VIRTUAL LANDSCAPE BRIDGING THE GAP BETWEEN SPATIAL PERCEPTION AND SPATIAL INFORMATION

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ABSTRACT

Most of the research in the field of Virtual reality and Visualization of environments has been done on the technical side, focusing on the technical limitations and trying to build systems that just work efficiently. But the nowadays availability of powerful computing machines and a variety of software packages (from 3D GIS to 3D computer games production) does not limit our imagination and meets our needs. We propose a methodology for geographic information visualization in virtual environments for participatory plan preparation. The methodology was tested in a virtual reality prototype, Virtual Landscape viewer, developed for a project that will significantly change the landscape in an area in the north of the Netherlands, the Meerstad project. The prototype integrates different geospatial datasets and the stakeholders are able to fly over the landscape and to "zoom in" to access detailed and different georeferenced data. In "landscape change projects", the stakeholders group is numerous and heterogeneous by nature, with different sensibilities and with different interests and concerns about the project. It is fundamental to display the correct information in a correct way to assure that all have the same understanding of the goals and consequences of the project. 3D visualisation provides an effective way of presenting large amounts of complex information to a wide audience, including those with no Geographic Information Systems (GIS) or mapping experience. The system was designed taking into consideration cognitive principles and is able to integrate high quality mapping of the current situation, 3D representations of the future and (geo)multimedia (regarding real world information). The people involved can understand the proposed plans and proposed changes. This new approach was built based on a geo-information infrastructure which supports open plan process and participation and is able to integrate all available sets of data.

1. INTRODUCTION

"Even though we navigate through a perceptual world of three spatial dimensions and reason occasionally about higher dimensional arenas with mathematical ease, the world portrayed on our information displays is caught up in the two-dimensionality of the endless flatlands of paper and videoscreen. All communication between the readers of an image and the makers of an image must now take place on a two-dimensional surface. 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".
[E. R. Tufte (1990), Envisioning Information] [8]

The overall goals of this research and implementation work is to explore the role of geo-information technology in open planning processes, and to develop an infrastructure to access (geo)multimedia information in the exercise of modelling and visualisation of virtual landscapes.

The specific goals were to do research on the integration of GIS data and multimedia data of rural areas in order to show and discuss landscape changes and other spatial policy measures with stakeholders. The implementation of the current research was done by developing a system to support discussions in the participatory process of design and decision making within the Meerstad project (Virtual Landscape Viewer). Intending that the flexibility of the system allows its use for other projects and purposes related to visualisation of spatial information in a fairly easy way.

1.1 Spatial Planning – Motivation for the work

The Netherlands is one of the most densely populated countries in the world where issues such as living spaces have to be cautiously considered. As such, spatial planning has a long history in the Netherlands. It is aimed at strengthening positive development trends and eliminating negative ones. In the past, the Netherlands has conducted a successful spatial planning policy network: the central government makes decisions on national issues; provincial and municipal councils have their own decision-making power on regional and local levels.

National policy naturally restricts the powers of local and regional governments, but the principle, however, is to keep decision-making powers as close as possible to the local level, promoting public participation democracy and a transparent process.

One of the major characteristics of the Dutch Spatial Planning scene is the very high plan-density. The so-called New Map of the Netherlands [1] reflects that there are over 5000 planned urban and rural developments in the Netherlands for the next decades (until 2020). Several kinds of planned developments are eligible for presentation on the New Map. These are for instance residential, business and infrastructure developments. But also plans for urban restructuring, new recreational resorts and new nature reserves. Nobody in the Netherlands believes that all this 5000 plans will be realised. The underlying assumption which is behind this well developed planning discipline, is that in a densely populated country governments and citizens do need very intensive discussions about the virtual landscape of the future.

1.2 Interactive Spatial Planning

Public participation is an actual subject in the planning process for developing new activities in rural and urban areas. In most of the planning projects local citizens, societal organizations and pressure groups are involved in the process together with one or more governing bodies. The fact that these different groups of the society should be involved isn't the issue anymore. The subject of discussion has shifted towards the amount of influence these groups should have. Different levels of participation are possible and with these levels the amount of influence does change. For the government this means that it has to consider to use its power in a more selective way by focusing on projects of national significance and by protecting the nation's main natural resources and ecological culture.

