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Visual Analysis Tasks for Three-Dimensional Interactive Environmental Applications

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Abstract

The goal of the paper is to discuss visual analysis tasks for three-dimensional interactive environmental applications. To achieve these objectives the paper firstly concentrates on identifying object content, which is likely to be used in environmental applications. Secondly the paper discusses presentation techniques of the object content in the applications. Thirdly the paper investigates interaction techniques for the visual analysis. Finally the paper describes the successful implementation of the presented techniques in an environmental example application (GeoPro^{3D}) used in the Environmental Information System (UIS) of Baden-Württemberg in Germany.

1. Introduction

The visual presentation of environmental data in three dimensions is becoming more and more important. The third dimension can contribute to a deeper comprehension of spatial situations. This includes two different approaches. Firstly, due to the fact, that the real world is 3D and human experience is gained from that world, modelled virtual 3D scenes similar to the real world are easy to understand. One example is the 3D visualisation of a digital terrain model compared to a contour line map, which can be misinterpreted by unexperienced users. Secondly, 3D can be extended by visual elements, which can not be seen in the real world. An example is the integration of geological layers below the ground surface. This visualisation deepens the comprehension of spatial interrelations for experts. Thus, the third dimension can assist in deepening the understanding for experienced and unexperienced users groups. Important for users is the visual analysis of the content of the scene. The presentation of the 3D scene should be clear and easy to understand and needed interaction techniques for further investigation should be handled easily.

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2. 3D object content of Environmental Information Systems

This section discusses the environmental objects considering the use in 3D environmental visualisation systems. According to Oliver Günther any real-world object can be regarded as an environmental object. He identifies the following environmental objects groups [Günther 1998]:

- Atmosphere (Clouds)
- Hydrosphere (Sea, Lakes, Running Waters)
- Cyrosphere (Snow, Ice)
- Litosphere (Rock, Soil)
- Biosphere (Cultivated land like forest and agriculture and non-cultivated land)
- Technosphere (Residential or industrial built-up areas and traffic routes)

Many of these environmental objects can be part of a 3D visualisation task, implemented in some of the following environmental information applications:

- DEMViewer - The 3D visualisation of digital elevation models in combination with individually designed maps as texture [Hilbring, Schneider 2003].
- GeoPro^{3D} - The visualisation of ground water in combination with planned construction sites for detecting conflicts [Hilbring 2002].
- Flood view - The simulation of flood waters [Diamandakis 2002].
- The simulation of glaciers in the Alps visualising the effects of climate changes [Biegger 2002].
- Melinda - A system for the evaluation and monitoring of contaminated sites [Leinemann 2001].
- Spatial analysis in Forest - The project analyses insect attacks in forests considering information about the terrain, soil, wind influence and former damages [Netherer 2002].
- Geological environmental analysis for detecting appropriate waste disposal sites [Malinverni 2003]
- The visualisation of weather models [Vis5D 2004].

The first goal of this paper is to identify objects content, which is likely to be displayed in a 3D environmental information system. Considering the environmental object categories and the given 3D visualisation examples, it is possible to abstract the following types of 3D object content for 3D environmental visualisations:

- Surface objects, representing the ground surface, geological layers, water layers or the top surface of a glacier.
- Volume objects, representing climate issues like wind fields or clouds.
- Point objects with specific information at defined coordinates.
- Vegetation.
- Men made objects like traffic routes and buildings.

Taking a look at the example applications one can note that the visualisation of the terrain surface is important for the understanding of the virtual scene and is used in many environmental applications.

3. Three-dimensional visualisation presentation tasks

This section concentrates on the visual presentation of the identified object content in the three-dimensional virtual reality. The virtual world should be easy to understand. Ideally it should have a realistic appearance. Thus, depending on the expert visualisation task of the environmental application, the 3D object content types need to be extended with meaningful information, so that the user can easily understand the object representation. Techniques, which can be used for adding meaningful information are:

- Adding object specific colour:
  On the one hand colours possesses conventional meanings: red lights are associated with danger, green with safety and yellow indicates a situation in which caution should be exercised [Domik 2004].
  On the other hands colours can be used to improve the recognition of objects. In maps water is usually coloured blue, forest is green, mountains are brown or grey. These colours corresponds with the real world.
  Depending of the goal of the 3D visualisation these techniques can be used for adding meaningful information to the objects.
- Texturing of objects:
  "Texturing, also called *texture mapping*, is a way to add visual richness of a surface without adding fine geometric details. The visual richness is provided by an image, also called *texture*, which gives the appearance of surface detail for the visual object." [Sun Microsystems 2002]. The image is mapped on to the geometry of the 3D objects.

