Integrated 3D-GIS and VR

Use of Virtual Reality and 3D-GIS within the Planning Process Concerning the Infrastructure

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Abstract

Within the planning process concerning the infrastructure, GISs are used frequently to process, analyse and visualise geographic data. Since works concerning the infrastructure more and more have an elevated, deepened or underground construction, the need for three-dimensional acquisition, processing and visualisation of data has increased rapidly over the last few years.

To process three-dimensional data, extensions to the GIS are designed. A good technique to visualise a three-dimensional reality is Virtual Reality (VR). Therefore, VR-techniques are used more and more frequently within the process of designing, decision-making and presentation of large operations concerning the infrastructure. By creating a (make-believe) reality, designers, politicians as well as citizens have the possibility to evaluate the prospective situation in a very direct way. Virtual Reality, however, cannot only be used as a nice show-box, but also as a real design tool for creating realistic visualisations of the design. Under these circumstances interaction with spatial information is a necessity. Thus, the next step would be to visualise spatial data during the planning process in a realistic and interactive manner, using a combination of a VR-system and a 3D-GIS. In this case Virtual Reality serves as a - almost by definition - solid visual interface for this specific purpose equipped 3D-GIS.

***Keywords**:* 3D-GIS, Virtual Reality, Visualisation, Planning Process

1.0 Introduction

Within the planning process of large works concerning the infrastructure GISs are used frequently to process, analyse and visualise geographic data. Traditional cartographic representations of spatial objects are often used for visualisation. However, the portrayal of a three-dimensional landscape in two dimensions on a conventional map is a fundamental limitation of traditional cartography and will lead to a loss of information and understanding. Since works concerning the infrastructure more and more have an elevated, deepened or underground construction, the need for both three-dimensional acquisition, processing and visualisation of data has increased rapidly over the last few years.

To process three-dimensional data, extensions to the GIS are designed. A good technique to visualise a three-dimensional reality is Virtual Reality (VR). VR offers new and exiting opportunities to visualise 3D-GIS data. Users can walk through 3D environments, see newly planned buildings and experience changes in the landscape. In most cases, however, interaction with the data is limited to viewing. At the most there is some limited form of navigation and query, e.g. the user walks around in the virtual environment and can point to objects in the scene and ask for information by a GIS database. The possibilities to query the GIS database in a more intelligent way and to access more advanced GIS functionality are limited.

We are currently developing a 3D-GIS/VR-system based on existing GIS and VR technology that links up with, and will eventually improve, the planning process concerning the infrastructure. However, before connecting the required hardware and software, it is important to look not only at the technical possibilities, but also at the user's demands to the system. The better the co-operation between users and system developers, the more chance that the system will be used successfully during the planning process concerning the infrastructure after implementation. Various aspects, which have lead to the basic set-up of a 3D-GIS/VR-system, are discussed in this paper.

First, we shortly describe the concepts of VR and 3D-GIS. Then we describe the different stages of the development path for large works concerning the infrastructure, which resulted from a research performed among several organisations that are involved with these works. Analysis of the research results leads to a program of conditions in which the introduction of three different views, ranging from 2D to 3D, is paramount. Next we associate the analysis and model manipulation techniques with these views. The views are being used to support both design, development and presentation of large plans concerning the infrastructure, such as a new track for a high-speed train, a tunnel under a waterway, etc. We conclude this paper with a short description of the design of the 3D-GIS/VR-system, which is currently being developed at Delft University of Technology [5].

2.0 Characteristics of Virtual Reality

Computer graphics techniques have been used widely in GISs to visualise data and to enhance the interaction of the user with the data. Existing visualisation techniques include plan-cartography, artist's impressions, scale models and photo realistic simulations [1], [6]. All these techniques have in common that they present a predefined vision of reality. It is not possible nor the intention to carry out a specific operation or analysis via these presentations. An analysis, e.g. defining a certain amount of environmental pollution, would result in a change or an adaptation of the design. As a consequence this results in a new, physical visualisation (e.g. on paper, polystyrene foam, photos).

Virtual Reality (VR) is a visualisation method that links up with these techniques [2],[3]. VR, however, can be used - not only as a nice show-box - but also as a real design tool for creating real-time realistic (3D) visualisations of the design. These new developments in Virtual Reality bring the promise of a much more involved way of interacting with the data: the user is right in the middle of the plan and can directly interact with the 3D data. So instead of watching the visualisation passively from a distance and not being able to interact with the design, the user is much more actively involved.

