instructor was available to help as needed, and the questionnaires were followed by an interview. The procedure was repeated in all monitor environments. Since this study focuses on visual issues, no interaction is possible except for navigation, and no attributes or informing text are accessible. A final software for full application would involve textual information, and in a complex future system it would also involve wayfinding, quering, attribute attachment and a larger geographic coverage. The subjects were initially informed about the limited possibilities in the test case and of the possibilities a full application could involve.

Data management

Results from questionnaires and interviews are presented in chapter 15 and 16, starting with the subjects and finalizing with the expert evaluators. The interview results are compared and grouped according to the addressed questions. As discussed in chapter 11, the group of ten subjects is just enough for the results of the questionnaire, being the qualitative method used, to be statistically sound. However, the fact that not all subjects answered all questions lowers the amount of data to below the limit of reasonable use of statistics. Hence, the results of the questionnaire are only used to calculate mean values to indicate a trend and not for further statistical analysis. The interview results are on the contrary not sensitive to the low numbers of participants, allowing statements to possess equal value. Interview statements are selected for reproduction in the results chapter (chapter 15 and 16) here, due to either a notable singular statement or to exemplify ongoing statements made by subjects and experts.

12. Test 3

Questions to address

Many situations profit from the six degrees of freedom, and looking at different ways of serving these 6 degrees sometimes seems to serve them more successfully than others. Though user's navigation in 3D worlds probably has been the most investigated HCI issue in 3D, mainly in terms of space cognition (Ruddle and Jones 2001; Li 2005) it is still the issue that gives the most users problems in achieving information and feeling at ease with 3D systems. In the last test, test 3, focus is on the following question;

How can navigation in 6 degrees of freedom be supported optimally?

Test 3 is made with the purpose of comparing three different regimes, to be able to identify advantages and disadvantages of each. Quantitative methods involving time measurements and questionnaires are used (see appendix A5 and D2). Time measurements are expected to reveal how efficient the various regimes of navigation are, while questionnaires allow other qualities than efficiency to be revealed. The test does not reflect how fast the subjects adapt to each regime, since a non-recorded initial period of trial is included. In the trial period, the subjects are offered both aural and visual introductions to the regime.

Preparations for Test case 3

To investigate how end users can increase their success in accessing 3D information, a comparison of three different kinds of navigational regimes in existing 3D software was chosen. The chosen software are the commercial products ArcScene and VR4Max Navigator Pro, along with the research product Grifinor developed at the Center for 3D Geovisualisation at Aalborg University. VR4Max represents a navigational regime based upon direct response on mouse action (one mouse click results in one movement), while ArcScene represents a classic flight simulation regime (movements are initialised). Grifinor is a mix of those two, creating a complex, sophisticated navigational regime. Most commercial software contains several navigation modes, usually fly, walk and object mode is available. For comparability, 2D sidemaps are not used. Likewise only the fly mode is used here, since Grifinor only contain this.

A 3D city model made at Aalborg University is build in 3DStudio Max and covers all of Aalborg City including suburbs. Buildings in the same area are furthermore automatically generated and visualized in Grifinor, resulting in a less detailed model than the 3DStudioMax version, at least concerning roof details. Facade photos are not used in any of the versions, and orthophotos cover the terrain of version A and C. Figure 12.1 shows a screen dump from the 3 visualisations.

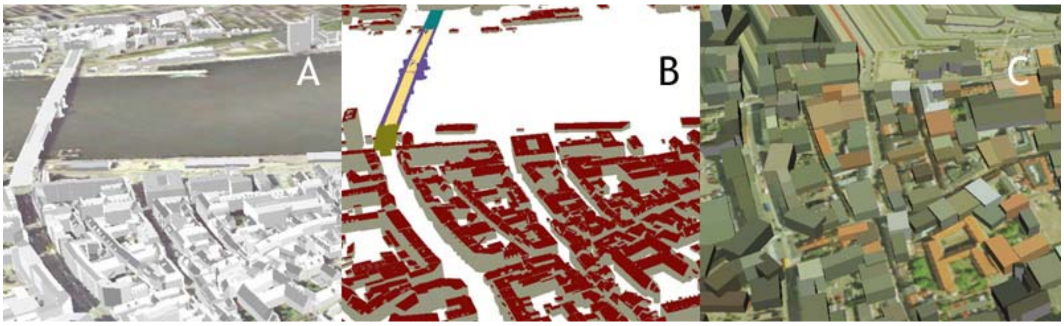


Figure 12.1: Screen dumps from A. VR4Max, B. ArcScene and C. Grifinor. The bridge going north-south is visible in A and B but not in C, since it was the northern border of the automatically generated model at the time of the test preparations.

The comparison method consists of measuring the time spent by subjects navigating a given distance. The distance is at first traveled by walking the surface, then flying, and finally repeated for each piece of software. Both tests (walking and flying) require here the control of 6 directions; up-down, forwards-backwards and right-left. Before measuring, the subjects were introduced to each navigational regime and given a short try-out period. The time measurement is expected to reflect a measurement on users' satisfaction, so that the faster the task is solved, the more satisfied the user is. This assumption is inspired by basic internet principles (Nielsen 1993). The subjects are afterwards asked to write down advantages and disadvantages of the navigational regimes of each piece of software.

Focus group and subjects

Geographical 3D models are often available on the internet, so the focus group was initially users having a minimum of experience with computers, software and internet use, in order to be capable of finding and installing the systems themselves. Apart from this, users of 3D Geovisualisation range from professional planners in public positions to private users searching the internet for information, and all of them are expected to benefit from six degrees of freedom. The result is a rather varied focus group, but it is outside the scope of this simple test to distinguish between these groups, though it might be relevant for the full understanding of the issue. The methodology relies on qualitative methods, dependent on a sufficient number of subjects (an absolute minimum of 10 but the more the better). It was therefore of high priority to engage as many subjects as possible. Taught by the previous tests 1 and 2 it is a labour-intensive job to find suitable subjects and because of the methodology and the wide focus group a compromise was decided at an early stage. Hence, 24 subjects were found between students and employees at Aalborg University. The main part of the subjects were experienced users of 3D systems (mainly through gaming), but none knew the three pieces of software beforehand. Only two have no experience with 3D at all, so results are expected to be representative for experienced users.

The subjects can be described from the following characteristica (appendix A5-A7): male students below 30 years of age, highly educated or about to complete a high education. They are very experienced users of IT and internet, many having experience as developers and in computer graphics. Their gaming habits differ; 12 subjects play games ”often” to ”regularly”while 12 play ”seldomly” to “never”. 15 of the subjects are used to using maps (often to frequently) and the majority of them regard themselves as having a sense of locality. There are three subjects that deviate from the general trends described above. Two of these are technical personnel at the university and belong to the age range of 40 to 60 (X9 and X12 in appendix A7). They are experienced IT and internet users, but have no game or 3D experience. One of them indicates, as the only one, to have no sense of locality. The last subject that deviates is X6 in appendix A7, who is younger than the average and is not a student. This last subject does however not deviate in any other way in the questionnaire. None of the subjects had any previous experience with the three items of software in question, except subject X11 who had tried VR4Max once before, but some time ago.

Test procedure

The subjects were invited for an individual test session at the usability lab in Aalborg University. A standart 21” pc monitor including standard mouse and keyboard were used. On arrival the subjects were introduced to VR4Max aurally and visually and were allowed to spend a few minutes to try it out. The visual guidance is enclosed (Appendix D1) so the subjects could confer to it during the try-out and the test. After a few minutes when the subject seems to have gained some control, time measurements of movements of a given distance are carried out. The given distance goes from Vesterbro at Urbansgade to the harbour, where a turn to the right leads to the courtyard at the Castle of Aalborghus. During the test this distance is travelled twice; first in flying mode as the crow flies, then, still in fly mode, along the road. The same procedure is repeated for each of the remaining softwares.

Data Management

A mean and a standard deviation based on 24 measurements of time, which is regarded as enough to constitute reliable results. Concerning the questionnaires, answers are given qualitatively.

Section 4: Evaluating the Usability Tests

13. Representation

Summary of test 1

Visual representations in 3D Geovisualisation have been the issue of (Verbree et al. 1999). The author group has developed a system, which supports planning processes by suggesting three types of representations: the Plan View, the Model View and the World View. The Plan View (PV) is an ordinary 2D colour map for initial orientation; the Model View (MV) is a simple 3D map for professional volume analysis and the World View (WM), a verisimilar photorealistic map in 3D for public presentations. The group of authers suggests using the WV for public presentations of a planning project. Using high representation for presentations does however involve some problems. Partly because high representations are costly both in manhours and in computation power, so if abstractions work as well for presentations, technological efforts could be reduced. Furthermore, over-interpretation might be more likely in high representations possibly leading to political conflicts in public planning. Following the main idea of bridging the technological aspects and the users as described in Chapter 9, these questions are sought to be answered through usability tests. The usability test performed includes interview and questionnaire with 10 subjects participating. Furthermore an expert evaluation with 2 experts participating is performed as described in Chapter 10.

Questionnaire

The questionnaire for the subjects regarding the representational views of the district plan consists of 14 questions. Only parts of the results are presented in the text, the whole questionnaire including answers can be found in Appendices B1, B2 and B3. In the appendix the personal pattern of answers of each subject can be studied (Appendix B3). Subjects are kept anonymous, but are coded X1 to X10, and the codings can be directly coordinated with the pattern of answers issuing the background of the subjects in Appendix A2. Evaluation of results is grouped into four issues; expectations, presentation and appreciation, the combination of views and task performance.

Expectations: The three first questions address expectations of the three views (Table 13.1). When using photorealism expectations concentrate on “2: buildings and surroundings will look fairly like the model”. Only two choose answer nr. three while working with the WV: ”3: Only the volume of the building becomes reality”. Those two are subjects X4 and X7 who do not separate much in other ways. In MV, only one subject chose 2. A shift towards less matching co-ordination between model and reality is shown; since most subjects choose answer 3 or 4. In PV again shows a shift towards less matching, since answer nr. 4 is the most common, though a tendency to move back towards “2: buildings and surroundings will look fairly like the model” also exists.

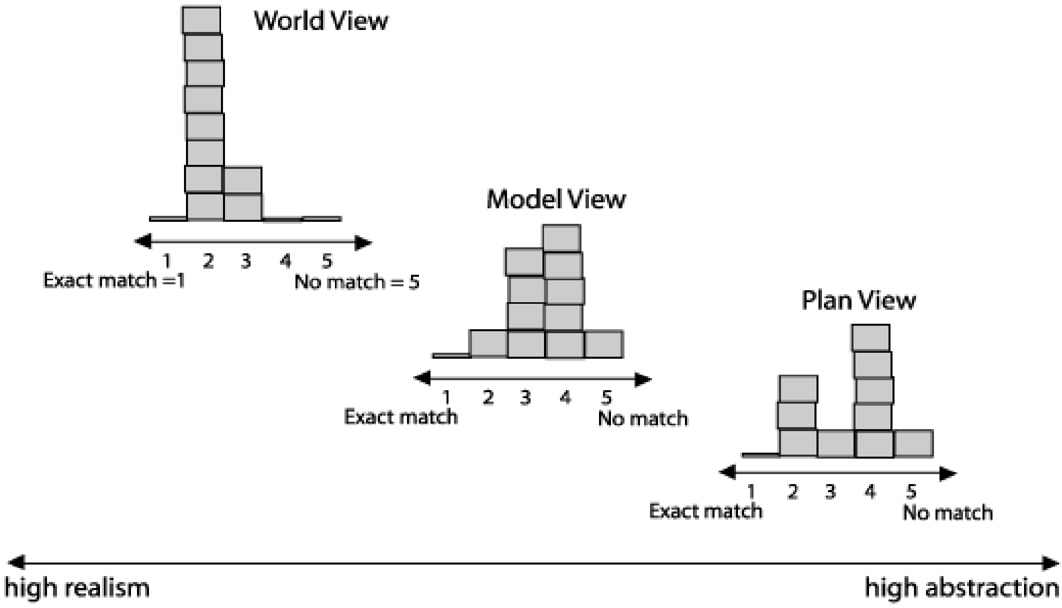


Table 13.1: Expectations. One box represents answer from one subject. The higher realism the higher expectations rise towards the matching reality.

Presentation and Appreciation: Generally, WV is regarded as the most preferred district plan visualisation (Table 13.2). Only one chose PV as the most preferable visualisation – it was subject X10 who is not familiar with the area and found it hard to orientate during the test session. Subject X2 was the only one to choose MV as the most preferable. He lives in the area, but separated from the others by having large experience regarding computer games and background knowledge, though he has no academic education.

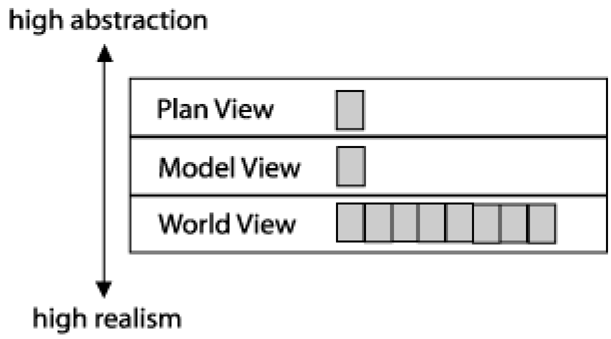


Table 13.2: Presentation and appreciation.Preferred district plan presentation. One box represents answer from one subject.

Appreciation is percieved as an important factor for a small majority (Table 13.3), and still rather important for a minority. Appreciation is generally related to WV, though it is not the case for subjects X2 and X10, who are the same two subjects that found PV and MV respectively most preferable. The most attractive presentation coincides with the preferred presentation view in Table 13.2.

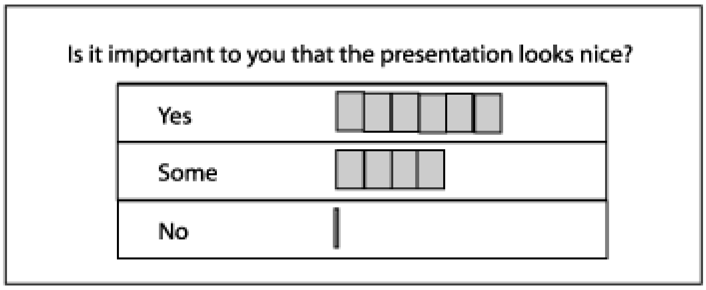


Table 13.3: Presentation and appreciation. A majority finds it important to rather important that the presentation looks nice. One box represents answers from one subject.