The terms interactive and participative planning are often used about developing changes in rural and urban areas. Frequently there is no clear line drawn between these two terms, which often results in the use these terms as one and the same. Dalal & Dent and Kluskens [2,3] have defined the differences between these terms. According to the levels of participation of Dalal and Dent (1993) [2], interactive planning is one of the different levels of participation that are possible. Interactive participation means that people participate in joint analysis, which leads to action plans. Interactive participation tends to involve interdisciplinary methodologies that seek multiple perspectives and make use of systematic and structured learning processes.

These groups take control over local decisions, and so people have a stake in maintaining structures or practices [2]. Kluskens [3] divides the term interactive participatory planning in two parts:

- Participatory is the process through which the government develops new spatial plans in co-operation with the citizens who are concerned, or associated (all interested parties or stakeholders), with the impact of the spatial plan. Participatory expresses the involvement of both the government and the citizens.
- Interactive is the part of the new trend he defines as "close and continuous mutual co-operation" in which knowledge and information is exchanged between the participating individuals (actors). Interactive expresses the relationship between the government and citizens.

One of the major, non-disputed advantages of participatory planning is the ability to gather "local knowledge" from citizens. The local citizens have the advantage above the policy-maker that they know the area very well and over a longer time. Although the local knowledge of the citizens is often based on emotion, this knowledge has meaning. The local citizens are the ones who have to live and experience the changed area. For that reason their opinion, wishes and ideas about the planned change must be considered. A higher number of participants involved in the process will lead to a conflict of ideas and concepts, because of their different view and opinion about the area. Another advantage of citizen participation in the planning process is that citizens get more insight in the problems and possible solutions in a planning process. When the final plan for the area incorporates requests and ideas achieved consensually by the stakeholders, public support is created for the whole plan. This public support is important for acceptance of and cooperation in the final plan (Hoogerwerf, 2003).

1.3 The merits of VR participatory spatial planning

Many projects in urban and environmental planning involve complex decision making processes that depend on the participation of a large and heterogeneous number of stakeholders, including technical experts, politicians, and citizens. As the debates are about the future, a shared understanding about the current situation, the facts, but perhaps even more important, the values and the perceptions are a necessary pre-requisite.

To support this complex process, there is a clear need for the ability to mix the reality and the future represented by a virtual reality. Or, in other words; to understand the visual effects from a specific spatial plan implemented in a local area you must try to imagine how the future physical elements, such as buildings, roads or trees will look like and how they will be integrate in the area. Planners have for decades used the ability to create perspective drawings and paintings where reality is mixed with planned objects. In the world of planners the use of 3D is becoming increasingly common. Architects and engineers use 3D techniques to present and test their designs. Some municipalities use 3D visualisation to illustrate new plans during consultation rounds.

In an approach where transparency is a key word and where inhabitants and enterprises are involved, high quality mapping of current and future situation is needed, so that, together with real world information (Multimedia), the people involved can understand the proposed plans and proposed changes. And to be efficient, this new approach has to be built based on a geo-information infrastructure which supports open plan process and participation.

The general aim of the project is to explore the possibilities to integrate and visualise spatial data from different sources, such as GIS data, aerial photographs, pictures, sounds and movies, and display it in a virtual reality (3D) environment creating the possibility to simulate and explore a different number of future scenarios.

2. CARTOGRAPHY AND VISUALIZATION

Graphical presentation of information has a long history, and some of the earliest extant graphical presentations are maps. Cartography has had, and continues to have, an important role to play in the graphical presentation of geospatial information [5].

Fairbairn et al [5] defined Cartographic representation "as the transformation that takes place when information is depicted in a way that can be perceived, encouraging the senses to exploit the spatial structure of the portrayal as it is interpreted. These representations are usually graphical, but may also be haptic or audible, or involve elements that mix other senses with sight." In the same paper, the authors consider the most critical issues in cartographic research to be those concerned with the characteristics of the data to be handled; the visual design and the user interface; representation purpose; user interaction with dynamic representations; and the changing technology to support new forms of representation (how representations can be accessed and enhanced). Having this in mind, we tried to apply these critical research topics into the development of a methodology and implementation of a tool that helps planners in communicating spatial plans in an interactive way.

2.1 Cognitive science

There are important cognitive aspects related to the visualization, perception and understanding of spatial information. The use of different information dimensions and media types that relate to different senses is useful for the understanding of spatial objects and their relations with spatial processes, and about planned situations and calculated scenarios [6].

The media used to help on the perception of spatial information may have four types of functions according to cognition science [7]:

- the function of demonstration,
- the function of putting into context,
- the function of construction,
- the function of motivation.