An ideal Virtual Reality system can give the user the impression that he/she is present in a synthesised three-dimensional environment. For the user to recognise objects, it is, first of all necessary to fill the space as much as possible with the realistic representation of a model of the study area. With works developing the infrastructure this is often a combination between the existing reality and the new situation. The image has to be created from the model in the same time, which corresponds with the change of viewpoint (real-time rendering). Besides real-time rendering, an important feature of VR is that users can manipulate objects by interacting within the virtual environment. Sounds can also be added. These requirements set up conditions for the hardware and software to be used, as well as for the modelling itself.

2.1 Systems

The basic concept of VR is the direct coupling of the head position and viewing direction of the user with the viewing position used to generate the image on the display. The head position of the user is constantly tracked and fed into the display algorithm to calculate at each moment a correct stereoscopic and perspective display of the scene. This strong coupling of the current eye position of the user and the image offered by the display system, gives the user the illusion of 'immersiveness'. The ultimate VR-systems completely immerse the user's personal viewpoint inside the virtual world. A major distinction of VR-systems is the mode with which they interface to the user. Current systems range from true immersive to non-immersive displays.

Window on a World

The most affordable system is the conventional computer monitor of the PC to display the visual world. This is called 'desktop VR' or a 'Window on a World' (WoW). The user himself is not present in the system, but it is possible to present an image of the first person on the screen. By offering nearly simultaneously an image for the left and the right eye through shutter glasses, the brains are capable to reconstruct a 3D-image.

Head Mounted Display (HMD)

Since most people have two eyes and thereby stereoscopically observe the world, it would be unnatural to present a three-dimensional reality on only one display instead of two. A head-mounted display (HMD) is an example of a fully immersive VR display (figure 1). It consists of a helmet or a facemask with two LCDs that effectively isolates the user from the real environment. However, a disadvantage of the HMD is that very powerful computing resources are needed to guarantee the required image update rate (> 20 frames/sec). When the user changes his/her viewing direction, a complete new image has to be generated instantaneously. This strongly limits the complexity of the scene to be displayed.

Figure 1: Head Mounted Display

Projection

Recently, projective display systems that project the image on a screen or wall (partly) surrounding the viewer, have become available. A good example is the CAVE. The CAVE is a cube of 3x3x3 meters with through-projection on three sides and a fourth projection on the floor (figure 2, left). The CAVE offers the user a stereoscopic surround projection and gives users the opportunity to be actually present in a virtual world. Using 'shutter glasses' creates the stereoscopy that offers images to the left and the right eye in fast alternation. A tracker registers the head position. In contrast to HMDs, no direct image update is needed when the user turns his/her head. The user just looks in another direction within the projected space. Only when the user changes position within the projection environment, the perspective has to be slightly adapted. The frame rate can therefore be lower and scenes that are more complex can be displayed without latency problems.

There are also projection systems that are simpler and less 'immersive' than the CAVE. The screen of the PC is replaced by a projection on a large cylindrical screen (Theatre VR) or by a projection on a screen from underneath a table (Virtual Workbench). The user of the system is not really present in the projected world, but because of the large viewpoint the view becomes much better. In order to obtain a good stereoscopic representation a refresh-rate of 2 x 30 per second is necessary. This is only possible with specially designed graphical hardware. With a single large projection screen, the 3D impression can still be maintained, but there is no surround projection. However, it is more suited for visual presentations to

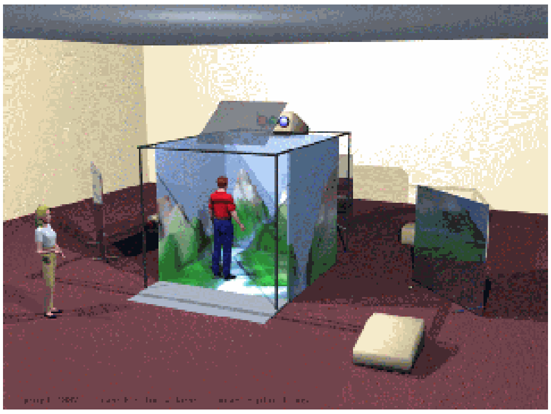
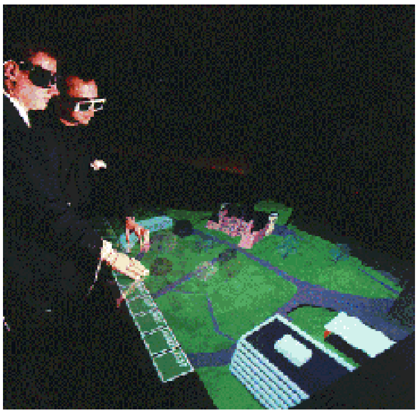
 