Generally, the subjects are not in doubt which building is in question, just by watching the three visualisations (Table 13.4). Only one subject X10 expresses some doubt, the subject that also had orientation problems. Question “M: Can you separate between suggested changes and approved changes?” cause more doubt where subjects X2 and X3 did not obtain an overview of approved and proposed parts of the district plan. Four subjects are rather satisfied and four are satisfied with the overview of the project they achieved.

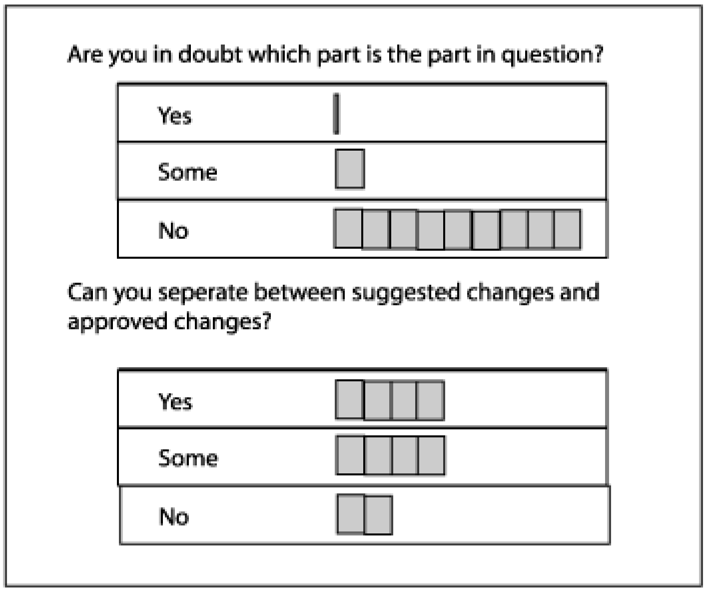


Table 13.4: Presentation and appreciation.

In question “N: Which of the views made it easiest for you to distinguish between reality and forthcoming changes? (Table 13.5), WV generally serves the largest overview of changes caused by the district plan. Those subjects who separate from this point of view is X8 who prefers MV instead and subject X2 who do not find any of them useful. X8 explains his opinion in the interview part below.

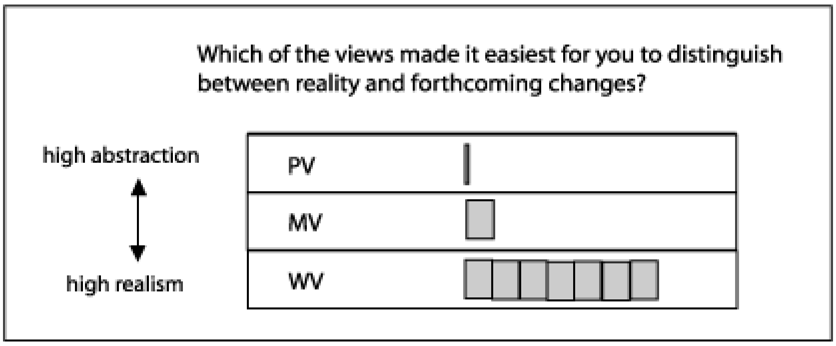


Table 13.5: Presentation and appreciation.

Combining views: The majority (6) of the subjects are not interested in using more than one representational view (question E) (Table 13.6). Question F requires comparison with the pattern of answers given in question E. Subjects X2 and X3 wish to work with both MV and WV, Subject X9 wishes to work with WV and PV – X9 indicated some problems of orientation due to being unfamiliar with the area as well, though not lost as subject X10. In all cases WV is one of the preferred options. Subject X8 answers WV twice, probably just to make sure that his preferences is communicated.

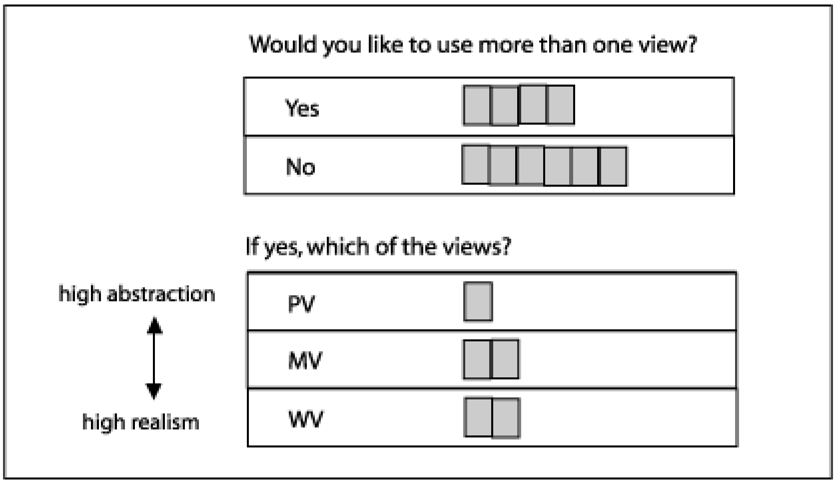


Table 13.6: Combining views.A majority is not interested in working with more than one view, and of those who are, all choose WV as one of the options (question E and F).

Task performance: Questions H and I go into the use of simplifications in the district plan and gives issue to how the subjects relate to the fact that only a little information is available (Table 13.7). A small majority of the subjects regard it as difficult to evaluate the plan when so few details concerning materials and textual information are available. A small minority are however not bothered by the amount of available information, and regard the evaluation conditions as ”rather easy”.

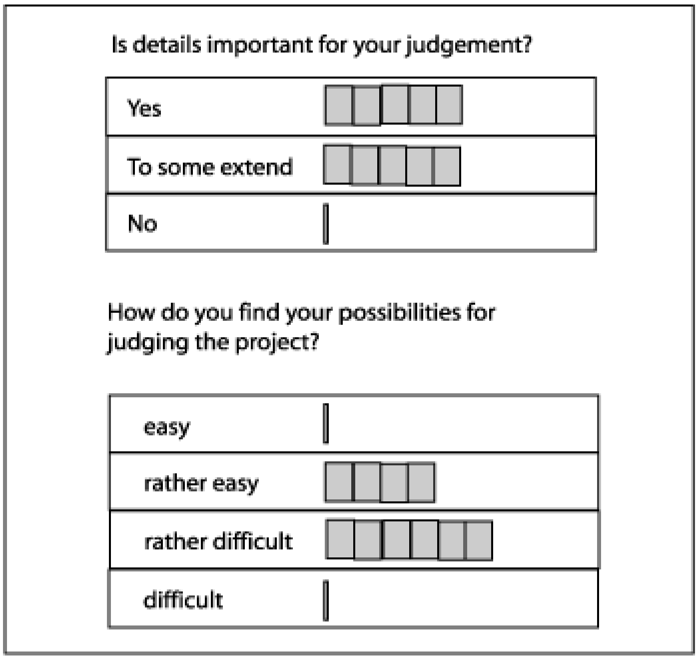


Table 13.7: Task performance.

Interviews

Interviews are done involving the same group of subjects as the questionnaires. During the test session, interviews were video recorded and a transcript of the interviews can be found in Appendix B4. Unfortunately the interview recording of subject X2 failed, so a transcript does not exist. This is expecially annoying since X2 is often separate from the others and hence the questionnaire of X2 is especially interesting to elaborate in the interview. In the following, notable statements are reproduced and for simplicity some are left out. This is not to be interpreted as them disagreeing. They have either avoided commenting on the question or that they were not asked.

Expectations: The subjects claim to be aware that all three views are an abstraction: “I understand that it is just a volumetric problem. It is actually the same as the 2D paper where it is just the area that is the issue (X6).”

Presentation and appreciation: Throughout the interviews many of the subjects generally prefer the WV (X1, X3, X5, X6, X7, X9) as it is being emphasized as being more recognizable and more imaginable. Most subjects however found the MV applicable and causes no problems of interpretation (X3, X4, X6, X8), though not optimally. Two subjects especially highlight MV for its simplicity, X2 (who’s interview got lost – this is referred from notes taken after the interview) and X8. X8 goes: “If it is only the building then it does not make a difference whether it is WV or MV. Because you do not find more details about the building itself, and the rest you know already. WV is fun to see, but it does not provide you with more information". Subject X8 separates from the other subjects since he is highly educated and works at the university as a senior lecturer. He is not really representative of the average citizen, though he falls into the focus group of citizens affected by exactly this district plan on a daily basis. Generally, interpretation difficulties are not an issue. Subject X4 says:"And it is clear what building is in question. When you have identified it, you can abstract from it and start focussing on the volume". Only X1 mentioned that she had initially been uncertain what the changes actually were, but quickly made up her mind and therefore showed no uncertainties in the questionnaire.

Combining views: During the interviews, only subject X9 and X10 found PV usable, both explaining this by better orientation support. Subject X10 prefers only PV, while X9 appreciates PV but prefers WV: "For the shadow analysis, the simplicity of MV is perfect. But to get an idea of the size I find the WV is nice to have". Generally the interest in working with more views is not pronounced, only subjects X9 and X10 who already regard PV positively, react positively on the idea of incorporating a 2D map into the 3D scene.

Task performance: The two 3D views are considered to be much more interesting than PV because you can compare a building with the neighbouring buildings. X3 claims: "Actually I use paper maps a lot, but still it is difficult to imagine how high seven floors are compared to the surrounding buildings using only 2D maps". Another subject (X1) still found assessment of size difficult in 3D: "What is missing in the model is people. To see how much space they take up. I can see the trees and the lamp-posts but they could be many metres high. I can also see the bus stop, but some human beings would help me to assess proportions better". X6 finds that visualizing the volume of the building is more or less the same in MV and WV but the WV is better for comparison with the existing buildings to perform size-assessment.

Most of the subjects do not claim to need orientation support. Several of them do, however, after some time regard the value of being able to rise a bit above the buildings: "I see that it is useful to see things a bit from above" and subject X10: "The best overview is a bit from above. I think that that was why I liked the 2D map, because then you have the overview before you start using the 3D presentation". Subject X9, who is not particularly familiar with the area (though not lost) suggests that an indication of position, for instance in a 2D map in the 3D scene might help: "A red dot could indicate your position – I think that would be really good.But if you are familiar with the area I do not believe that it would be important". Subject X4 finds that photorealism works as recognizable landmarks: "I prefer WV, because the landmarks help you to determine where you are. It is more difficult in MV".

Other comments: Being neighbours, most of the subjects received 2D paper information a few months before the test. This information was sent from the municipality as a part of the public hearings connected with the district plan. Several subjects, among them X3, referred to this information: "It is interesting to see in 3D, it gives a different impression than the paper information that was sent to me by the municipality". Subject X9 mentioned that the lack of a larger housing estate in the visualisation to the south and to the north changes the general impression of the area. Finally, many subjects note the unilateral focus on visual representations and mention that in a realistic case attributes and interaction will improve communication: "I think that the most important is that you know how to fly through the model. Zoom in and so on. And then you should know that it is not exactly going to be like this, regarding for instance colours". One of the subjects mentioned that the traffical situation in the area suffers from high density and high speed, and that this should be an important issue in a real cases.

Expert evaluations

Architect: The architect expert uses verisimilar and photorealistic WV visualisations, and sees no problems in including vegetation since it should not constitute misunderstandings since the target group knows the trees already from the real world. He would visualize the new library building with a more clear distinction to the surroundings by using transparency or dotted edges, for instance. There is actually a case where politicians misunderstood a visualisation due to colour codes, at the most central square in Copenhagen, and the case developed into a scandal. Finally, also the architect note the unilateral focus on visual representations and mention that in a realistic case attributes and interaction will improve communication. Finally, there should of course be information attached also to make the implications of the project clear.

Urban Planner: The urban planner prefers to use simple views like MV instead of WM for public presentations in order to avoid exaggerated expectations. Whether simplifications should be used (something like MV) is a matter of performing analytical tasks and documenting them afterwards, but also not to get too close to a solution that might not be the final solution. "As an official we have to take care how close to reality we can be. We are not selling a product, we need to be neutral. " For the urban planner, this consideration overrules other advantages such as orientation, size assessment, imagination and appreciation. But "it is different from landscape to landscape. In a city centre the facades are usually preserved and then it is easier to use WV than in new urban areas where changes often occur". Vegetation softens the implications and should also be avoided in order to create a "worst case" scenario intentionally – so a "worst case scenario" is the one that is considered and decided upon, because worst case might last 5-10 years before plants have grown sufficiently to soften the landscape. Contracting a visualisation "... is just a question of stating what we can use for the district plan. But you have to be acute and aware of what is delivered to you from the architects" - not only in terms of expectations but also technically. Errors occur in terrain and object data and can result in misinterpretation of the original vision.

Discussion

Expectations: From the questionnaire it seems that the utility of WV generally create higher expectations regarding the reliability of the visualisation. This means that users tend to expect that the visualisation is more true to how things will turn out to be in the real world. Answer nr. 3 ”Only the volume of the building will become reality” is expected to be the most neutral and realistic answer, and it is this answer that most subjects choose when working with MV compared to WV. This could indicate that exaggerated expectations more likely occur in WV. Results from the interview contradict this. Here expectations do not trouble subjects much – they seem to be confident with their own understanding of the relation between model and reality. Furthermore it does not occur to the subjects that they, in the questionnaire, have varying expectations dependent on the level of realism. Combining the results from the questionnaire and the interviews seems to underline the difficulties of communication, since subjects seem to rely on the credibility of their own interpretations, while they at the same time actually do expect a higher relation between model and reality the higher the level of realism is. The statements coming from the urban planner can hence only be supported here.

Presentation and appreciation: Discussing the two 3D views, MV and WV, subjects and architect expert generally prefer the WV. In contrast, the urban planner who is responsible for the communication process during a public presentation of a district plan is sceptical due to a risk of exaggerated expectations and misunderstandings, a risk that can be confirmed by this study as well. Adding interaction and attributes in a real case constitutes a large part of imagination and appreciation as well as they would lower the risk of misunderstandings of the implications of the project. MV is however not directly rejected by the subjects during the interview, most of the subjects like MV though they prefer WV. MV could be improved by adding a colour code and a legend, probably for the benefit of recognition and orientation.

Verbree et al, do not present their theory followed up by practical tests or cases, but (Cartwright et al. 2005) has constructed a test case comparable to this test. Two groups of subjects are invited to determine the level of representation adequate for an urban model. One group (five subjects) is citizens and the other group is professional planners (10 subjects). They are all asked to evaluate a shopping street in Melbourne, Australia:

1. Level 1 was a simple visualisation of the part of the main road in the study area - Sydney Road. This was a 3D world that only contained transparent shells of the buildings in the study area. This was considered to be a basic level of information for community discussion of urban developments in the area. This level can be compared to MV in this thesis.
2. Level 2 had roads added and the surrounding buildings were colour-coded to indicate the current building use. A sky dome was added, which provided the means for the model to appear to continue above the buildings, whereas the level 1 model only provided a flat dark blue backdrop.
3. Level 3 had all of the buildings in full detail. Road detail remained as it appeared in level 2.