One way to use texture mapping is to map images containing real world textures on top of the 3D object content. Using for example satellite images or aerial views as textures for a digital elevation model leads to a more realistic impression of the terrain. Another way is to use images containing additional information about the objects as texture. The example shows a topographic map as texture for the terrain containing names and land use categories which can not be found in an aerial view.

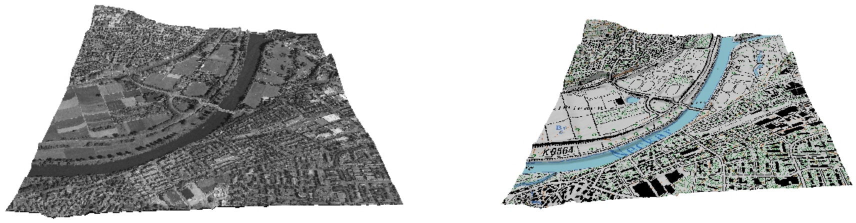

Figure 1:Terrain textured with aerial view and topographic map

- Adding explaining text elements:

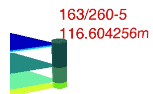

Figure 2: Borehole with explaining text elements

Despite the use of colour or texturing techniques several objects might need further explanation. In that case the adding of text elements in a virtual scene might be helpful for providing additional information. Each object can be accompanied by one or more text parts. Using this technique, objects can be identified by their ID or measured values of objects can be displayed.

4. Interactive visual analysis tasks

This section describes interactive analysis tasks for the user for analysing the object content of the environmental 3D scene. We can distinguish between tasks, which are useful in all (including environmental) 3D applications like orientation and navigation, picking or “interest clipping” and in tasks which are unique for environmental applications like loading new terrain parts or the creation of profiles.

Once the user has an understanding of the virtual scene he wants to investigate the contents. Firstly, he needs to change the view for moving in his region of interest. Changing the view includes two steps: *orientation* and *navigation*. Before the user can change his viewing direction he needs to orient himself. Thus he needs to know his position. An overview window containing the entire scene and marking the viewer position can give this information. A virtual camera in the overview window marks the position of the viewing platform. That is the virtual position of the viewer. A frustum of pyramid borders the object content, which is visible in the main window. This frustum is called *viewing frustum*.

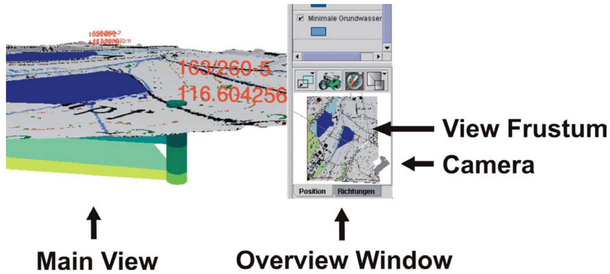

Figure 3: Overview window

Once the user knows where he is, he wants to explore the 3D content of the scene changing his position and viewing direction. This is called navigation and can be achieved by using the normal mouse. Each button is allocated by one navigation type: one for zooming, one for panning and one for rotating the scene. The navigation types could be also connected with the cursor keys on the keyboard or with virtual buttons in the graphical user interface of the program displaying the 3D scene. Each navigation process changes the position and viewing direction of the viewing platform in real time in the overview window and the corresponding visible section in the main view.

Secondly, the user wants to gain additional information about objects in the scene. This goal can be achieved by picking and "interest clipping". *Picking* describes the selecting technique in a 3D scene. The user selects the object of interest by clicking with the left mouse button. The object will be highlighted and is read for further processing. *Interest clipping* is a techniques which gives the user the possibility to specify his viewing region of interest. The user picks his objects of interest, which can be represented by a single object or by a group of objects. By picking these objects a region of interest is defined. This region is clipped from the scene and displayed for further visual analysis. The next part of the paper will concentrate on techniques, which are unique for 3D environmental applications.