Figure 2: Surround projection in a CAVE (left) and projection on a Virtual Workbench (right)

groups. An interesting development is the so-called Virtual Workbench. This is a table with projection through the tabletop: the 3D image can be visualised on top of the table or inside the table (figure 2, right). The user is not 'immersed' but rather looks from above on the displayed objects. It offers a presentation mode that is normally associated with a 3D-scale model.

Augmented Reality

A very special form of VR is Augmented-Reality (AR), where the user has a full view on the real world, and the computer generated information is superimposed or fused with the real information, e.g. to label objects and buildings and to display information on these objects. AR can be realised with either an optical or a video look-through HMD, and it requires the same fast update rate as the standard HMD. AR is in particular of interest for mobile use.

2.2 Modelling

The geometry of an object is often derived from a complex model, which originates from a CAD-package. Often geometry in itself is not enough to determine the identification of objects. By making use of photo realistic textures in the proper way a simple model can look like a real house. It is also possible to work up a simple polygon with describing attributes, originating from a GIS-database, as a within the VR-world recognisable object of a house or a factory.

2.3 Software

Within the VR software there exists a strong division between authoring-tools and more general viewers. The authoring-tools are meant to build the world, and have basic functionality for geometrical and visual representation of the model. The viewers are partly available as so-called 'plug-ins' for Web-browsers. This holds especially for the Virtual Reality Modelling Language (VRML), in which the VR-scene is stored as a flat ASCII-file. The VR-scene is embedded inside the HTML-page, and by this the size of the data file of the VR world is limited. If the file is too voluminous, downloading the file takes too long to wait for.

Besides a geometrical and visual representation, objects are often linked with behaviour. As a result of this objects can move and can react on each other and on the user present in the VR-world. 'Collision detection' is only one of the preconditions, which makes this possible. Interaction with objects on the directions of the users is a complex matter. For this purpose a control mechanism has to be offered for both the virtual and the real world.

3.0 Characteristics of 3D-GIS

A 3D-GIS distinguishes itself from a 'normal' GIS by:

- the dimension of the spatial data in the system;
- the operations, manipulations and analyses which can be carried out on the data.

In a normal GIS, storage of data is still often based on

2D layers, possibly with an extension to 2_D surfaces. Even if a more object-oriented approach has been chosen, the nature of spatial relations between objects will be two-dimensional in general. This approach is feasible for geographic objects, which are almost directly related to the surface of the earth.

Underground, or on the contrary in the air, layer- or surface-based modelling becomes too artificial. In this case a data structure based on voxels (3D-pixels) is more appropriate. A disadvantage of this structure is the creation of the image in case of presentation of the data stored in the database. In case of layers of soil or the atmosphere this is not of real importance. As soon as man-made objects - the core of the works concerning developing the infrastructure - are involved this becomes of great importance. In this case a hybrid method can be chosen. The man-made objects are stored twice. The first time as a 2D representation in a 2D-GIS database and the second time as a CAD-model in an object library. Spatial relations and analyses are executed on the 2D-GIS database; for the VR presentation a choice can be made between the CAD-model or the 3D model diverted from the 2D representation. The whole is recorded on multi 2_D surfaces of the surface of the earth.

4.0 Linking VR to 3D-GIS

The linking of a VR-system to a GIS in order to support the planning process of works concerning the infrastructure has to go further than just extracting geometric data from a GIS-database in order to visualise them in a 3D environment. Visualisation alone is not enough. The same holds for a 2D-GIS map, which is not an aim in itself. In the past GISs have been used for this purpose. Nowadays one holds the opinion that the various data visualisation possibilities offered by GISs - not only a maps, but also tables and diagrams - serve as an interface between the user and the system. This visual interaction is of vital importance for the development of a good applicable GIS/VR-system, in which all GIS aspects can be implemented.