4. Level 4 had signage, suspended beneath verandas, above verandas and as sandwich boards on the street included. Road detail was enhanced with different textures on footpaths. Street furniture was also included, as well as seats, bicycle stands, rubbish bins, parking signs, etc. Light poles and overhead tram power cables were also added. This level can be compared to WV in this thesis.
5. Level 5 had cars, trams and people populating the main road - Sydney Road. This model was further enhanced with synthetic shadows.

Subjects from both groups prefer levels 3 to 5. This suits the results of this thesis well, since both professionals and citizens choose photorealism, though smaller details are regarded as unnecessary or even disturbing. The research team is surprised to find that professionals and non-specialists agree as they had expected that professionals would have preferred simplifications due to their training in volumetric problems. In the final conclusion Cartwright chose to continue his model development using level 2,5, being a colour coded simplification, where only landmarks contain photo realism. This is mainly done to ease time of production, but it is also based on interview statements by the professional group where simplifications are not rejected though not optimal, very much in line with the results in this thesis.

Many researchers advocate for simplifications and refer to cognitive theory and gestalt theory, saying that simplifications support easy perception and concentrate the message. Much traditional cartography is also based upon these assumptions. Some researchers claims that photorealism complicates the image as it is suggested by several 3D Geovisualisation projects (Rice 2003; Döllner and Buchholz 2005; Shneiderman 2002). To the contrary, perceptional theory does not explain why subjects prefer a rather high level of representation, closer to photorealism than to the abstraction of the MV used in this thesis, so explanations are therefore to be found elsewhere. Designers would argue that high realism draws attention through the establishment of emotional connection to a recognizable scene and hence causes preferences in this direction (Norman 2004). Basically the problem of visualisation of district plans is that it is not detailed information that is to be shown, but it is the framework of the project that is to be communicated. Frameworks are however not very attraction-getting, but when aestethics and images are added it is much easier to make citizens relate and make people proceed with their evaluation of the project, and in this way it is difficult to avoid discussing aestethics.

Studies of perception of landscape visualisations are a developed field within Landscape architecture. (Orland et al. 2001; Orland and Uusitalo 2001), (Orland et al. 2001; Orland 1994), (Orland 1992), (Danahy and Wright 1988; Danahy 2001),(Danahy 2001), (Perkins 1992) (Lentz 2004). The goal these authors have in common is to create a perfect image of the landscape as a product. They study the aesthetic and communicative aspects of images made on the basis of 3D models, and usually do not include practical implications or user studies. This study is, however, not meant to explore exactly how aesthetics are introduced in 3D Geovisualisation by developing optimal examples, but it is rather a study of the concept of quality in 3D Geovisualisation in a wider context. On that basis, landscape perception studies are not directly comparable with this thesis, though inspiratory.

Two forces or directions seem to dominate the discussion of representations in general. One direction leads towards automatic processes that have photorealism and high realism as the visual ideal. The other direction leads towards more experimental and abstract representations and styles. In this context it is not interesting to recommend one or the other, but is relevant to create awareness of the consequences of either direction. Choosing abstractions, emotionally based attraction and attention-getting qualities are lost, and in choosing high realism, the practical implications can be practically impossible. Simplifications then often overrule the labour-intensive and computational-intensive photorealism, which also can be necessary. But technological arguments should be separated from users' preferences, since this test shows that there are no reasons to use simplification for the user's sake.

Compromises between high realism and abstractions are often relevant. The use of landmarks is maybe the most popular; another more sophisticated is the use of styles. The strong attention-getting impact photorealism could be compensated for by using other attention-getting means, like interactive and communicative regimes, where for instance the use of avatars or mixed representations also can be useful to aid size and relation assessment. These methods are used in "The Electronic Neighbourhood" (Holmgren et al. 2004), in Copenhagen, Denmark (Figure 13.1). The virtual entrances and the interactive posts remind the user of his appearance in a virtual, abstract world.

Figure 13.1: Example of the interactive spaces, in the "The Electronic Neighbourhood". The houses act as entrances into different aspects of the project, and the central pole is a navigation pole from where the user can jump to other positions of interest.

In (Döllner and Buchholz 2005) a cartoon-style is suggested (Figure 13.2), consisting of sketchy and outlined drawings as a contrast to the photorealistic attempts:

"Non-photorealistic computer graphics denote the class of depictions that reflect true or imaginary scenes using stylistic elements such as shape, structure, colour, light, shading, and shadowing that are different from those elements found in photographic images or those elements underlying the human perception of visual reality. As (Durand 2002) points out, non-photorealistic computer graphics offer extensive control over expressivity, clarity, and aesthetic, thereby the resulting pictures can be more effective at conveying information, more expressively or more beautifully" (Döllner and Buchholz 2005).

An example of the use of styles is (Döllner and Walther 2003), who have developed a range of stylized edges (Figure 13.2b) and very simplified visualisations, but they have not so far been user tested in, for instance, urban planning cases or in commercial/entertainment cases.

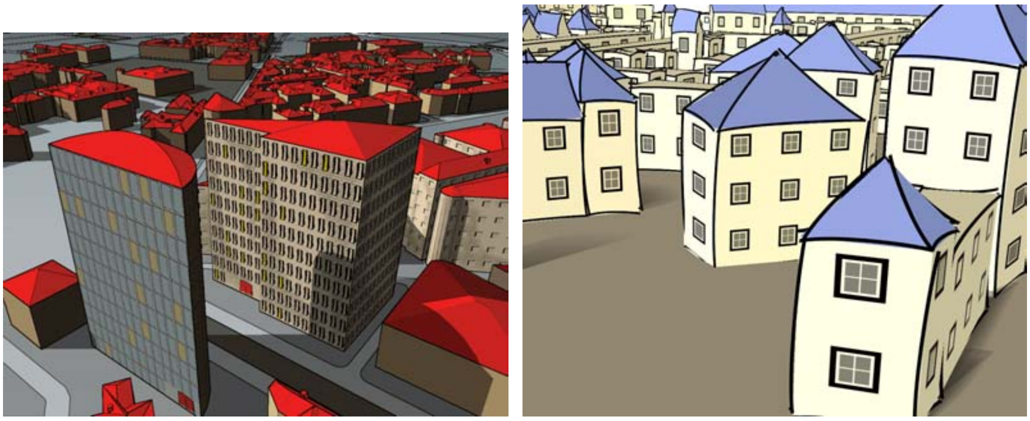


Figure 13.2a and 13.2b: Two examples of cartoon-style in object-oriented geovisualisation.

In the future, technological advantages of simplifications could possibly be combined with a detailed object oriented texture library that would be able to create an automatically generated and almost photorealistic representation in a multivariate system. This will probably make high realism much easier to create, but if recognizable scenes and atmosphere-creation is necessary, some manual work will probably still be necessary.

Combining views: The immediate reaction in the questionnaire addressing the questions on benefitting from more views was no. Several subjects changed their mind during the interview probably because the implication of the question is not visible for non-specialists having no experience with the media and its possibilities. For that reason the use of side maps has been studied by (Fuhrmann 2002), and orientation aid was found while combining the 3D scene with an additional 2D view.

Task analysis: WV is not only emphasized as the most attractive, but also the best visualisation to perform task analysis with, like orientation and communicating the important heights. The 2D maps are mainly used by the few subjects unfamiliar with the area. Some of the subjects who are more familiar with the area have second thoughts during the interview and mention that the 2D has been useful a few times when orientation was lost shortly. Especially test person X10 who started working at the university recently had problems in orientation. She preferred the 2D view and this is reflected in her other answers as well, hence 3D is not suitable for orientation tasks in the form as it is used in this case.

Using a transparent volume for volume assessment, or in other words weakly indicated volume, basic design principles suggest that the volume will not be percieved as dominant as a massive volume and hence it can be misleading if the visualisation is used for public presentations. If it is only used for analytical tasks it will probably be adequate. (Döllner and Buchholz 2005) suggest using inexact or different stilized edges on objects to indicate the condition of the buildings in the landscape (Figure 13.3). They furthermore stress that this is one of the disadvantages of high realism such as photorealism, that it does not offer such possibilities. An example of transparancy is used in a 3D visualisation project from Beirut (Horne 2004), but also shows the incorrectness in volume assessment that such a visualisation solution can cause (Figure 13.3).

Figure 13.3: Visualisation of Beirut. The housing stock of Beirut is under renewal. Transparent outlines indicate changes in the urban landscape.

Related cases: Cases where serious misunderstandings between architects, citizens and politicians exist in Denmark (Figure 13.4). It is therefore discussed whether standards for 3D visualisations should be imposed, but so far it has not been possible to find a solution flexible enough both to be efficient and useful in practice. It is then the responsibility of the politicians and the planners to ensure quality and reliability.

Figure 13.4: a) Realizations of visualisations that went wrong: The grey shopping centre in the far background, behind the central station in Aarhus, Denmark, was not supposed to be visible from this angle. B) The central bus terminal of Copenhagen, Denmark, appeared much less dominant in the visualisation than it turned out to be. 10 years after, passionate discussions still exist whether millions should be spent to rebuild it.

Methodology critizised: Chapter 11 concluded that the focus group and the group of subjects matched each other in a satisfactory way. There might still be an error in the process of signing up subjects. Those citizens and employers who signed up for this test might be especially interested in that particular district plan or planning processes in general, and is thus not representative for the focus group in general. No elderly or retired parts of the population signed up though they are still potential internet users and they live in the neighbourhood. Though such a source of error exists, the group of subjects represents different parts of the users of the area having different background and it is therefore considered as a satisfactory group.

The results of the questionnaires from tests 1 and 2 are only concluded upon 10 attempts. This is the lower limit of positivistic empirical quantitative methods and though usability tests often rely on few subjects as for instance the Cartwright case, which included about the same amount of subjects. The results gained from the qualitative and quantitative methods in this thesis do however not contradict in general and the quantitative tests seem therefore to be reliable. In criticising the interviews some of the issues discussed are of an abstract character (associations, appreciations for instance) and consistency in interviews turned weaker than expected since it became difficult to establish comparable discussions with all subjects. Some subjects are more interested in certain aspects than others, and some more talkative than others. The inclusion of expert evaluations has been efficient and useful.

Conclusions

Using high realism for presentations is suitable when size assessment, support for orientation (though extra support is needed for users unfamiliar with the area) and the creation of appreciation is important. Users clearly prefer high representations in any case, conflicting with the technological realm since it is practically problematic to support. When political / legal interests are in focus, high representations are however dangerous choices, due to the risk of over-visualisation and to exaggerate expectations of the final project.

Though radical methods for visualizing the building in question are not used, subjects did not have problems identifying it. Focusing on software for district plan visualisations, it does not seem to be important to offer various levels of abstractions and not necessarily a 2D sidemap as well, though users from outside the focus group might be seriously lost in a 3D visualisation. The period of test sessions lasted 14 days and required a period of 2 months preparation, which has been manageable and the method seems to have delivered results that has given answers to the research questions of the representation part and the methodology is therefore generally successful.

14. Rendering

Summary of rendering part of test 2

The technological possibilities of 3D Geovisualisation offer an aesthetic regime where narration or cognitive manipulation of elements can be used as means of visual communication. These means are commonly used in commercial media, architecture, gaming and film industry, fields where 3D Geovisualisation plays or has the potential to play a role in the future. In architecture narration, aesthetics have traditionally been a large part of the field, also after the introduction of new digital media. A test case of commercial interest is built, consisting of a smaller part of a visualisation of a tourism portal in the city of Aalborg. The issue is investigated by the use of interviews and questionnaires for subjects, and by the use of expert evaluations. The methods are designed to cover four aspects in relation to the above questions:

Appreciation. Issuing appreciation is a direct way to address user preferences and an important element in commercialism in general.

Realism. The level of realism ranges from verisimilar to abstract and can be used as a communication means. High realism, such as photorealism, is desired by many providers but is often performance demanding to attain and maintain.

Depth cognition is a large part of creating a virtual realism. It is therefore a major 3D issue and also differentiates it from other media like 2D maps and web maps.

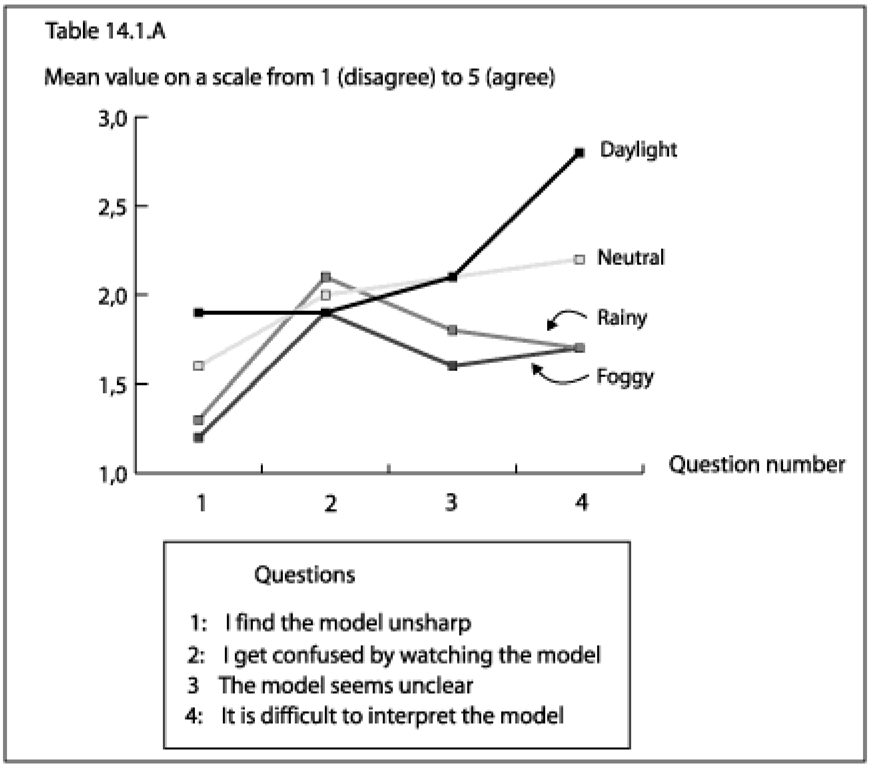
Exploration. Exploration has been proposed to be one of the major advantages of complex systems, allowing for data and information exploration mainly for professional purposes. Here focus is on the user's visual exploration of the virtual world.