Terrain is not bounded in the real world, but due to memory and performance issues it is not possible to load the entire existing terrain data of an application in the 3D viewer at once. The solution is to load a starting terrain part which can be automatically (during navigation) or interactively replaced by other terrain parts. The automatic reloading of new terrain parts is often used in 3D terrain viewers. It is helpful for users wanting to explore the terrain and objects displayed on top of the terrain. Applications using this approach can be used by experts for urban planning purposes or by the public for planning hiking tours. The interactive reloading of new terrain parts is appropriate for applications where the focus of the user is concentrated on a specific region, including objects below the terrain surface (eg. geological layers). In that case the user might want to explore the loaded region from different viewing angles, before he decides to reload a terrain part in a desired direction.

The creation of 2D cross profile views is another typical environmental interaction technique. For creating 2D cross direction slices the user firstly needs to specify the place of the profile by positioning a slice using the cursor keys viewing from top of the scene. Once the appropriate position is reached the users starts the creation of the profile. Finishing the calculation of the profile it will be displayed in the view.

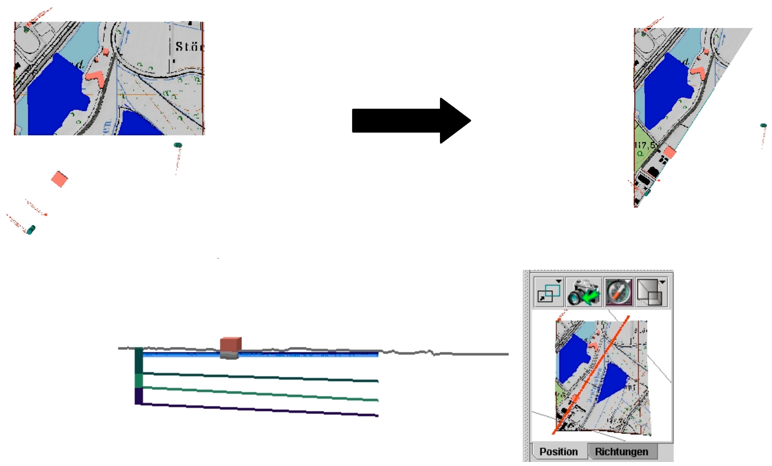

Figure 4: Creation of generic profiles

5. Use of presented techniques in an example application - GeoPro^{3D}

This section describes the use of presented techniques, which are implemented in GeoPro^{3D}, a three dimensional environmental example application. GeoPro^{3D} is a specialized tool for the visual analysis of the groundwater situation in spatially bounded regions [Hilbring 2002]. It is developed for the "Umweltinformationssystem Baden-Württemberg", an environmental information system within the development project AJA (JAVA oriented applications) [Mayer-Föll 2003]. The "Landesanstalt für Umweltschutz" is attending the technical aspects of the development.

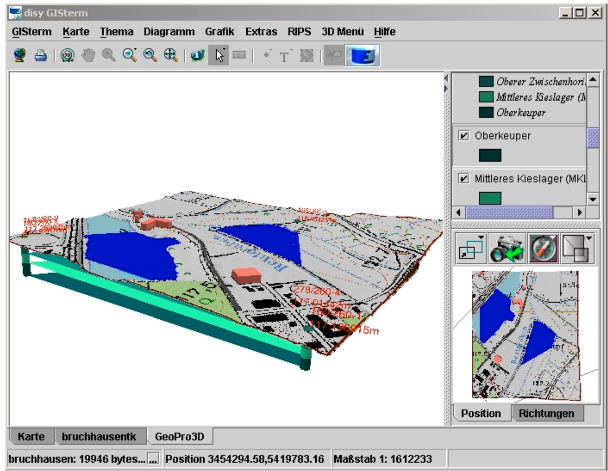

Figure 5: GeoPro^{3D}-Scene

The example application will show the successful integration of the described presentation and interaction techniques. The goal of GeoPro^{3D} is the visualisation of the ground water table and hydro geological layers in combination with planned construction sites. GeoPro^{3D} creates a virtual scene using user specified information about the terrain texture, ground water measurement points and buildings and routes. The scene contains the following content:

- The ground water table is visualised in three ground water layers (minimum, medium and maximum). These layers are coloured in different shades of blue.
- A borehole layer is created containing all ground water measurement points. These boreholes are accompanied by text elements containing the borehole id and the terrain height of the borehole.
- Hydrogeological layers are created by triangulation between the boreholes.
- A terrain layer is created from a digital elevation model in 5m resolution textured by an aerial view or a topographic map containing text elements.
- A building layer is created containing 3D building and route objects created by the user specified information. The objects are placed on top of the terrain.