Visual interaction can be distinguished into orientation and navigation, selection and query, and manipulation and analysis. If the user is immersed in a 3D environment, this functionality has to be present in the 3D environment as much as possible. This can be established by making use of the virtual world itself, by offering virtual controls and - if desired - by supporting them by real controls. This is called visual interaction.

4.1 Orientation and Navigation

A user of a GIS/VR-system likes to know where he/she is and where he/she can go. This can be reached via a good identification and interpretation of the virtual world. Besides virtual controls, like a following compass, key maps and street maps are useful as well. Real controls are indispensable in this case. Without a 3D-mouse or joystick moving is unthinkable. Only if the whole virtual system is as mobile as the user – something which might be achieved by means of an ‘augmented reality’ system - it becomes possible.

4.2 Selection and Query

During a query of geometric and thematic data and relations within a study area defined by the user, it should be considered that a virtual world is in fact a virtual representation of the digital landscape model (DLM), matching the one which has been stored in a GIS. Because the user is present within this representation, he/she might not be aware of the fact that a selection or query does not refer to what he/she sees - the digital cartographic model (DCM) - but to the underlying landscape model. Input in the DCM starts a process in the DLM, which gives an output in the DCM. This output has often a more schematic and thematic nature than the input. For selection and query the user has the same virtual and real controls at his disposal as during orientation and navigation. These controls are complemented with the use of a normal PC. It is unfeasible and not desirable to copy or to replace all the possibilities of a combined use of keyboard, mouse and screen by an equivalent in the virtual world. The use of VR-systems, in which the user is totally isolated from the outside world, like with a ‘head-mounted-display’, should be discouraged.

4.3 Manipulation and Analysis

Real GIS operations, like manipulation of objects present in the real world, performing analyses or modelling the real world, are even more complex than selection and query. It should be considered that noise nuisance, reduced view or other disruptions in a 2D-GIS result almost out of necessity in numerical values, whereas an impression or a perception are far more illustrative. A VR-system has the possibility to support these qualitative analyses; the possibility to walk around for fifteen minutes and to apply for further details in a make-believe world, can contribute a lot to the decision-making process. From an end user it may not be expected that he/she steers towards a rather intensive calculation and a well provided process of parameters. The GIS/VR-system should however offer a certain subset of this analysis to the user via a number of different scenarios or variables by means of a number of meaningful controls variables (e.g. to choose between different heights or materials for a screen against noise nuisance).

5.0 The Planning Process and the Use of 3D-GIS

Before we describe in more detail the linking of VR to 3D-GIS, it is important to know more about the different stages of the planning process of large works concerning the infrastructure. In this way we can design a system that links up closely with the activities during the planning process.

Research of the planning process, performed among several organisations in this sector in The Netherlands [7], tells that it can be divided into three phases: phase of orientation, phase of design and modelling, and phase of presentation and final decision-making. During this process, reality is described from global and small scale to detailed and large scale, and more often from 2D to 3D. Each phase knows a different use of GIS.

5.1 Orientation (Plan Study)

During this phase, the problem is studied and all relevant information is collected. After a first analysis of the problem, one or more sketch designs are made on maps with a scale of 1: 10,000 to 1: 100,000. The impact of the design on its environment is analysed by specialists from different disciplines. The different variants are compared and one or two main variants are chosen for further elaboration.

The use of GISs is confined to standard 2D functionality for creation and manipulation of geographic entities, and for analyses with respect to the impact on traffic, population, economic parameters, environmental issues, etc. Typical queries are buffer, overlay, network and closeness analyses. Modelling is limited to symbolic and abstract entities such as contour lines and profile lines, axes, etc. Objects are only indicated by position and contour. Visualisation is through 2D maps, tables and diagrams.

5.2 Design and Modelling

The two or three remaining alternatives are now elaborated and buildings and constructions, such as bridges, viaducts, banks, are dimensioned and drawn as 3D objects. The overall shape, however, is still rather simple and not very detailed yet. More important are the size, the dimension, the relation between objects, the general arrangement of objects, etc. Central is the ability to arrange and manipulate the different components and to analyse their role in the total solution. Visualisation is often done with a 3D scale model. Interaction is in the manipulation and arranging of the objects. Once the general arrangement is set, attention shifts to the technical details and realisation problems.