The usability test performed included an interview and questionnaire with 10 subjects participating. Furthermore an expert evaluation with 2 experts participating was performed. Since all questions are repeated in three different monitor environments for studying the interface category (see Chapter 15), for simplicity focus it is here solely kept to results from using the pc monitor. A few statements are, however, derived from discussions during the use of one of the other monitors, but only if they are related to discussions from previous steps and only if they are not related to the monitors.

Questionnaire

The questionnaire including answers can be found in appendices C1, C2 and C4 and it includes 97 questions. In the appendix the personal pattern of answers of each subject can be studied (appendix C4). Subjects are kept anonymous, but are coded X1 to X10, and the coding can be directly coordinated with the pattern of answers issuing the background of the subjects in appendix A4. The subjects are however not the same group of subjects used in test 1. The questionnaire uses a scale of 1 to 5, 1 means total disagreement, 5 total agreement, 3 is indifferent/do not know. The sum of attempts is ideally 10, since 10 subjects participated, but some places subjects have avoided answering resulting in a lower sum. The mean value reflects a mean of the answers 1 to 5.

Technological issues: Questions regarding technological issues show in Table 14.1A that no disturbing or uninterpretable parts exist in the model, since mean answers are between 1.2 to 2.8. There is a tendency to answer more positively in D, then N, R and least positive in T. In Table 14.1.B, versions are compared and the mean value is close to 3, suggesting that the subjects generally have no problems interpreting any of the versions, though there is a small tendency to an easier interpretation of R and a more difficult interpretation of T.



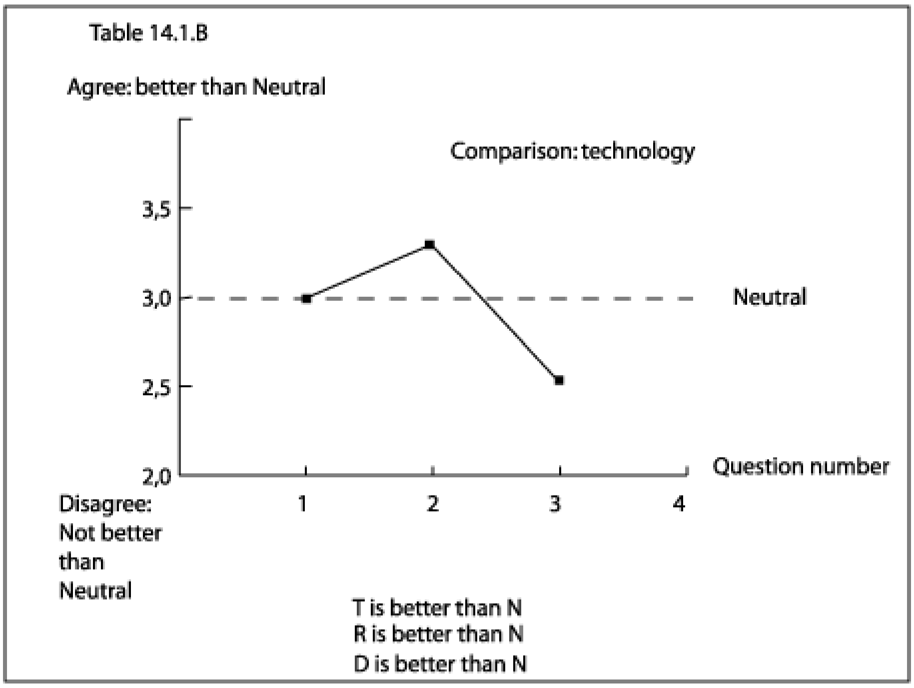


Table 14.1 A: Segment of the questionnaire issuing technology. Because of the different characters of the questions the questionnaire is separated into two parts, 14.1A is negative questions – users disagree in the negative questions. 14.1.B compares the versions directly.

Realism and depth cognition: Issuing realism and depth, version N is regarded as the least realistic incorporating fewer depth cues, while D is more successful here. In Table 14.2.B shadows are not interpreted as annoying - rather realistic, but not directly aiding the interpretation of the scene. Answers in Table 14.2.B show that the subjects do not regard the fog as a depth cue, but also that it does not directly disturb the interpretation of the scene. With a high spreading, these results however reflect large disagreements in the group.

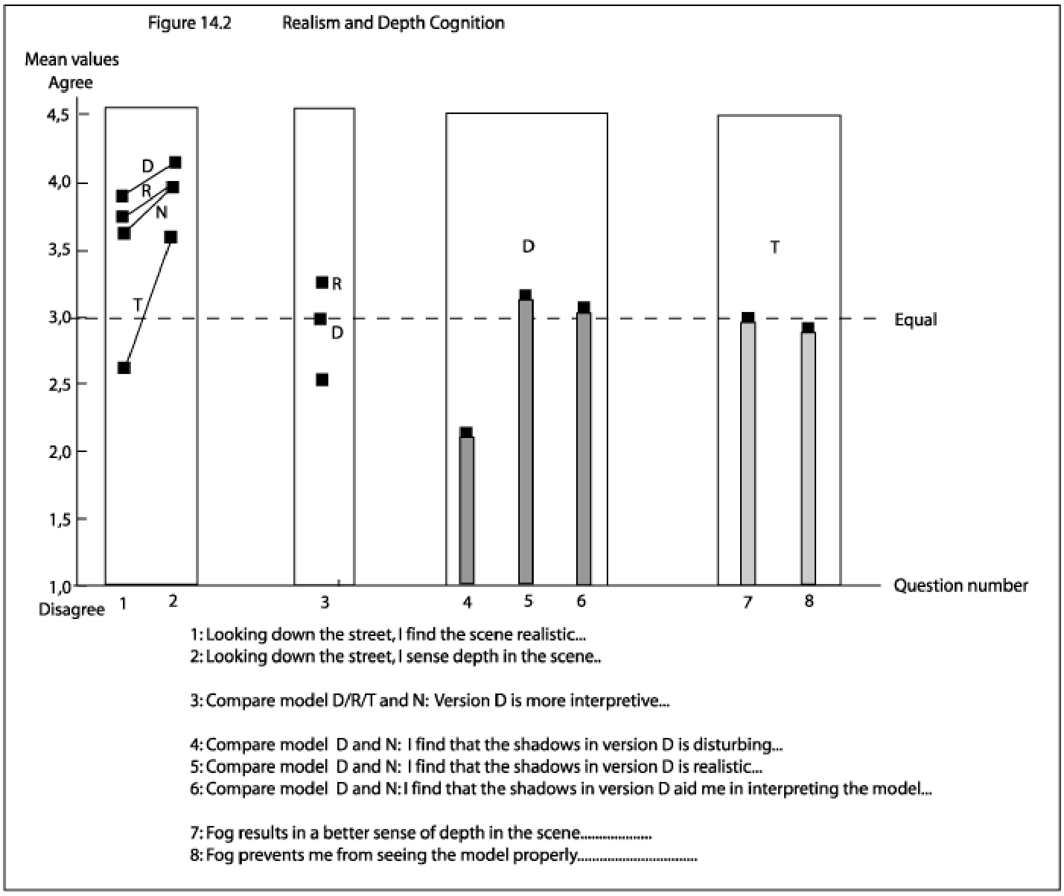
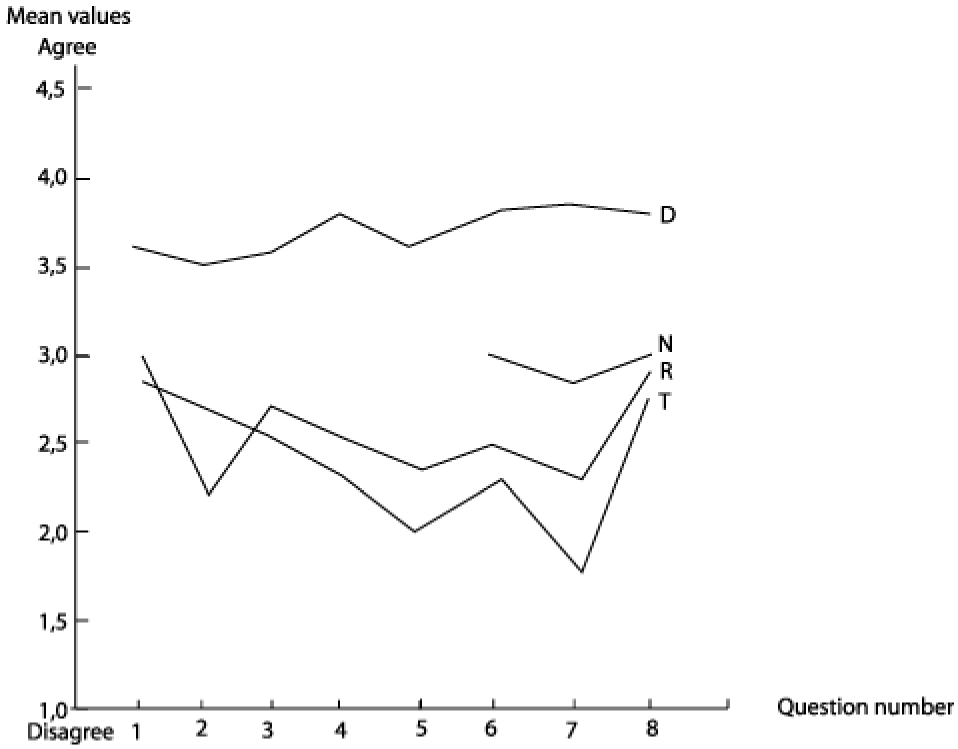


Table 14.2: Segment of the questionnaire about realism and depth cognition. The questionnaire is separated into four parts; 15.2.A issue realism and depth in the fourth part; Questions 1-2: a comparison of realism,Question 3, 4-6: A comparison of the four versions and Questions 7-8: issue the foggy version.

Preferences and appreciation: Version D results in the highest reliability and attraction. This is found in Table 14.3, where version D scores 3 or above 3, reflecting that subjects agree with the positive statements given. Version T lies below 3, reflecting a disagreement with the positive statements. That D is the most preferable version can also be seen in Table 14.3 where versions D, R and T are compared with N. D is generally preferred from N. Version R is also rather positively regarded when it comes to attraction, though it does not include commercial value.

Figure 14.3.A Preferences and Appreciation



Questions:
1: I would like to visit the tourist attraction in real life.......
2: Seeing the model makes me whish to see the tourist attraction in real life..
3: I think the model create a good atmosphere…
4: I feel good watching the model.....
5: I find the model suitable for commercial presentations
6: The tourist attraction looks good....
7: The town looks good..........
8: I find that what I see looks good...

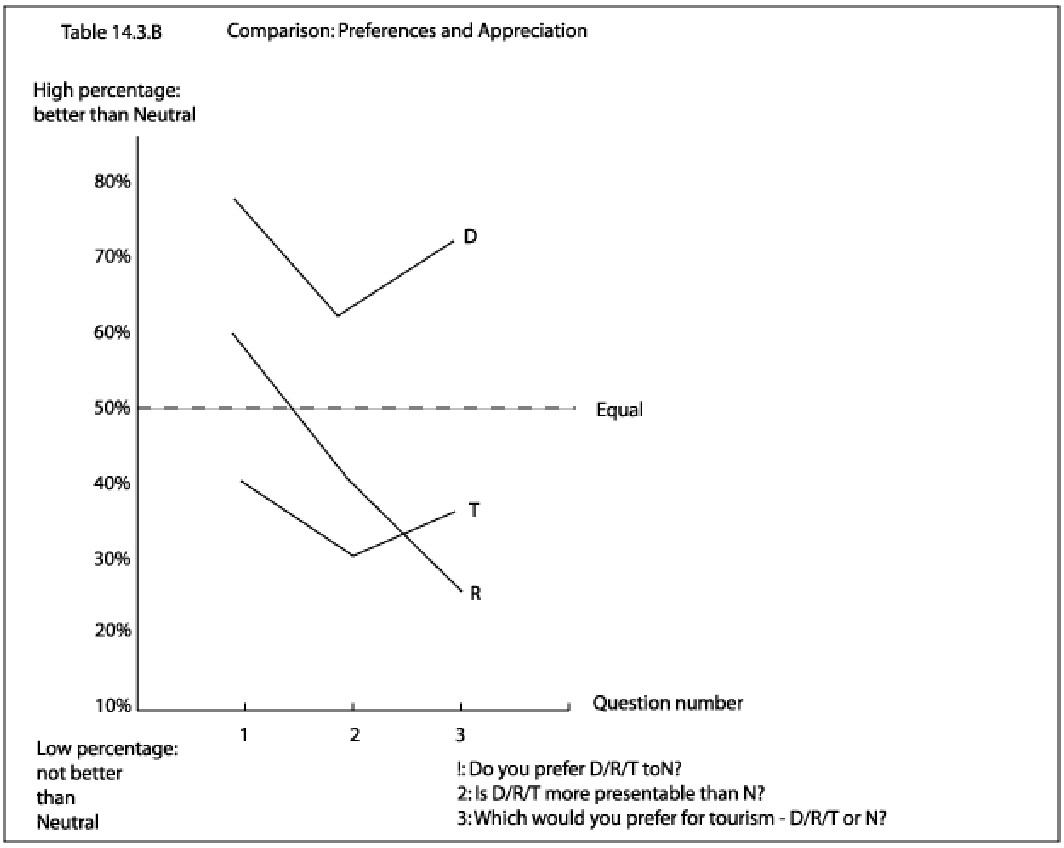


Table 14.3 A: Segment of the questionnaire issuing preferences and appreciation.Table 14.3.A include three expressive versions D, R and T. Table 15.3.B compares all versions directly.

Exploration and associations: Table 14.4 issue question of exploration and association. Common for all three questions is that version D scores rather highly while a mean of three reflects indifference to versions R and T. Regarding association all mean values are under 3, reflecting that the subjects do not perceive any associations in connection with the use of the model (appendix C4).