The *function of demonstration* is achieved by using media to give a realistic picture (demonstrate the idea, object or landscape). This can be achieved with the support of photos, videos or Virtual Reality. The media with the *function of putting into context* should help the user putting the detailed information into a bigger context, like an overview of the area (for spatial context), or sounds that are related to a particular area may help the user to identify and position the given information. The *function of construction* is related to the creation of complex mental models by the user (mental models are constructions of knowledge about information units and relationships). Abstract media of pre-prepared information is best suited for this function, such as graphs, diagrams or abstract layers. For last, the media can have the *function of motivation.* The media with this function intends to arouse on the user interest and attention. This can be achieved with animations, interactive objects; e.g. interactive fly-overs are a typical example for this function [6].

Besides the media functions, when developing a system to visualize and perceive spatial information, one should have attention to cognitive processes of:

- Short term memories limited cognitive capacity;
- To increase important information;
- To avoid the overload of a single sense;
- To support double encoding if information.

Because *human short term memory* has the ability of keeping just seven information units at the same time, the spatial information system should not provide too much information simultaneously. Multiple representations can overcharge the human cognitive capacity, but they can also emphasize important information and improve information processing, if used in the right way (maps, pictures, sounds, videos can be used in combination *to increase important information*). Also, a combination of visual and sound information helps the user perception by avoiding the *overload of a single sense*.

The human memory can store information in a pictorial and a textual format (*double encoding*), so pictures in combination of written or spoken text should be used to describe information [6]. We tried to include all these principles on the development of the Virtual Landscape system.

3D visualisation provides an effective way of presenting large amounts of complex information to a wide audience including those with no Geographic Information Systems (GIS) or mapping experience. It allows the user to relate the information to reality more easily and can give a realistic picture of future changes in the landscape.

To represent the changes of future projects in the landscape, planners have used for many years the combination of real world representation with virtual/future objects. The traditional ways already uses 3D, either by creating beautiful perspectives drawings and paintings that integrate the future elements with the existing ones (nowadays, also done by super imposing digital pictures) or creating physical elevation models that can be complemented with information that represents the plan. Both this approaches have a big disadvantage of lack of flexibility. It is virtually impossible to interactively change the plan without having to recreate the illustration or physical model. Also the ability to show visualisation of more abstract geographical information in a 3D perspective is not possible [9].

Furthermore, for interactive plan processes, dealing with numerous and heterogeneous stakeholders, flexibility plays a fundamental role. An example of this Flexibility is the capacity of displaying the overview plan but also zooming in to particular details and retrieving extra information from those details. The policy makers are interested on the overview, and the inhabitants are interested in accessing the consequences around their homes.

To fly-over an area using a mosaic of aerial photographs and topographic information can give a much more realistic and dynamic view of the study area.

3. THE CASE STUDY

The project Meerstad aims at the creation of a new lake and city, with the appropriated infrastructure in an area of interest larger then $700km^2$.

Right from the beginning, the project Meerstad has started as an open planning process. Together, the governing bodies, local citizens and societal organisations have created a concept Masterplan. The main objective of this open planning process is to take into account the wishes, ideas and thoughts of the local citizens. Starting point for the development of Meerstad is an open communication process and work together with participants to create a Masterplan [10].

DLG Groningen initiates the introduction of the Virtual Landscape in the project Meerstad. The current and future situation of Meerstad will then be presented via the System here described (the Virtual Landscape Viewer) to the participants. Important will be the reaction of the public to this new way of communication between the government and the citizens (to be analysed in the future).

4. METHODOLOGY

Cartwright et al (2001) (11) state that Virtual Environments (VE) is expected to be an effective interface for geospatial information because humans have day-to-day experience of navigating within three-dimensional space. The realism of both representation and navigation devices is expected to minimize the “cognitive effort” required to explore and interact with data. Some problems were identified by Cartwright et al (2001) [11] regarding the use of VE in geospatial exploration specifically regarding the fact the viewers become lost within the immersive space, some of the reasons comprehend: the 6 degrees of freedom; navigation over distances and speeds unfamiliar in the viewer’s experience and lack of visual detail in the representation of space.

For the development of the Virtual Landscape viewer we took these problems into consideration and tried to avoid them. The Virtual Landscape Viewer has implemented the 6 degree of freedom, but also prefixed flying heights where only 2 freedom degrees are allowed, and the change between states is done with a “click” on an interface button; in the presented system the speed is controlled by the user and the visual detail is very high, consequence of using level of detail management (the resolution starts at 0,5m/pixel and decreases depending on the users distance to the terrain). The next chapter will describe the process and components of building the Virtual Landscape Viewer in detail.