The use of GISs in this phase shifts from 2D to 3D modelling and analysis. Buildings and constructions are modelled with a CAD-system and linked to data in the GIS, and the 3D information is used to calculate volumes, distances, sound contours, shadowing, line-of-sight, etc.

5.3 Presentation (Decision-making)

Once the design has reached the status of a well-engineered proposal, it will be converted into a form to be presented to all participants in the decision-making process. This can be either through detailed drawings, artist's impressions, CAD renderings, photo-collages, or with very detailed and realistic scale models. The different variants and alternatives will have to be compared and their consequences and performances clearly outlined for each of the different participants (e.g. designers, politicians and citizens). The more realistic the presentation can be, the better the plan is communicated.

GIS analyses in this phase involve the impact of the new design on its environment. The design is evaluated with respect to its exploitation, maintenance, usability and environmental quality. Cost estimations and a planning for the building process will be made at this point. Visual analysis is the main task at this stage of the plan process and a more realistic visualisation will only improve the presentation of the plans.

5.4 Requirements to a GIS/VR-system

Problems during the planning process in the existing situation arise because of lack of 3D functionalities to analyse and visualise the 2D/3D data. To visualise the design and its influence on the surrounding area (2D) maps of the area, sketches of the works concerning the infrastructure, scale-models and animations are used. These visualisation media are very static and show a very simple view of the (future) situation. Also, there is little or no interaction between the spectator and the data.

From this analysis of the planning process the most important requirements for the new system are therefore possibilities for 3D analyses, a good visualisation and interaction with the data. The presentation itself is not the final purpose. For a good visualisation that supports both design and decision-making, it is important that data can be visualised using different media (e.g. on a conventional computer screen, CAVE, Virtual Workbench) and using different dimensions.

6.0 Views of the Planning Process Concerning the Infra-structure

A linked GIS/VR-system can only be used as a decision support system within a certain organisation if the whole process of data exploration, processing and manipulation can be carried on through data (analyses) and presentation. In order to take advantage of a GIS/VR-system with multiple thinking, working and handling levels within one organisation, it is important to distinguish between the phases of the planning process (chapter 5).

Combining the three discerned phases of the planning process and interaction modes with the different VR visualisation techniques, we derived three modes for the modelling and visualisation, which we called 'views'. Every view offers a specific form of functionality, from which the results are passed to the other views. Views fit close to the planning process, and vary from global map ('*Plan view*') via a design mode ('*Model view*') to a presentation mode ('*World view*'). In each of this views the GIS functionality and, by that, the visual interaction are tuned to the objective, i.e. to design and present simultaneously a large work concerning the infrastructure in a good and clear way. These views or modes can be used simultaneously or intermittently, and each provides a repertoire of interaction possibilities that is apt -but not necessarily limited- to that kind of visualisation and interaction.

6.1 Plan View (2D)

In the 'Plan view' the information is just 2D and covers a fairly large area. This is the regular 2D-GIS interface where the GIS data is displayed in a conventional map format. The user can create and manipulate the objects as 2D symbols (points, lines, polygons and text) and simple 2D vector or raster representations. This 2D view mode offers standard GIS functionality through graphical interaction and alphanumeric queries. Navigation is possible through panning and scrolling. The level of detail can be adjusted by zooming in and out or by adapting the scale of the map or the level-of-detail of the map representation. The display system is a standard monitor or a window within a VR-system.

6.2 Model View (2_D)

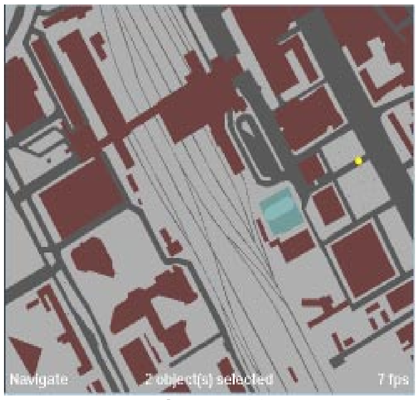
In the 'Model view' the altitude component becomes more important. The model is described as 2_D or 3D geometry. The representation is still simple and symbolic: basic geometry without realistic detail, as would be used for a 3D scale model. This form of representation is very suitable for manipulating the individual objects such as needed for positioning and orientation. Objects can be grouped or organised in a hierarchy or layer and can be manipulated using these relations. Geometric constraints could be defined to align roads and bridges and guarantee continuity in connections under transformations. In addition to 3D data, also symbolic information can be displayed such as reference lines, object attributes (e.g. land use) and manipulation handles.