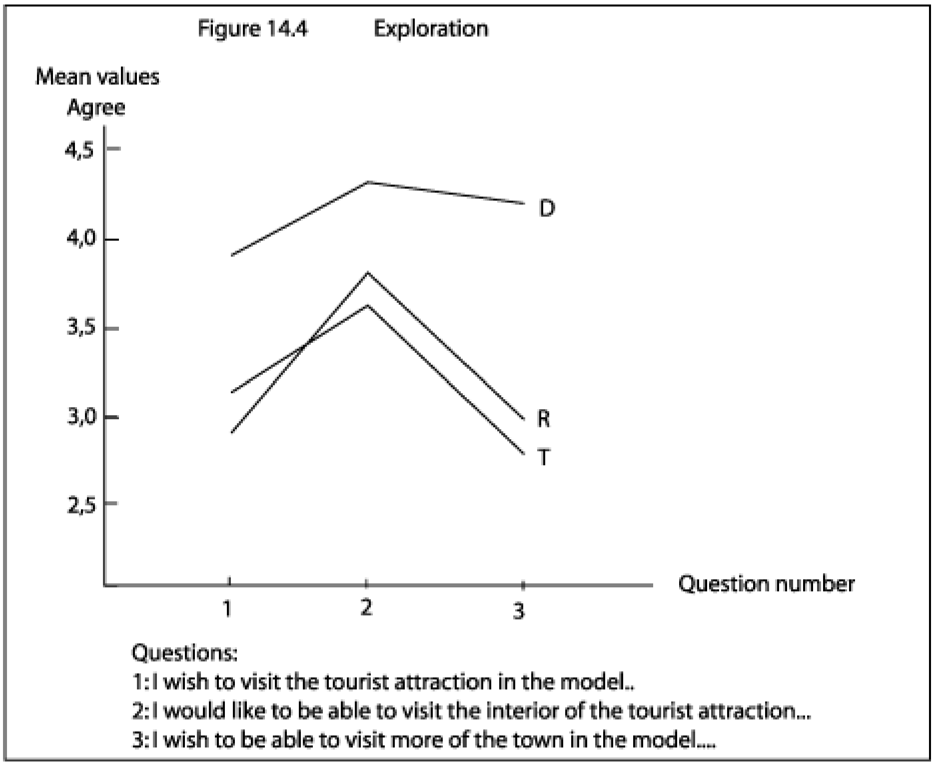


Table 14.4: Segment of the questionnaire issuing exploration.

Interviews

In the following, especially interesting statements are given and for simplicity some are left out. Full interviews of all subjects can be found in appendix C5, and the personal codes X1-X10 symbolize the same subjects as in the questionnaires. Unfortunately, most of the recording of subject X5 failed and therefore only 9 interviews are transcripted.

Technical/interpretal issues: Only a few errors in technical and graphical quality, sharpness and slightly dark textures in the graphics have been commented on. These comments issued expectations on physical logic; for instance the animated flags represent wind, and when they occur together with fog this would be an unrealistic situation. Likewise some mention that the rays of sunshine occurring on the photorealistic façade (which are preferred to be recorded in sunshine) appear strange in the dark versions. In version D the rays also fall differently on facades than on the shadows generated by the model on the rest of the scene, e.g. the roads.

Realism and depth: The photorealism is highly estimated as contributing strongly to the atmosphere in the scene. It is also a competition parameter: ”People who see this on the Internet are probably used to seeing lots of things like this, so I believe that high realism is necessary to catch their attention”. Regarding the photorealism, none of the subjects can imagine a more simple realism being more attractive or aiding them in any way, and several mention that high realism has a high importance. They have no problems viewing the model and see no problems in combining a complex 3D view with attribute information or route explanations. X10 says “You mean that if you could keep high realism including facade photos covering the tourist attraction itself and then the rest is just boxes? It is a bit hard to imagine, but as other parts of the model looks realistic you are more encouraged to take a look down the road, this you would not do if it was only boxes. Then you would be more indifferent. But of cause you would focus even more on the tourist attraction”. Some subjects pointed out that realism and planning also depend on the situation and the motivation. X9 describe it like this:” I am just considering what it would mean if I go to a town I do not know well. And the more realistic the more attractive and the more I wish to go there. It also depends on whether the decision is already made. If you know that you are going there. But I think it is positive that the model contains so many details.” The sky, which has different textures in the four versions, and the light in the horizon in the sunny version are mentioned as enhancing the sense of depth as well, and contributing to appreciation.

Preferences and appreciation: The sunny version is the most attractive version to all of the subjects and X1 explains: ”I definitely think that the sunny version is more lively, - it is this thing about creating atmosphere, and somehow it actually irritates me that I think it looks so much better with the sunlight”. Graphical sharpness, textures, sky and animations are elements in the scene assigned to create a nice atmosphere connected to the tourist attraction and its surroundings. N is a bit sharper than the others due to the shadow calculations, but this is not generally taken as a positive characteristic. X1 expresses it like this: “You can see immediately that this one is too clinical. It seems old fashioned”. X1 and X9 also reject N while X7 is more positive: “I like version D. I also like N, but it is a bit more like a game”. However, those subjects who have an order of preferences chose the neutral scenario as number two after the sunny version. The rain R and fog T versions make people associate with gloomy places. X7 expresses it like this: ”it is because there are negative emotions connected to it. Last autumn I cycled here in the pouring rain, I had never gotten so wet before. I just happen to remember this; I just think it is connected to something negative. So, it is mainly the feelings I have towards the weather, it is nothing about the graphics in itself”. In comparison with the neutral version, X3 says: “Well, if the goal is to attract people, fog or rain is not preferable. Even the neutral version is better, I think”. Being inside this fog yourself is not very nice; “It is suitable for a horror movie, but it doesn’t make you wish to be there”. X1, X7 and X9 are positive towards using fog and refer to a more realistic look and it enhances the feeling of depth. X2, X3, X4, X8 and X10 rejected this and X3 explains “I would rather be able to see the city clearly”. Most subjects (X6, X8, and X10) say that the antipathy against fog is because some of the sharpness and visibility is lost, both at a close range and at a distance preventing them to look for land marks. Some are, however, positive towards using a weak layer of fog, almost invisible. Using fog or mist is generally not accepted as a suitable way to blur the edge of the overview model (Figure 2B). The minority of the subjects accept the fog in the overview because it is more natural and it can be appropriate in nature for instance X1: “Fog creates a sense of depth like in renaissance art by lowering the intensity of the colours. Perspectives can be created in this way, so actually the fog is cool. But it is not very nice to be in the fog”. The foggy version might enhance an effect of depth, as it is used in artistic paintings, as one of the subjects mentions. Most subjects approve of the four animated flags in front of the casino (can partially be seen in Figure 11.1A-D), while some criticized the quality being too artificial and too periodical, among them X1: “There is something about those flags that I do not like. They are in the same phase and that is too much”. Nearly all subjects suggested that a scene should rather contain just a few (a few is enough) natural animations of high quality, imitating e.g. drifting clouds, cars, cyclists or pedestrians. Without life in the streets, the subjects feel that they are alone early in the morning – for some scary, for others a silent moment. The sunny version can be improved through graphically brighter content, green plants, sunshine and a few clouds in the sky, as well as through interactivity facilities that call attention to the attraction using e.g. colours or signs.

Exploration and associations: The subjects often mention that visiting the interior of the Casino is desired, but also to continue down the roads: “It is a shame that it (the model) is not larger, I feel like going for a run around town.” Only one subject recalled previous events by looking and discussing the scenes.

Expert evaluations

The Tourism expert: The sunny version is the only one suitable for commercial purposes. A few, but good, tasteful animations and interactive possibilities will improve the appreciation of the scene. Virtual guides, tool tip information and a graphical design where colours or texts are used as markers should be handled with care so as not to overdo the style – few tones and one font only. This would also make people pay attention to the attraction. But the model should be optimised to sell exactly this tourist attraction and in this case the interior and the general atmosphere are important: ”We use pictures from the gaming tables, and evening pictures from the exterior. It is a tourist attraction that you would visit in the evening, and there should be some intimate Las Vegas atmosphere as well, with lamps outside. For the Casino itself it will mainly be the interior – because the building itself is not very nice and it does not harmonise well with the surroundings either. And therefore it is the atmosphere we should portray. A large part of the tourist experience is that you visit life, and this you do not find here. Here you have a nice-looking street, but it is totally dead.” It is often the situation that the attractions themselves are not beautiful, and this does emphasise the need to sell the site in the right way. In the tourist-industry history and atmosphere are also created through small stories connected to elements in the streets – e.g. sculptures representing a story or a memorial, stories that could be incorporated in the virtual scene.

The Design Expert: People are used to high realism from computers, television and games and that is the way people want it. The tourist must have a realistic impression or recognize the scene. The virtual space must be convincing, otherwise it is perceived as a game or a joke. But it should not be so realistic that commercial interest is overlooked. The goal is to present the site as well as possible and to present it in a recognizable way, which includes some level of realism. ”In this case the attraction has to be well unpacked because you have got to sell it right, and this unpacking requires that you must follow some of the ideas we have of what fascinates us, among that are all the details that we fall for. All the new games sell because of good graphics and an extraordinary amount of details, realtime, shadows etc.” That is especially important for animations in the scene because they strongly draw users’ attention and therefore they should be realistic and follow physical rules. Modern human beings are used to scenes and metaphors, but people can be divided into segments and for some market segments a simplified representation can be justified, but not when used in general or in models where appreciation is a central issue. ”This thing about sorting and simplifying information, that is something we do as professionals when we design, draw or work in 3D or whatever we do.” The high level of details is part of our understanding and our high demands of quality today, but in ten years there might be a different understanding of design. ”If you want to sell the attraction, then there is nobody who wants to sit and watch such a shoe box in 3D. It requires no attention. People are getting used to all this 3D, and this surface mapping and the shadows are a large part of it. But you can find other directions in the 3D industry not being based on realism, but still fascinating. In caricatures the demands are totally different and the surface mapping is totally different. It is not realism.”

Discussion

Technological Issues: Interpretable or major technological difficulties do not seem to affect the subjects, but minor technological irregularities might affect some answers and some interpretations. It is mainly the enhanced sharpness of the neutral version that causes irregularities, and minor logical physical inconsistances that annoy some of the subjects, like the flags and the divergent shadows.

Realism and depth cognition: The subjects connect realism with the sunny version, but also emphasize that this version as more easily interpretable. Photorealism is regarded as an important factor in interpretation, recognition, exploration, attention and visual appreciation, and the idea of using simpler representations is not directly appreciated. In this test, the attraction of the scene is based on the discussion of atmosphere, and for this the facade photos are important for indicating the distinctive character of the street through shops, colours and notices, as a sign of human activity. Human activity is exactly the main ingredient in the concept of atmosphere. This is why no one is positive towards the possibility of using abstractions in the model, but the rejections might also be related to a lack of imagination due to low experience using this media. Even though bad weather in Denmark might be more realistic than sunshine, this kind of realism does not make it suitable for presentations. The neutral version is regarded as the most unrealistic, but also the simplest. The neutral version causes the least depth perception, indicating that scenes manipulated by fog and shadows, and enhanced by graphics (for instance sky and clouds), contribute to depth perception. When asked directly, the subjects did, however, not think of fog or shadow as a means of depth perception. Concurrently, depth is perceived by using cues, often without being aware of them, being an example of the fuzzy transition between cognition and perception, between what is consciously perceived and what is automatically learned. The fact that when several depth cues are present they are added into an enhanced depth perception; this might make it difficult for the subjects to distinguish between the cues (Young et al. 1993).

Preferences and appreciation: In all methods used version D is the preferable version, then N, R and finally T. D is emphasized as creating the highest degree of reliability, attraction, commercial value, depth and explorational value. Generally D is also regarded as the easiest to interpret which results in the highest score in technological questions. Some regard N as a good solution, though N results in the lowest score regarding depth and realism. The questionnaire showed that R and T actually resulted in some appreciation, but not attraction in a commercial context. This did not dominate the interviews, where only few advantages in R and T are emphasized by few subjects. The only subjects directly positive towards T are X9 and X1, both in interviews and questionnaires. They are both academics, and especially X1 says he compares the fog with common image theory. This is probably not representative for the focus group in general. The answering pattern of X1 and X9 are also more rejective towards version N than the other subjects, meaning that X1 and X9 prefer any expression (D, R or T) better than none (N). Hence, they seem to reflect a ”temperamental”, academic segment of users. Subjects and experts generally agree about which means are useful to create a positive atmosphere, if for instance improvements should be conducted: bright and good weather, animations, especially of life in the streets, and green plants. They also agree that animations should not dominate, just a few is enough but they should be in high quality - meaning that they should be natural, not mechanical. Technologically speaking, it is possible to fulfil the requests of the expert concerning the night-life atmosphere, though not as exemplified in this study (Figure 14.1). The media is not very precise in the sense that the methods used to create the four different versions will in this case cover the whole scene. For an evening attraction like the casino, a night atmosphere is appropriate, but for daytime or childrens' attractions, for instance a “Las Vegas atmosphere” is not exactly appropriate. A solution could be a compromise by using the general positive means (sun, brightness, life) or to create “rendering zones” around each tourist attraction where an individual atmosphere can be created. In the internet virtual world SecondLife, the weather changes as an example of the importance of dynamics just for the dynamics itself, as nature and weather change in real life.

Figure 14.1: An evening scene from Aalborg from the same model as the tourist attraction model but at a neighbouring location.

Exploration and associations: The possibility of accessing interiors and larger parts of the city has a high value for the subjects. There is, however, a general tendency of people always wanting more and from a practical point of view, so the provider needs to draw a line. In the questionnaires it is, however, measurable that in the sunny version, the desire to get more information becomes larger indicating that a positive atmosphere is important for exploration, and here also high realism might play a role as a positive factor for the subject's interest in exploring the city. Exploring the model content through interaction possibilities is known to encourage even more curiosity and contribute to a positive impression of the scene (Nielsen 1993).

Methodology critizised: Chapter 12 concluded that the group of subjects matches the focus group well in most ways, except from the educational level. A rather large over-representation of highly educated subjects exists compared to the mean in the population and also compared to an ideal focus group. Practically, it was not possible to acquire more subjects than the four found through the local tourist bureau within the timeframe of the test. Finally, some bias would still be likely since persons signing up for such a test might have a special interest in tourism or media communication in general. A few do use academic references to art for instance, indicating that more advanced analytical methods than an immediate emotional/sensorial grounded reasoning be used, but it is definitely not generally reflected in the results.

Uncertainties in the quantitative method are not calculated due to a lack of material. This makes the results of the quantitative methods difficult to interpret in terms of how significant the answers are. The results of the questionnaires were only concluded upon 10 attempts, being the lower limit of positivistic empirical quantitative methods. Especially critical are the cases where only nine attemps exist, because a subject have missed a question. The results gained from the qualitative and quantitative methods in this thesis do, however, not contradict themselves and the quantitative tests seems therefore to be reliable. In general the results gained from the interviews have been more fruitful, and it has been more difficult than expected to find clarity in the large data sets gained from the quantitative test than expected. The effort made to combine the interface part and the rendering part has in this case complicated the procedure. The use of different ways of asking about the same issue (by asking for comparison between version and asking positively and negatively) has been too complicated and the efforts done here have not resulted in a corresponding quality of results. As for the interviews, the abstract issues that are generally directed seem to be more efficiently covered by the qualitative methods used. The inclusion of expert evaluations has been efficient and fruitful for the discussions of realism and appreciation.