4.1 The Virtual Landscape Process

Regardless of technology, planning processes aim at the elimination of misunderstandings in the communication of the new ideas and to visualise the different alternatives. Visual communication of ideas is fundamental to the success of the planning process. It is necessary to have insight on the planning offices and focus on the need for data and information technologies. Having this in mind, we developed a process that allows the fast development of a Virtual reality tool for communicating the planning documents (schematized in Figure 1).

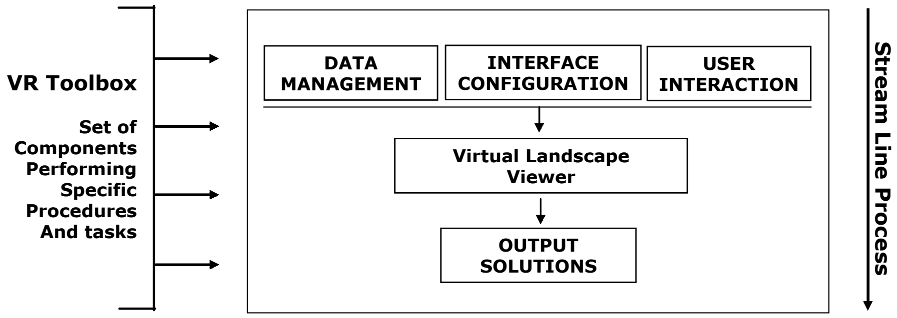

Figure 1. Components chosen for the development of a VR Toolbox for rapid Spatial Planning application development and distribution

4.2 Requirements and development environment

The system was built having in mind the following requirements:

- Need to show an area of $784km^2$;
- Real time feed back on Interactivity,
- Integration of different data sources;
- Display multimedia;
- High resolution display (0.5m, 1m , 2m, … resolution, depending on user position)

It was also necessary that an average computer could have access to the system, so the following hardware requirements were also proposed:

- Pentium IV 1GHz (or equivalent)
- 256 Mb Ram
- Graphic Board with 3D Acceleration and 32 Mb Ram (or equivalent)
- 30 GB of disk.

After a preliminary research, a developing environment was defined. The developing environment proposed was not from the GIS framework, but from the computer games world. The System was developed in Virtools™. It has the main advantages of flexibility, allowing us to develop any kind of interactions and it provides access to a SDK (allowing custom expansion); Already includes Computer Graphic Primitives; The developments can be ported to a Behavioral Server (Internet Server); free access to a Web Player plug in; Easy to use (graphical programming) and Modular programming. But it has some disadvantages, mainly related to the fact that it is not a GIS environment, it did not understand the concept of Geo-Referenced features, and it had no Terrain algorithms. These cons were overcome by the flexibility of the development software which allowed us to develop these features in a relative short time.

4.3 Data Management

The system comprises a wide variety of different kinds of data: maps, aerial images, videos, photos, digital elevation models, sounds, 3D building models that represent existing infrastructures and future ones.

The process starts at the planning office, looking to the available data and managing this data with commonly used available GIS and multimedia tools. These first processes of selection, simplification and conversion allow the virtual landscape viewer to use any kind of data available about the planned project (see Figure 2).

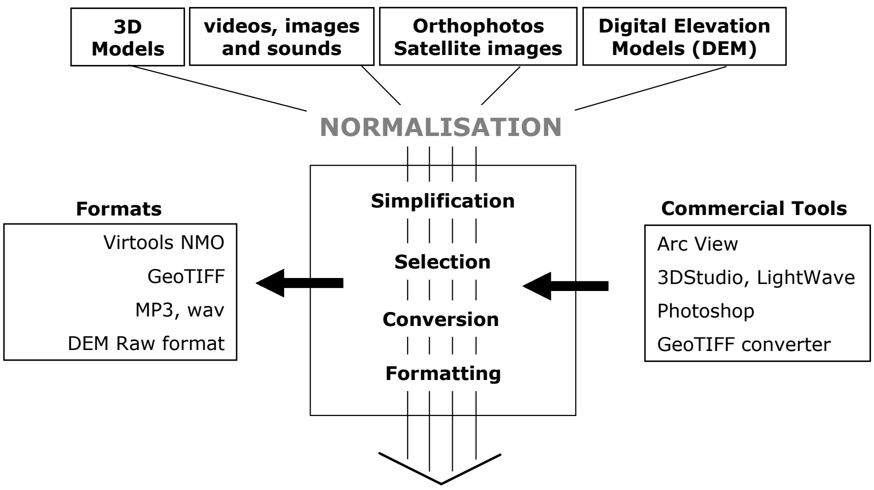

Figure 2. Process of data Normalization integrated on the Data Management component.