Visualisation is through a bird's eye view: the user looks down on the model as if it is a 3D scale model. This view offers an overview on the area of interest, giving users the ability to make changes to the model without losing sight on the (overall) effect of these changes. The Virtual Workbench is a suitable display system for this viewing and interaction mode.

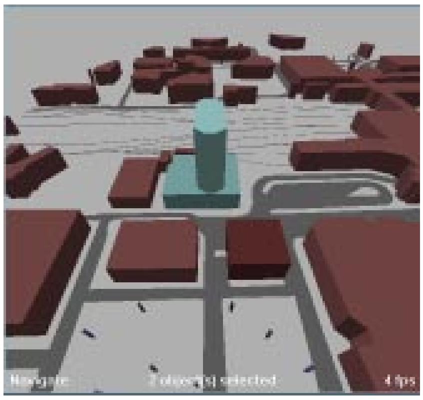
6.3 World View (3D)

The 'World view' is complete 3D-GIS and is in fact used for the final presentation of the decision-making process. This is the immersive view on the 'virtual world'. The user sees the model from a certain position within the model. The purpose of this view is to give a realistic impression of the plan, both visual and audible (tactile feedback is still a problem). The image quality of the display should be comparable with video quality and the image update should be very fast to allow 'walk-throughs'. Real-time image update is needed to maintain the illusion of 'immersiveness'. A HMD can be used as display system but systems with surround projection, such as the CAVE, are preferred.

A special form of the 'World view' would be an augmented-reality display on the spot, where the virtual objects are merged into the view on the real world. This would allow plan visualisation within the real environment, e.g. to project a new rail track through an existing environment.



Plan view (a)



Model view (b)

World view (c)

Figure 3: Different view modes visualising a part of the centre of the city of Utrecht in the Netherlands.

6.4 Functionalities of the Views

Figure 3 shows the three views: Plan (a), Model (b) and World (c). Although the views correspond with different phases of the plan design process, this does not mean that the views can not be used alternately. At some point, it may be handy to return to the 'Plan view' because it may be easier to specify a GIS-query in this view than in the other views. Or to return to the 'Model view' to change the position of an object, because the necessary overview to manipulate an object will not be sufficiently supported in the 'World view', and in the 'Model view' it is more convenient to display symbolic lines for references, etc.

Further, for each view there is a preferred display system. The 'Plan view' is most efficient on a monitor with window and mouse interaction, the 'Model view' with a Virtual Workbench and two-handed interaction (see fig. 2, right), and the 'World view' with pointing and navigation interaction tools (see fig. 2, left). However, it would be very inconvenient to always have to change display system when turning to another view. Therefore, all views should be supported on all available systems. It should be possible to open a window in the 'World view' to display the 'Plan view'. Similarly, it should be possible to display the 'World view' on a standard monitor, even if this would mean loss of stereo and sense of immersion.

Each view will have its own geometric model representation. The 'Plan view' will need a 2D symbolic representation of lines, text and pseudo-colours. Buildings are indicated with their contours. Symbols, texture or colours indicate land use. The second view, the 'Model view', will have a basic 2_D model representation, such as a TIN (Triangular Irregular Network), possibly with multiple surface layers, to represent the ground level and 3D objects, composed of elementary building blocks to represent houses, buildings and constructions. Finally, the 'World view' will have a very detailed 3D-CAD model, enriched with texture maps and procedural models (trees, clouds, etc.). Thus, the system will have to support several model representations simultaneously and to provide conversions automatically in case the model is changed in one view and then viewed again in another view.

The modelling will also have to support interaction and manipulation of objects through parameterisation, such that objects can be scaled and dimensioned. Further, the model will have to be constrained by geometric relations in order to support the interaction (leave the desired number of degrees of freedom), to keep the model consistent and to keep objects aligned with each other, e.g. a road with a bridge. The user should further be able to add grouping relations between objects to allow meaningful manipulation of groups of objects.

GIS functionality (i.e. analyses and queries) should also be supported in all views, although each view may have a specific way of interaction to select objects and to specify the query operators. E.g., in the 'World view', it would be most natural to have the symbolic (alphanumeric) information specified with a spoken-language interface, while in the 'Plan view' a more conventional interaction method may give a better user support.