Conclusion

Aesthetic effects used in a commercially interesting case result in measurable and distinct perceptive interpretations. Clear statements are used to describe version D compared to the other versions including the neutral version, and especially pronounced when qualitative methods are used. General trends regarding positive effects are emphasized by the subjects. These are light, highly realistic, refined but simple dynamics and narration in the model, and they work as important bridges between the technology and the emotional life that is dominant in the realm of the users.

15. Interface

Summary of interface part of test 1 and 2

The spatial feeling is shown to be documented in various ways and argumentations from it’s effects can be found in cognitive studies. What exactly the value added is, however unclear, and it is the aim of this interface study to see whether it is possible to gain more precise information on this. The study of interfaces is combined here with the study of representation and rendering. Therefore, it becomes a study of the effect of the interface on the representational study concerning district plans, and a study of commercial tourism in the rendering study. For practical reasons it has not been possible to include small monitors or the CAVE, hence the monitor study includes a mono pc monitor, a stereo pc monitor, and a panorama. The two interface-parts are designed differently;

Test 1 concentrates on the users’ experiences of the different monitors. Weight is here on subjective impressions, leading to the use of qualitative methods.

Test 2 wishes to measure whether any difference in the monitor environment’s influence on perceptive fields while a model i studied – if the monitors result in a measurable dependency concerning interpretation, here in the case of commercial tourism. Methodology chosen to reflect this includes the use of quantitative methods.

The questions for the interface part are designed to issue utility, appreciation and depth perception in relation to the two cases and the interface environment used. The paradigm used for the interviews can be found in appendix B4. For the interface part in test 2, both a questionnaire and an interview with subjects and experts are included. The questionnaire and interview paradigm can be found in appendices C1 and C4. References to the subjects are denoted as X'1-X'10 and X''1-X''10. X'(x) refers to the same subject as referenced in the representation part of test 1 and X''(x) refers to the same subject as referenced in the rendering part of test 2. This means that the individual pattern of answers of each subject can be found in appendices B3 and C4. Because of the non-uniform questionnaires and types of results they are not divided into topics.

Results, test 1

Interview results, test 1 (urban planning case): The panorama is preferred by most subjects (X'1, X'3, X'4, X'5, X'6, X'7, X'9) who are motivated by this with a life-like feeling ”It is like being there” which makes it easier to relate to. One subject claims to gain a larger overview. Some mention a disadavantage due to an easier loss of overview. When asked to choose between the small monitor most chose the stereo monitor as the preferred one (X'1, X'4, X'5, X'7, X'9); though their next sentence is that there is not much difference. Subject X'10 found orientation easier in the small monitors (alm. pc and stereo) compared to the panorama. Still, she says that the panorama seems more realistic because you feel you are ”out there”. Subject X'8 did not find larger differences in any of the monitors, much like his answers in the representation part of test 1 where the different versions did not change much to him – revealing a very analytical way of seeing things.

Expert evaluation, test 1: Neither the Urban Planner nor the architect are interested in working with anything other than ordinary pc monitors. The Urban Planner uses larger monitors for presentations, in order to let the presentation be visible in a larger room. He regards this as a good solution creating a sense of space, like in the panorama.

Results, test 2

Questionnaire results, test 2 (tourist attraction case): The questionnaires in test 2 are designed so that the same representation-related questions are answered for each monitor. According to the questionnaire major variations do not exist. A subset of the questionnaire, where answers vary more than once, looks like this:

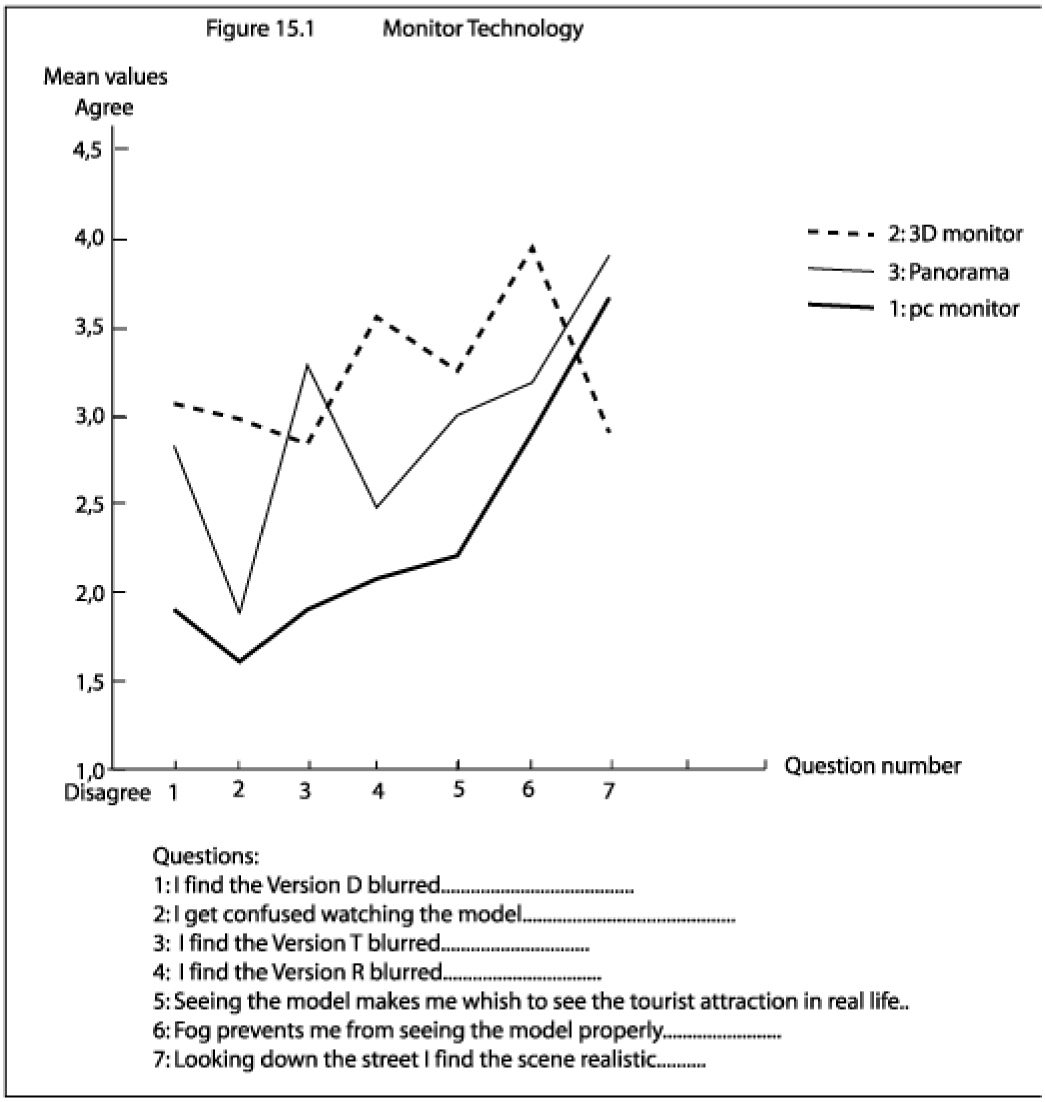
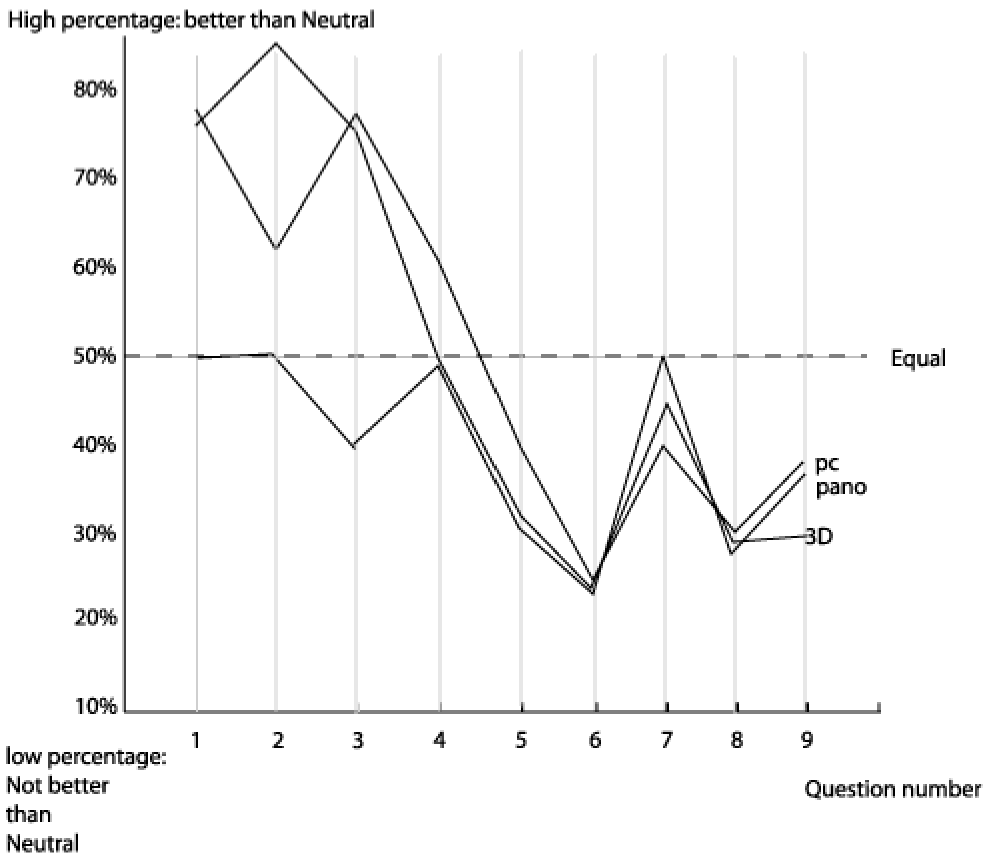


Table 15.1: Monitor technology.

The first four questions issue interpretation of the image. Here all subjects find the ordinary pc monitor the most clear and least confusing, while the 3D-monitor is more unclear and confusing. Also a more unclear image can be found in the panorama compared to the pc monitor. The 3d monitor and the panorama seem to have an effect issuing the question ”to see the model makes me wish to visit the place in real life”.

The next questions are related to attraction, exploration and realism. The typical pattern is that the panorama is received as the most positive followed, or sometimes overtaken by the 3D monitor. An exception is ”This reminds me of once I was there myself” where the pc monitor recieves the highest positive score. Some of the questions ask the subjects to compare and rank the neutral version in relation to the other versions. X is either version D (daylight), R (rain) or T (fog); N is the neutral version.

Table 15.2 Comparison: Monitor influence on appreciation



1: Compare version D and N: Which do you prefer?........ D N
2: Compare version D and N: Which do you think present the tourist attraction best?...... D N
3: Compare version D and N: Which would you prefer yourself in a tourist presentation?.. D N
4: Compare version R and N: Which do you prefer?........ R N
5: Compare version R and N: Which do you think present the tourist attraction best?....... R N
6: Compare version R and N: Which would you prefer yourself in a tourist presentation?... R N
7: Compare version T and N: Which do you prefer?........ T N
8: Compare version T and N: Which do you think present the tourist attraction best?........ T N
9: Compare version T and N: Which would you prefer yourself in a tourist presentation?.. T N

Table 15.2: Monitor influence on appreciation.

Version D is clearly preferred compared to N in the pc and the 3D monitor, but not in the panorama. Except from this, there are not many variations, or ambiguous patterns in the answers to interpret them as significant.

Interview results, test 2: Subjects X’’1 and X’’2, X’’3 find that it is difficult to focus in the stereo monitor and because of the functionality of the stereo monitor only half the amount of pixels exist resulting in a serrated impression. Others agree, but prefer anyway the stereo effect due to enhanced depth and realism. Subject X’’1: ”If you are not disturbed by indistiction and some serrations, then I would prefer to work with the 3D monitor. I think you achieve a bit more feeling of the environment you visit. In the other monitor it appears too flat. It is not much difference, but a little”. Most liked the panorama (X’’1, X’’2, X’’3, X’’10), and say that it makes the model appear more realistic, more impressive. The realistic size makes the subjects feel more present and aids size assessment. In the panorama, small differences are suddenly visible (for good or for bad), and the subjects often mention that in the facade photos there are people dining in the restaurant of the hotel next to the Casino. This is not very clear in the small monitors. The panorama is also criticized for making the image darker, so the daylight version rather looks like twilight (X’’3). Finally it is criticized for being blurred, although the panorama is most preferred in any case.

Expert evaluation, test 2: The tourist expert finds that panoramas are useful in tourist offices or at other large places, but emphasizes that the economical investment is a major factor.

Discussion

Attraction and utility: In test 1 the panorama reflects a realistic and true-to-life impression where the experience of being present in the virtual world impresses several of the subjects and aids them in the task of estimating the consequences of the district plan. This is in fine accordance with previous tests by (Kjems 2001; Lee and Peng 2003; Hacklay 2002). In test 1 the 3D monitor is preferred to the pc monitor, though not much difference is found. The reserved answer is probably caused by the rather serrated and, for some test sessions, blurred image, that is the technical problem that, of course, bothers the subjects. The majority did, after all, prefer the 3D monitor. So what is left for the pc monitor is its’ sharpness. In test 2, there are generally not measurable differences in the way the subjects perceive elements of the tourist model according to the monitor used. The only noticable difference is a more positive attitude (attraction rises) in the 3D monitor and especially in the panorama. Also here, technical problems influence the answers for the 3D Monitor and a little in the panorama. The interview methods used are broadly speaking painting the same picture as the questionnaire; though the interviews that allow the subjects to reflect freely usually result in more powerful expressions.

Orientation tasks: In some ways, the subjects experience that overview, and thereby orientation, is supported by the panorama. In other ways, orientation was percieved as obstructing orientation. The true-to-nature size that the panorama delivers encourages users to move as one would do in real life, in walk mode. Walk mode is also suggested by (Verbree et al. 1999) for use in World View - suitable for presentations. If walk mode becomes the singularly used mode, it is not suitable for orientation tasks and therefore not suitable for people who are not familiar with the area. Used together with fly mode it still gives the opportunity to achieve an overview from a bird's-eye view, but then again requires some level of interaction skills.