After the data has been normalised (converted into the format used by the Virtual Landscape Viewer), the next step is to Construct the Virtual Landscape (see Figure 3). The Aerial photographs mosaic is reproduced in different resolutions and these different sets of data are tiled into smaller sections, to be handled by the level of detail algorithm that takes into consideration the distance of the user to display more or less resolution in the viewer. The next step refers to the creation of the actual Virtual Landscape, where textures are associated with each digital elevation model. The last step of creation is the generation of scenarios where the data from the plan, layers and multimedia data is added to the base representation.

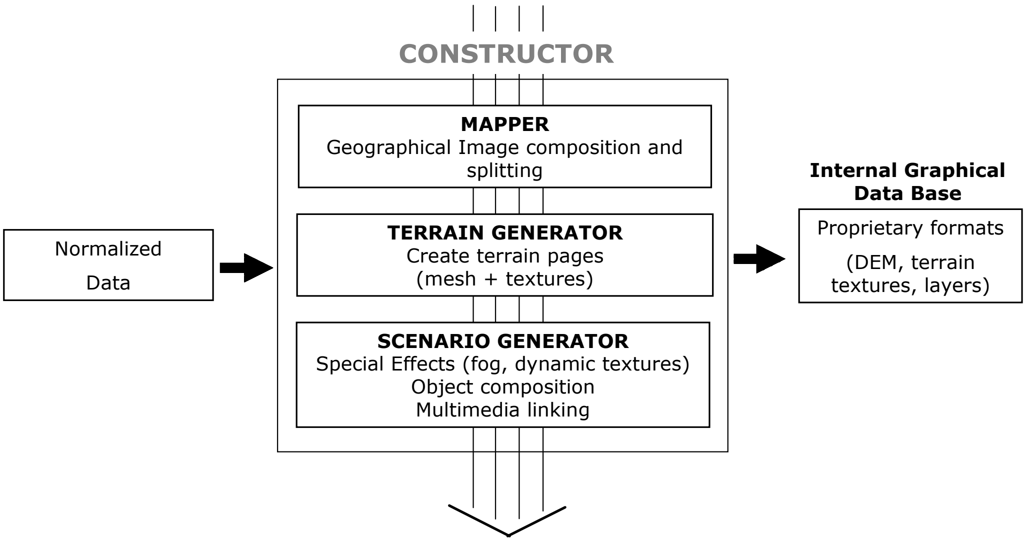

Figure 3. Process of Virtual Environment construction integrated on the Data Management component.

After the steps of data management, the Virtual Landscape Viewer has to be configured to use the appropriate recently created data sets and the user can start exploring. The virtual landscape base data, future situation scenarios and multimedia are added on the fly and the user can start exploring.

4.4 Interface design

The design of the interface for the Virtual Landscape Viewer, should take into consideration perceptual problems, which are very relevant in a multimedia environment, these are related to the resolution, colour and sound, and to the response times. The interface is composed of different buttons with intuitive icons and also the small overview map is also an interaction interface, it shows the current position and the user is able to move to another position by clicking on it.

Figure 4. Bottom button interface.

Figure 4 shows the user interface of the Virtual Landscape Viewer. From left to right:

- Map Button - Show Hide the small overview map for orientation;
- Layers Buttons – Show Hide Layers of the scenarios;
- Views Buttons – Go to Specific relevant position Orientation;
- Paths Buttons – Travel in pre-defined relevant path;
- Free Flight – Allows the user to fly freely in 6 degree of freedom;
- Level Flight – Flies in a fixed height (easier for new users);
- View Options – Configures the visibility of elements (compass, speed/position info);
- Restart button – Takes the user to the original position.

All buttons have a small description activated on mouse over.

4.5 User Interaction

The user interaction can be performed via the keyboard keys, mouse clicks and movements or any other Human computer interaction hardware like joystick. In summary, the user is able to freely move in space, Increase/Decrease Speed and click on objects to retrieve extra multimedia information. Other features include the possibility to follow predefined paths and move to relevant predefined positions.

Orientation and navigation concepts are related to the “travel metaphor”, which is used in these systems. To aid on the orientation several mechanisms should be enabled:

- Identification of the current position of the user in relation to the overall structure of the system, performed by the orientation map.
- Reconstruct the route that lead to that position, enabled with the restart button;
- Distinguish the different options for moving on from the current position, via the menu buttons;
- Distinguish direction movements, the compass indicates the direction the user is facing.