At the other hand, the system should not only support geometric simplification but also enrichment of the geometric model. It will not always be feasible or be too costly to model a complete realistic-looking environment. Methods will have to be supplied to semi-automatically derive complex and realistic-looking geometry from a limited set of input parameters and general knowledge about how things look. E.g., a procedure could be devised to give the elementary building volumes of the 'Model view' a realistic 'town-like' appearance in the 'World view'. Houses that have an agricultural function can be displayed as farmhouses, etc. In that respect, the system will have to support both model simplification and model enrichment.

Finally, the three views also require different ways to navigate through the data and to interact with the data. The 'Plan view' is very suitable to specify, select and explore data. Navigation is through scrolling, panning and zooming or through browsing exploring hypertext links. In the 'Model view' relations, constraints, layers and other hierarchical and grouping structures will have to support manipulation and interaction. View point changes and navigation will be steered by real head movements of the user. In the 'World view', navigation will be moving the virtual eye point through the 3D scene. Pointing will do selection.

Table 1 gives an overview of the three 'views' and the corresponding model representations and types of visualisation and interaction.

	Model	Visualisation	Navigation	Selection	Manipulation	Analysis
Plan view (2D)	2D-GIS - topography - attributes	- cartographic map – table	- pan and zoom - scale - specify position - scroll	- query - position - distance - attribute	- create - remove - position - orientate	- buffer - overlay - network - neighbour
Model view (2_D)	2D-GIS +topography +attributes (extrusion) - multi-TIN surfaces - relations	- 3D scale model - symbolic representation - handles - references	- view-point - centre of interest - zoom	- relation - layer - group	- position - translate - scale - rotate - define relations	- line-of-sight - contours - volumes - distance - shadow
World view (3D)	- 3D-CAD polygons - textures - video	- immersive - realism - level-of-detail	- walk-through - move - pointing	- info - data - detail	- options - variants	- impact - sound - sight

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

7.0 System design

To realise the above-mentioned concepts, we will develop several VR interfaces for a 3D-GIS system, using standard GIS, CAD and VR components. Currently a system called Karma VI is developed [5] as part of the project “3D-GIS&VR”of the Dutch LWI-foundation. Karma VI is based on existing GIS (ESRI SDE) and VR (Sense * WTK) technology to support the design, development and presentation of large plans concerning the infrastructure in The Netherlands. Karma VI uses the multi-view approach where each view mode has a preferred VR display system. Next to the different view modes, an essential feature of the system is the support for manipulation and editing of GIS data from within the VR environment.

For the GIS, we have chosen one central data server. Data from other GIS sources will be imported and converted if needed. CAD model data will also be imported from external CAD-systems. Given the existing (low-level) CAD interfaces only simple geometric data can be imported. The constraints and parameterisation will have to be added within the VR-system. During interaction, the CAD data will be in the VR-system for efficiency reason. After the manipulation, database updates will be executed to keep the data in GIS consistent with the VR-system.

For the VR visualisation, several modules will be developed to support the different views. These modules will be developed using one VR toolkit. The modules will run on all the available equipment, either simple monitors or more specialised equipment such as a CAVE or a workbench. Each system will be able to support all the views, possibly simultaneously, or shared with other equipment.

The different views will need different geometric representations. This can be realised in one of the following ways. Maintain:

- a central representation and derive each time a specialised model from this central representation. Interactions and modifications are executed directly on the central model. In this way, the consistency is easily maintained, but projection to other views is not trivial;
- several representations simultaneously and pass changes made in one representation to the other ones. This requires model conversion technologies.

Given the complexity of the ‘World view’ model, the first option is not feasible. However, we could use the constraint graph representation that is needed for the parameterisation and for the support of the interaction and manipulation, as a central data structure. The different representations for the different views are then derived from this constrained-based representation.

8.0 Conclusions

A Virtual Reality System - used as front-end of a GIS - has a surplus value if a user can make use of this linked system as a 3D-GIS. To reach this aim it is necessary that within each of the design phases, which take place in a project for the development of large works concerning the infrastructure, the user is supported in the right way. The three view modes for modelling and visualisation make that possible. However, for analysis and model manipulation, a good elaboration of the concept of visual interaction is of vital importance. In this way, we can avoid that VR is used only as an (expensive) presentation technique in which GIS only functions as a data source. VR should be used as a tool and not as an objective!

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