Experts and monitors: Unfortunately it was not possible to achieve comments from the monitor environments from the expert evaluators, since they apparently did not find much of interest here. None of them are interested in working with other monitor environments other than the ordinary pc monitor in daily situations, but found the panorama suitable for presentations for a larger audience. That the experts did not take much interest in monitors, is in agreement with (Ruddle and Jones 2001; Swindells et al. 2004) who do not recommend immersive monitors for professional use.

Methodology critizised: The test arrangements have been complicated by the fact that two parameters are in focus at each test. This made the tests rather long-ranging, and sometimes tiring for the subjects. Probably, this especially resulted in less focus on the monitors since the content of the visualisations came to dominate subject attention. Some subjects did not have many comments to questions about monitors resulting in less consistant and comparable results in the interviews. This also reflects that some of the subjects are more talkative than others which is more clear in the interface test than any of the others. Better and more easily interpretable results are probably obtainable if each test session focused solely on the monitor environment, separated from other issues. Test 2 did not deliver many measurable and unambiguous results. Test 1 has been easier to work with than test 2 and the resulting outcome is better compared to the efforts made. The advantages of the chosen interface methodology is that over the entire 3 years of the PhD project, the test procedures were shortened in time and greater resources were needed. Another possibility to raise the outcome of the interface part is not to link interface focus so closely to the problemformulations of the other categories (representation and rendering) as it is done here. Problem formulations for the interface part could be more isolated and non-abstract for instance containing a specific task that is to be performed in each monitor environment.

Conclusion

During the tests working with the panorama develops a more positive and imaginative attitude towards the visualisation. This is reflected in the 3D monitor as well, pointing at a general trend that says that the more immersive the monitor environment the more attraction and imagination are supported.

16. Interaction

Summary of test 3

Many situations profit from the six degrees of freedom, and looking at different ways of serving these 6 degrees sometimes seems to serve them more successfully than others. Though users' navigation in 3D worlds probably has been the most investigated HCI issue in 3D, mainly in terms of space cognition, it is still the issue that gives the most users problems in accessing information and feeling at ease with 3D systems. In the last test, test 3, focus is on the following question;

- How can navigation in 6 degrees of freedom be supported optimally?

Test 3 is made with the purpose of comparing three different regimes, to be able to identify advantages and disadvantages of each. Test 3 is made with the purpose of comparing three different regimes, to be able to identify the advantages and disadvantages of each. Quantitative methods, involving time measurements and questionnaires, are used. Time measurements are expected to reveal how efficient the various regimes of navigation are, while questionnaires allow qualities other than efficiency to be revealed (see appendix A5 and D2). The time measurement is expected to reflect a measurement on users' satisfaction, so that the faster the task is solved, the more satisfied the user is. This assumption is inspired by basic internet principles. The subjects are afterwards asked to write down advantages and disadvantages of the navigational regimes of each piece of software. The test does not reflect how fast the subjects adapt to each regime, since a non-recorded initial period of trial is included. In the trial period, the subjects are offered both an aural and visual introduction to the regime.

Three different kinds of navigational regimes in existing 3D software were chosen. The chosen software are the commercial products ArcScene and VR4Max Navigator Pro, along with the research product Grifinor developed at the Center for 3D Geoinformation at Aalborg University. VR4Max represents a navigational regime based upon direct response on mouse action (one mouse click results in one movement), while ArcScene represents a classic flight simulation regime (movements are initialised). Grifinor is a mix of those two, creating a complex, sophisticated navigational regime. The comparison method consists of measuring the time spent by subjects navigating a given distance. The distance is at first travelled by walking the surface, then flying, and finally repeated for each piece of software. Both tests (walking and flying) require here the control of 6 directions; up-down, forwards-backwards and right-left. During the test this distance is travelled twice; first in flying mode *as the crow flies*, then, still in fly mode, along the road. The same procedure is repeated for each of the remaining software programs.

Questionnaire

Time measurements show that the flight simulation regime of ArcScene serves the fastest solution in both walking and flying tasks. ArcScene is followed by VR4Max and finally by Grifinor. Commenting on the three pieces of software in the questionnaire, most subjects stress that simplicity in the navigational regimes is the most important factor, leaving Grifinor to represents a too advanced regime. 75% (18 subjects in all) of the subjects find the direct response of the VR4Max regime the most simple and preferable. The rest, 25% (5 subjects), highlight ArcScene, whose gliding flight is preferred by the few, but criticized for easy loss of overview by the others.

VR4Max: The advantages of VR4Max are especially the simple and controllable navigation. The movements are vertical which means that the camera angle does not have to be changed and thus does not result in even more actions to be remembered. The constant key operation needed during motion supports the feeling of control, because motion stops when operation ends. The feeling of the system running out of control does not then exist. The use of keys is perceived as being homogenous, thus predictable; and speed control, through pushing the mouse, is perceived as easy interaction. The use of combinations is limited, which lowers cognitive loading. The disadvantages are slow interaction and serrated acceleration and deceleration. Though the lacking camera angle control supports simplicity, it is also mentioned as a disadvantage, since flexibility is lowered. Likewise, a few subjects rather emphasize the constant mouse activation and difficult speed control though most describe then as advantages.

ArcScene: The navigation system of ArcScene is based on a flight simulation regime. As such, it is perceived as intuitive and easy to control having floating and pleasant movements. When speed is initiated the user does not have to activate the keys constantly to keep speed, which a minority emphasizes as an advantage. Those who emphasize this are also those subjects who prefer ArcScene rather than VR4Max. Speed is controlled by mouse click – some find this easy. ArcScene uses cursor-icons to give information on the speed mode, which is a useful guide to many subjects. Some of the disadvantages mentioned are that for moving in upwards direction it is necessary to tilt upwards, causing orientation to be lost. Flight simulation regimes also cause navigation along the ground to be difficult – speed control and braking have to be remembered - raising the cognitive load. Directional interaction is easily performed both in ArcScene and VR4Max by pointing at the target.

Grifinor: Grifinor uses elements from flight simulation navigational regimes. As with ArcScene, speed is kept constant when movements are initiated, and likewise emphasized by a minority as preferrable. The special sideways, angular and panning movements obtained in Grifinor through key combinations are also emphasized by some, though only one describes this as easy navigation (but still prefers ArcScene). Most subjects find Grifinor difficult because it is impossible to see which movement in the 6 possible directions is activated. Hence, when braking or stopping these movements are very difficult resulting in large, and for some insuperable, cognitive load. Grifinor relies on "pulling" the images when turning. This resulted in some confusion, because the mouse is to be turned left when a right direction is performed. Navigation in Grifinor is solely performed through the mouse where also the scroll button is used – most found the management of the scroll button troublesome.

Time measurements

Subjects fly much faster *as the crow flies* than by following the road, where challenges in height and left-right turns exist. Navigating *as the crow flies*, it is possible to describe a trend where ArcScene is the fastest, VR4Max second and Grifinor results in the slowest mean time used (Table 16.1). Navigating along the road differences are larger, resulting in a larger standard deviation. But the trend is the same: ArcScene is fastest, VR4Max the second and Grifinor follows close behind.

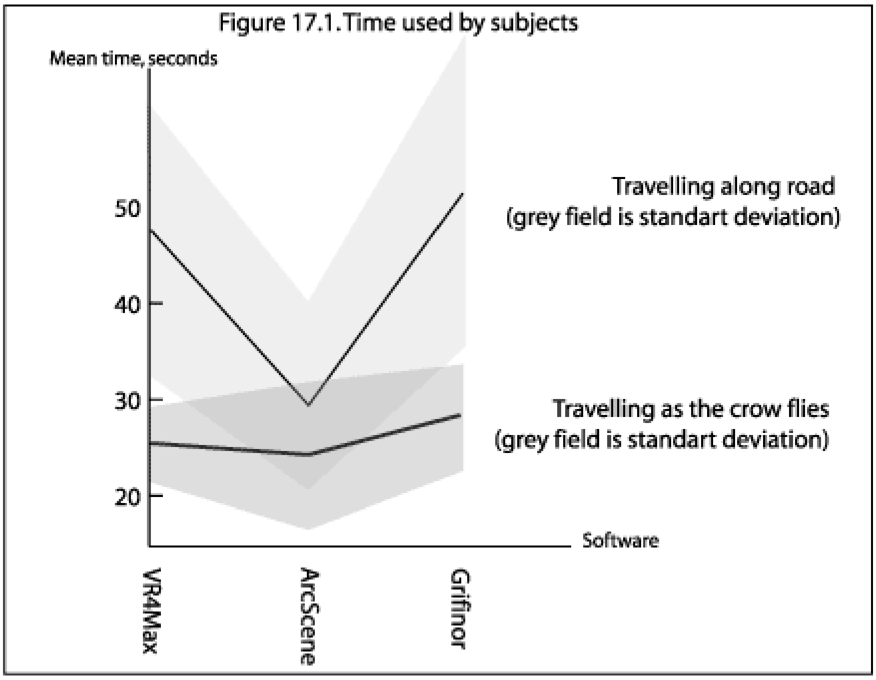


Table 16.1: Mean time in seconds used by subjects to solve the navigation tasks. Standard deviation is included in brackets.

Discussion

Speed and efficiency: Though VR4Max and Grifinor result in a comparable time spent for solutions, VR4Max was clearly preferred for use compared to Grifinor. ArcScene is, on average, much faster to use in the walking test and a little faster in the flying test. Anyway, 18 of the 24 subjects (including the two inexperienced) prefer the slower but simpler VR4Max solution. So the initial assumption saying that a user's satisfaction is proportional with how fast the task can be solved is not the case. A user's satisfaction is, rather, reversely proportional with the mental work needed to perform a navigational task. Flight simulation regimes are only popular among a minority of the subjects (X8, X10, X11, X15, X16 and X18 in appendix A7). They do not separate from the others according to the questionnaire, for instance when it comes to questions of experience. The only thing they seem to have in common is that they have emphasized the pleasant flying movements of the flight simulation and that they solved the time measurements in ArcScene as the six fastest subjects. In real situations, some tasks call for coarse navigation rather than fine navigation. Movements over large distances might be supported optimally by flight simulations, while shorter distances and fine navigation in urban planning is more relevant. For finer navigational tasks the initialization of procedural movements as used in flight simulations demands large mental concentration and is hence not optimal. For ArcScene, and especially for Grifinor, it seems that developers have had too high expectations regarding users' mental capacity, in relation to the use of the initialization of procedural movements.

Experienced/inexperienced users: The two 3D-inexperienced subjects preferred VR4Max, which was preferred by most of the experienced users as well. Even the experienced subjects emphasize that navigation regimes must be simple. The mental work needed in Grifinor seems to be rather demanding even for users who are familiar with 3D systems. In this test experienced and inexperienced subjects do not express differences in preferences, but this is only based on two inexperienced subjects participating. The results of this test then only indicate that there is no major difference in preferences in navigational regimes, but conclusions should only be based on larger groups of inexperienced subjects. Many of the experienced subjects base their experience on games. They then expect key combinations based on mouse and arrows. However, the game realm does not really solve the navigational problems of 3D Geovisualisation since movements are based on the simple and natural real-world movements of back-forth and left-right. Up-down movements are only supported by jumps and activated through singular keys or key combinations.

Critique of methodology: Test 3 is simpler in its construction and methodology, resulting in easier interpretable results. Time measurements could have been combined with an error detection to hold the time up against, instead of the questionnaire part of pros and cons. But again, combined methods are essential. In future tests on user navigation in 3D Geovisualisation, efforts should be done to define and work with smaller segments of the focus group. This makes a comprehensive discussion of work flows topical for these segments, where for instance zooming and changing visual angles are relevant tasks for planners.

Other comments: Two subjects chose to scroll instead of flying – this seemed to enhance the feeling of control for them, though they travelled the distance slower than the mean. Many subjects especially struggled with the allowance of movements inside a building or inside the Earth. Especially the inexperienced ones, but also several of the experienced, seriously lost orientation when entering or bumping into objects.

Conclusion

A user's satisfaction is not proportional with the time spent, but rather conversely proportional with the mental work needed to perform a navigational task. To increase the user's success in accessing the intended content of the systems, it is therefore necessary to serve up simple, easy controllable navigational regimes, even though the users are experienced. When comparing the three pieces of software, ArcScene, VR4Max and Grifinor, the most simple and controllable navigational regime is delivered by VR4Max, through their direct response system.

17. Conclusion on Test Cases

Summary of test case conclusions

Representation Conclusions: Using high realism for presentations is suitable when size assessment, support for orientation (though extra support is needed for users unfamiliar with the area) and the creation of appreciation is important. Users clearly prefer high representations in any case, conflicting with the technological realm since it is practically problematic to support. When political / legal interests are in focus, high representations are however dangerous choices, due to the danger of over-visualisation and to exaggerate expectations to the final project.

Rendering Conclusions: Aesthetic effects used in a commercially interesting case result in measurable and distinct perceptive interpretations. Clear statements are used to describe version D compared to the other versions including the neutral version, and especially pronounced when qualitative methods are used. General trends regarding positive effects are emphasized by the subjects. These are light, high realism, refined but simple dynamics and narration in the model, and they work as important bridges between the technology and the emotional life that is dominant in the realm of the users.

Interface Conclusions: During the tests working with the panorama develops a more positive and imaginative attitude towards the visualisation. This is reflected in the 3D monitor as well, pointing at a general trend saying that the more immersive monitor environment the more attraction and imagination is supported.

Interaction Conclusions: User's satisfaction is not proportional with the time spend, but rather reversely proportional with the mental work needed to perform a navigational task. To increase the user's success in accessing the intended content of the systems, it is therefore necessary to serve simple, easy controllable navigational regimes, even though the users are experienced. When comparing the three pieces of software, ArcScene, VR4Max and Grifinor, the most simple and controllable navigational regime is delivered by VR4Max, through their direct response system.

Methodology

Efforts done here to include a three-step methodology, including questionnaires, interviews and expert evaluations and has resulted in a far wider description of the issue than if only one methodology had been used. A wide description is important where the main objective is abstract and complex, as here especially in test 1 and 2. Optimising this three-step methodology, the questionnaires could have been sharper, especially in test 2. One of the reasons for the complex questionnaire in test 2, is the inclusion of both rendering and interface problem formulations in the same test session. Even though the questionnaire had been sharper and shorter, the test session might still be too long for a subject to cope with. It is then better to split the problem formulations into two separate sessions to reduce the period of time used. This does not necessarily imply a new test case but it implys the ever-lasting problem of finding suitable subjects. Only in test 3, more well defined goals are formulated, the summative method stands alone. The combination of time measurements and questionnaire, though both summative methods, is still important to catch different aspects of the issue, here by leaving place in the questionnaire to comment on qualitative importance.