Anchors were defined to act as orientation points for relevant places and also contain multimedia links to extra information. The links can be to Pictures; Videos; Internet pages; Sounds; Simple Notes. The Layers of the plan, have also interaction has anchors. The user can set each layer to visible or invisible and the layers (because they are abstract representations of reality) have links to multimedia data that has the *demonstration function*.

4.6 Virtual Landscape Viewer

The data display in the Virtual Landscape Viewer is organised in four information layers. The first is a Digital elevation Model, the second are the textures (e.g. aerial photo or thematic maps), the third layer is a 3D model layer (3D models of the existing houses or 3D models of the future changes in the landscape) and the top layer is a multimedia layer, where the (geo) multimedia (georeferenced pictures or movies) are accessible via links in the user interface (see example of the geo multimedia link in Figure 5).

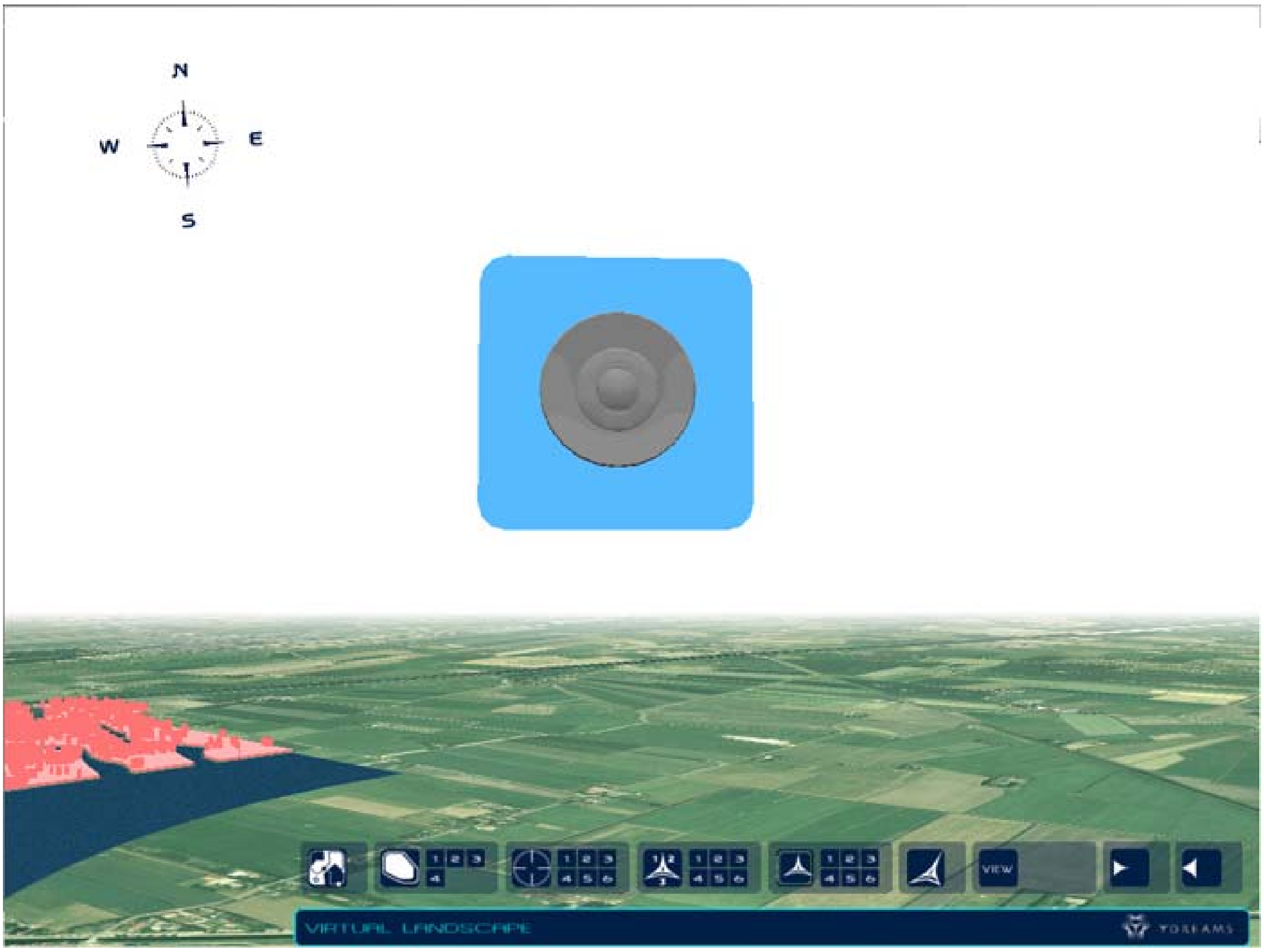

Figure 5. 3D object that represents a link to a relevant sound. The links are georeferenced and give access to the multimedia.