The task of the user is to analyse the created scene. Firstly he can use the navigation and orientation functions for exploring the scene. Secondly GeoPro^{3D} includes several tools for further analysis:

- Interest clipping of the building region:

The user can pick one or more buildings in the scene using the selection function. They will be highlighted in yellow. By picking the buildings the region of interest is defined. The activation of the interest clipping functions cuts the region from the scene and displays it in the main view for further visual analysis.

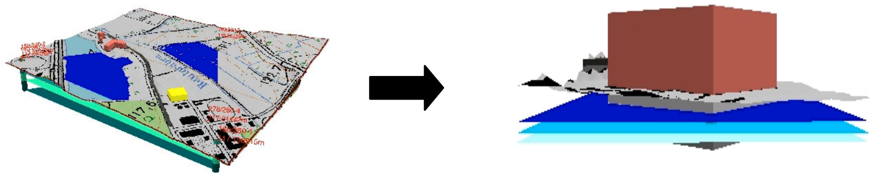

Figure 6: Analysis of building with interest clipping

- Interactive reloading of terrain and accompanied boreholes:
  Sometimes the users notices that a neighbouring region might be of interest for the analysis of the scene. Solving that issue GeoPro^{3D} extends the function for reloading adjacent terrain parts. Loading a new terrain parts leads also to the creation of new GeoPro^{3D}-Scene objects, like boreholes, hydrogeological layers, water layers and text elements lying in that region.

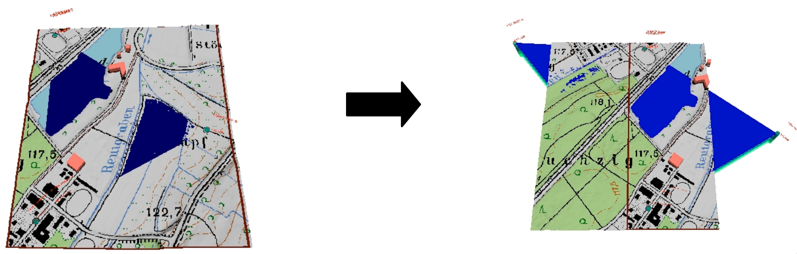

Figure 7: Reloading function

- Creating 2D profiles along roads :
  GeoPro^{3D} offers a function for creating cross profiles along the run of a route displayed in the scene. Firstly the user picks the route. Secondly he defines the starting point and the distance of the cross profiles in a user dialog. The first profile will be displayed and the user can interactively call the creation of the next profile. This functions combines picking and the creation of cross profiles.

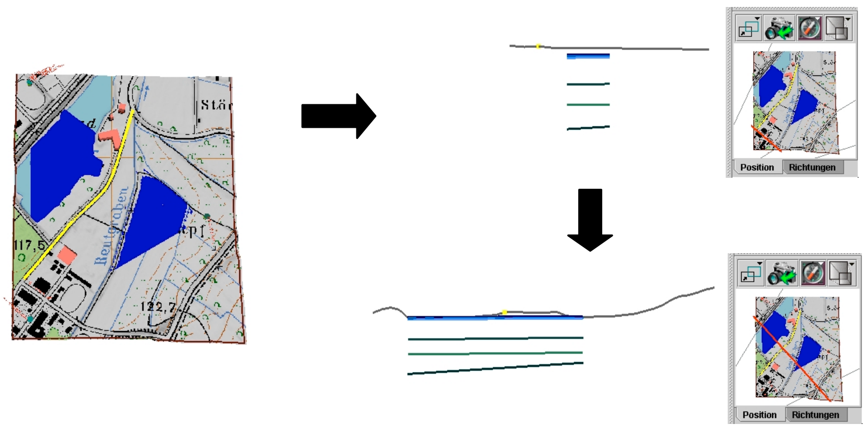

Figure 8: Creating 2D profiles along roads

6. Conclusions

The example application GeoPro^{3D} shows that due to the wide variation of 3D visualisations in environmental information systems it is not possible to cover every specific task in a collection of visualisation and interaction techniques. But it is possible to create a pool with common techniques, which can be selected and combined for solving specific visualisation and interaction tasks.

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