To ease the problem of of finding suitable subjects enough, it could have been a possibility to meet subjects on the street and invite them for a short session in test locations close to. That causes restrictions in the size of the model since the model must be accessible on a pc and it leaves out the use of larger monitors and the facilities in the usability lab. But it could be a possibility in some cases.

Conclusion on test cases

Several of the cases reveal different interests in 3D Geovisualisation, hence users preferences are not necesarily the preferences expressed by other stakeholders. In the case of representations and interaction some surprising results exist, showing other representational and navigational preferences than those coming from researchers and developers themselves. In relation to the cases used here, it is emotional, social attachments and control that is more important to the users than expected from other stakeholders. In the case of rendering, there is not exactly a mismatch between stakeholders, though minor unexpected implications showed up. And for the interface part, an agreement seemed to be the case both for the effect of immersive environments, but also to some extend an agreement in relevant literature on utility of the immersiveness. Concludingly, in developing projects it is especially fruitful to consult users on representational and interactive issues, while rendering and interface issues can more likely be used in coordinance with conventions and common expectations that already exist in the field.

Section 5: Evaluating the Media model

18. Discussion and Conclusion on Media Model

Summary of media model

As described in the introduction it is a user-centered approach that is chosen to study the concepts of quality in 3D Geovisualisation. It is also described how users from non-professional spheres potentially can contribute to the development of 3D Geovisualisation, both regarding short-term economical interests and long-term theoretical development. Addressing non-professional users, 3D Geovisualisation is not just a set of systems and tools, but a media where various possibilities of communication exist. As in any other media it is important for the producer to know the content and means of the media well, in order to turn up or down for the different content in order to optimize the message. When identifying characteristics and categories of the media, a reductionistic method is used here to conceptualise the structure of the media and the means of the media are regarded as isolated phenomena. This categorization is to be understood in a nominalistic sense, meaning that it is fruitful for the understanding but not necessarily a realistic model of the true world. Main characteristics of the media are identified in section 2, derived through the description of a model of 3D Geovisualisation. This model consists of 4 categories; representation, rendering, interface and interaction (Figure 18.1 – same as Figure 4.4).

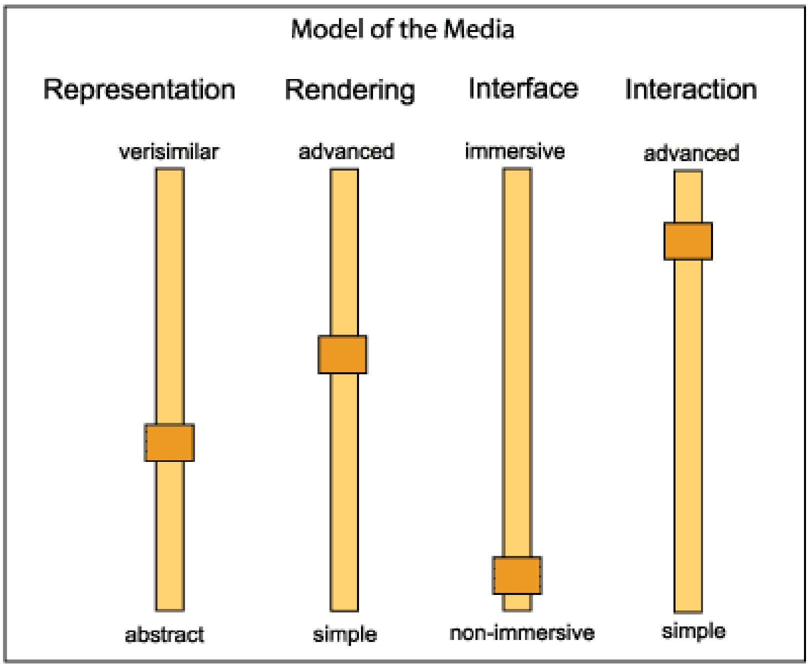


Figure 18.1: The four categories constituting a model of 3D Geovisualisation . Content and means can be turned up or down – and thereby an optimised result can be achieved. Position of adjustment knobs is arbitrary. (this figure is the same as Figure 4.4).

Revising the media model

Subjects often refer to several categories when asked in which way they could imagine improvements. When subjects are asked how navigation could be improved, they talk about representations. When asked how the high rendering of the tourism case could be improved, they talk about representations and the other way around. This suggests a system that is more based on some kind of relationship than on a reductionistic system as implied by the media model (Figure 18.1). Instead of "turning up and down" the different categories they interact, possibly in a synergistic way. For instance, do high abstractions not call for especially high level of rendering effects and sophisticated methods as they are used in Lenne3D or SplinterCell. This would be more natural and expected in highly realistic models. The attraction-creating effects of high realism can in contrast be enhanced by rendering methods or immersive monitors. Synergy implies basically that the two means do not add up linearly, but react enhanced, stronger and more convincingly than if they are used alone. This synergic system is only meant to be descriptive here, since it is not realistic to lay down any mathematical formula. Human beings and relevant cases will probably be too complex to grasp and convert into a useful formula.

There is also a tendency that some of the categories "belong together" dependent of the context. In professional cases, less high representations seem to be sufficient while many interaction possibilities enhance the professional need for analysis and exploration. Rendering effects are not necessary. But regarding interfaces, the picture is more scattered – for some purposes immersive/semi-immersive interfaces are not necessary, for others they are. For commercial interest, a high level of representations, rendering effects and immersive interfaces are necessary. Here interaction constitutes a more scattered picture – in some cases interaction does not have a high priority beyond basic navigation tasks, for others it constitutes an important part.

Media specification

A future activity to follow up on this thesis could be to develop the media model to be supportive at different stages in software development. Through initial stages in software development considerations on technological solutions and priorities are made. Adding the media model in this process support the identification of means and effects used to emphasize the message. This process can turn the final product into an even more accurate communication tool. If for instance a user's ability to orientate is an important parameter in a future 3D system; it is shown by the test cases in this thesis that there are several ways to support this:

- high realism/photorealism, eventually only landmarks
- 2D support, eventually through sidemaps
- Controllable navigation

Different technological and data acquisition challenges exist to each of these solutions. It is then possible for the development team to choose between different means according to their resources available and still meet this need for orientation support. If all of the three features mentioned above are incorporated into the software, orientation tasks are supported at a high level. If only effort is made to ensure a controllable navigation it is probably not that high. Mainly because there will always be some users that do not discover or like that way of being supported, while preferring other ways. With a "media specification" it is therefore possible for the team to document and overview at what level of support the software will deliver according to each user-relevant theme in the media. In this way a development process circulates around the user and the user's needs, documenting it but still being able to respect limits due to technology, time and/or money. Many more usability tests of scientific quality are, however, needed before a clear picture of the accurate effects of each mean in each case is available.

Conclusion on Media Model

The media model was originally based on a linear and discrete model. The work with users and cases implies that it is rather a synergic and continuous system, where the various means used together can amplify or reduce the result. It has however been possible to categorize all concepts that appeared while working on this thesis, and the four categories are therefore generally suitable as an umbrella that describes 3D Geovisualisation. The categorisation has then contributed positively in exploring the media and in working with its means. The categorisations are also suitable for formalisation into a specification useful in iterative development projects. This specification could work both to overview and to document which means will support the focus group. The advantages of using a media model has in summary been:

- providing a method to work fully user-focused, both as developers and as HCI personnel.
- to address non-professionals through the concepts of a mass media.
- it is possible to identify fields in the media model where special care should be taken as we have seen in Chapter 17.
- a media specification could be useful in software development projects to formalise a user-centered focus.

Section 6: Evaluating the Concepts of Quality in 3D Geovisualisation

19. Discussion and Conclusion on Concepts of Quality

Technological qualification

The qualification of 3D Geovisualisation that is prevalent today is very focused on the technological possibilities. This way of qualifying is reflected in the "build and they will come"-attitude, where technological development is expected to be a solution in itself. Challenging this attitude has become even more important these years where 3D Geovisualisation has rather experienced inertia than unambiguous success. Furthermore, as it has been argued here, focus groups of 3D Geovisualisation are changing from the traditional professional realm to the wider segments of mass media addressing average citizens and consumers. Satisfying these focus groups in competition with all the other possibilities modern human beings explore every day, 3D Geovisualisation has to be much more precise in communication skills. Also in competition with rival compagnies on the GIS-market and related compeeding fields, communication is a main parameter.

User-focused qualification

This thesis tries to challenge the present technological focus in the field and works with non-professional users and common media concepts in order to enhance a user-focused attitude. The work introduces a new way of understanding 3D Geovisualisation by fully incoorporating the user. The method places the user in a central position trying to identify elements and issues that the user experience directly. A user-focused attitude needs, first of all, to be based on the specific knowledge derived from usability. A focus on usability and application in society is important in order to optimize communication and interaction and it is this kind of qualification that can point at new ways and new directions in 3D Geovisualisation in the future. Though technologically focused approaches sometimes get a rough treatment here, technological development are of cause the basis of it all and technological advances is crucial for the future. The kind of technological focus that is not useful for the field is when users and applications are forgotten. This is not accentuated to let technology and phenomenology move away from each other, but it is emphasized to underline that:

- technology is not sufficient to fully understand the conceptual level of 3D Geovisualisation.

- it is important to have a realistic insight into the realm of the user. What can be expected from the user and what preferences might the user have?
- it is necessary to put an effort into working with real cases and real users.

General qualities of 3D

Several times throughout this thesis it has been discussed what 3D offers its users compared to 2D. To summarize the results from the three tests, it seems that, especially for imagination power, size assessment and attraction (in terms of creating positive emotions) 3D seem to work well. When it comes to overviewing visual content, utility value seems to be bifurcated. On the one hand 3D is advantageous since it is possible to zoom in and out, viewing angles can be changed and content can be rich. On the other hand this results in a large cognitive demand on interpretive and interactive tasks. An overview of advantages and disadvantes is summarized in Table 19.1.

	advantages	disadvantages
Orientation		x
Overview	x	(x)
Support imagination power	x	
Support size assessment	x	
Support interconnection and emotion	x	
create attraction	x	

Table 19.1: Advantages and disadvantages in 3D

It is hence not relevant to discuss whether 3D is good or bad for district plan visualisations for instance and hence to recommend or reject 3D in general. It is rather a question of considering what is the most important to obtain in each case. If imaginative power and attraction is important, 3D visualisation is a good choice. If orientation is important and 3D is in question, choices on interactive support have to be made carefully since some of the non-professionals or those less familiar with the area will experience serious problems.

Qualifying for commercial industries

As long as the present political situation exists there are relatively few demands in society on the other qualities that 3D can provide, as it is disucssed in the introduction. The only quality in 3D that previously has become a succes is the ability of drawing human attention. A main activity in human attention is on its relationship to itself, its close relations and its surrounding social contacts. Any item that allows human beings to play with these issues have a possibility of becoming successfull in wider circles. If 3D Geovisualisation should experience this, the best suggestion would then be to focus on applications that can support human beings in performing those social tasks. In this context several of the future applications mentioned in Chapter 1 could belong to such activities and following future developments here will be interesting. Addressing non-professionals both in the entertainment industry and in general also involves a fundamental respect for the focus group and it is crucial that scientific and professional spheres using 3D Geovisualisation are open to the quite different understanding, preference and workflow that non-professionals sometimes have.

Theoretical formation in 3D Geovisualisation

Through the specific findings, where the most important are summarized above, this thesis has made a step towards a better understanding of how 3D Geovisualisation works with and for its users. Talking about contributing to theoretical formations in 3D Geovisualisation, or geovisualisation in general, is probably an exaggeration, but in the long run this is an ideal. The framing of a theory is the sign of a mature media. Such a development will result in a situation where developers and producers are less dependent on their own experiences, and it will result in a situation better equipped for a future of many diverse 3D solutions, more and wider focus groups and more relevance in each user's everyday life in a society of high technology. Finally, the field of geovisualisation has a tendency as an interdisciplinary field to develop new concepts, almost independent of each other. A maturisation and a development of a theoretical background would result in higher consistency according to definitions and improve cooperation, internal communication and knowledge sharing.

Conclusion on A Qualification of 3D Geovisualisation

The qualification that is prevalent today is very focused on technological development and less focused on users demands. This thesis meet this situation by introducing a model to support a new way of understanding 3D Geovisualisation by fully incoorporating the user. The model places the user in a central position trying to identify elements and issues that the user experience in realtion to 3D geovisualisation. This new way of understanding the user in 3D Geovisualisation also increase the focus on the potential of non-professional and commercial applications. This is mainly because 3D is not much requested today for its analytical qualities but for its qualities of attracting human attention. To continue a user-focused development and to understand new focus groups, it is crucial to gain more results through HCI-activities in 3D Geovisualisation and gather these into a body of knowledge that might end up with a profound theoretical framework in the future.

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Acknowledgements

When I look back at the years at the Center for 3D GeoInformation at Aalborg University, mainly two things come to my mind. First, how lucky I have been to get this unique opportunity to enter into a realm full of curiosity levelled at any imaginable - and unimaginable - concept in this world. Though I maybe sometimes looked as if I have had more than enough voyages of exploration in my everyday life, this exploration has kept me attached to the work all through the years. What secondly comes to my mind is all these fantastic people I have had a chance to meet. Some I have got to know over a long period, others shortly, but all have become a special part of me and my work.

First of all I wish to thank the guys at 3DGI and VR Media Lab for always being so perspicacious and never letting me get away with anything too easily! Thanks for all the meetings, lunch breaks and discussions we had – and thanks for Grifinor! (quite a nice job you did there :-). The girls from Geomatics, Lise, Pernille and Mette; you have been incredibly inspiring! I also need to mention the staff in the institute who with impressively high spirits did their best to make things run.

To those of you whom I have only met shortly at conferences and in London; I am so grateful for these moments and the inspiration you brought with you. Michele, Aidan, Andrew, Lily, Mauro, all the other CASA-people, Pedro and the other Vespucci's and many, many more. I wish these moments had been much longer.

Finally, a special thanks to Lars Bodum, who patiently survived my company directing me through the whole process, strongly assisted by Erik Kjems. Also a special thanks to Michael Batty for introducing me to CASA and the wonderful research environment there. And last but definately not least, a special thanks to COWI for letting this project become a reality.

Århus, Denmark, 15. October 2007

Appendix (Danish text)