Regarding the technology developed, it was integrated an algorithm to display the right amount of detailed information that depends on the user position, *information intensity* manager or level of detail manager. This algorithm displays the highest resolution (0.5 m/pixel) in the tiles closer to the user and reduces the resolution for tiles more distant. This technology also refers to Paging Remote Server Distribution Management.

The combination of the conventional cartographic information with images and sound (*double encoded info*) can enrich the user experience and the whole message to be transmitted. Because *human short term memory* the information display is alternated in order to not offer too much information at the same time.

The Planning component of the Viewer is emphasized by its layer structure. The current situation can be displayed via the base current data (aerial photos + DEM + existing 3D buildings) and the future alternatives can be turned on and off via a button on the interface. The tool was designed to facilitate discussion regarding the planned alternatives.

4.7 Outputs

The interactive Virtual Landscape Viewer is the main output of the system (see screen shot in Figure 6). But the interactive fly-through the area of interest and extra data retrieving is not the only possibility of the system. The outputs are also flexible depending on the situation they will be used and comprehend different objectives: Interactive fly through for Information, Public Participation, Interactive Planning and Interactive Discussion forums. Output non-interactive high quality video output subsets or photo realistic Image rendering, for the Media for Dissemination and Communication.

Referring again to the types of functions of the geo communication medias, this system was build having in mind the *function of motivation*. The goal is that the system is easy to use, intuitive and fun.

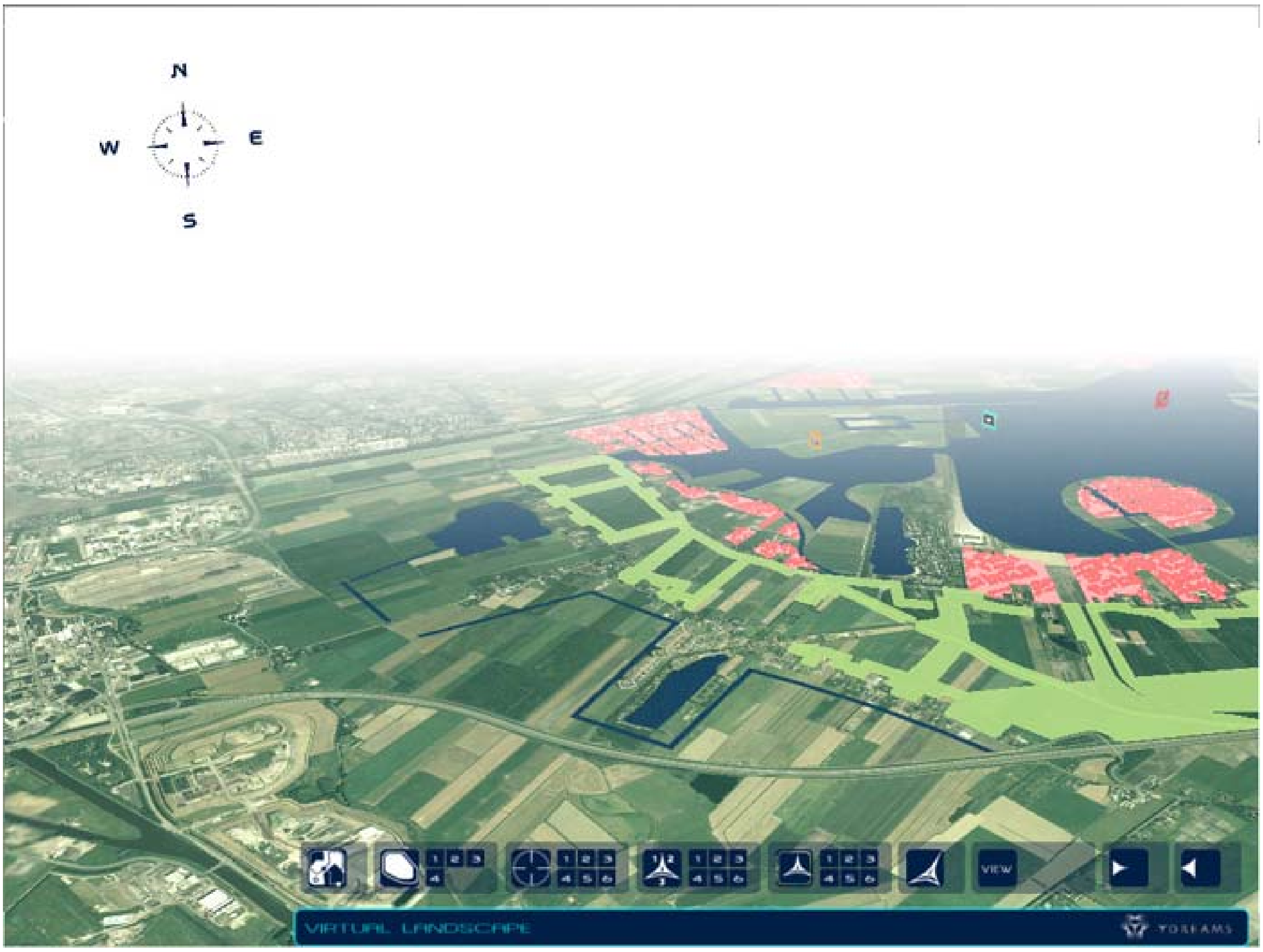

Figure 6. Screen shot of a virtual fly-over the Meerstad study area. The layers in pink and blue represent the future changes in the landscape and can be set visible or not, and contain links to (geo)multimedia data.

In the research agenda of the cartography research for Virtual environments Slocum et al (2002) [12] defined four "I" factors important in creating Geo Virtual environments:

- *Immersion*
  Determine the situations in which (and how) immersive technologies can assist users in understanding geospatial environments. Cave and Headed mounted displays are typical hardware systems that allow a strong immersion, but sound (or even music) can increase the immersion feeling of the user.

- *Interactivity*
  Develop methods to assist users in navigating and maintaining orientation in GeoVEs. This challenge is closely tied with research on interface design and metaphors. The system was build for integrating high level of interactivity but also including orientation features.
- *Information intensity*
  Develop methods to adjust the intensity of information in the GeoVE. The prototype allows the user to have an overall view of the project but also to zoom in to particular areas and retrieve specific multimedia information of important points.
- *Intelligence of objects*
  Develop suitable methods for interacting with objects in the GeoVE. The development of an intelligent help system is planed as a further development of the Virtual Landscape Viewer (not yet implemented).

The proposed system was build taking into account this guidelines, and will be used to research on the user level the degree of the usability for each "I".

5. CONCLUSIONS

The system developed met all the proposed requirements. The consideration of cognitive design principles was a determining factor for the success of the Virtual Landscape Viewer. Having in mind the background of spatial planning, the developed and implemented Virtual Landscape Viewer showed that with existing tools and a computer game development environment it was possible to create a Communication Tool to facilitate on the dissemination of plans for the planners and the stakeholders. Recent developments in computer hardware and software allow us to use Technology for the people. We can say that hardware is no longer a limitation for the development of realistic and extensive virtual environments. The researchers can focus on questions on the cognitive science fields, and evaluate the right level of immersion or interactivity to use for understanding Geo Virtual Environments.

The chosen software approach reflects an open development process that is easy to extend, being able to meet the needs of planners and users.

The methodology proposed takes into consideration the adjustment of geo-visualizations methods to the cognitive characteristics of group users (stakeholders) via a flexible development and use environment. The system is also able to integrate high quality mapping of the current situation, 3D representations of the future and (geo)multimedia (regarding real world information). The people involved can understand the proposed plans and proposed changes. This new approach was built based on a pre-existing geo-information infrastructure which supports open plan process and participation and is able to integrate all available sets of data.

6. FUTURE WORK

The next steps to be considered are the evaluation of dynamic representations, in terms of what layers and interactivity levels are more appropriate for interactive plan preparation and evaluating the effectiveness of the proposed Geovisualization Methods. There is a protocol established that will allow the collection of data referring to the cognitive responses of the users of the use of Virtual Environments as a spatial communication tool. The perception of the users will be evaluated taking into consideration individual and group differences (sex, age, previous experience, and stakeholder group).

7. ACKNOWLEDGEMENTS

To all the developers and researchers of the Virtual Landscape Project for the enthusiasm and dedication. To the other members of the Steering committee (Adri van de Brink and António Câmara) for keeping the project in track always with the right goals.

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Interest research areas: Technology and Sustainability, Information services in Natural Areas; Wireless technology; Multimedia and Spatial Visualization