

## INTERACTIVE ANALYSIS FOR 3D-GIS TOOLS

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### ABSTRACT

Interaction is a very important part of software development. This article explains different interaction techniques for universal GIS applications. Further it investigates these techniques for the dedication in a three dimensional GIS environment. It is possible to define two main categories: universal interaction types and application specific interaction types. The interaction functions belonging to the first category are necessary in almost every 3D GIS application, while the interaction functions belonging to the second category envelope a wide range of specific functions. Thus they are hard to generalise and must be developed for each specific case. This article will show examples of the first category in a 3D software development system and examples for the second category, featuring a specific 3D GIS application.

### KURZFASSUNG

Interaktion ist ein wichtiger Teil der Softwareentwicklung. Dieser Artikel erklärt verschiedene Interaktionstechniken für allgemeine GIS-Anwendungen. Diese Techniken werden weiterhin für den Einsatz in einer dreidimensionalen GIS Umgebung untersucht. Es ist möglich, zwei Hauptkategorien zu unterscheiden: allgemeine Interaktionsarten und anwendungsspezifische Interaktionsarten. Die Interaktionsfunktionen der ersten Kategorie sind in fast jeder 3D GIS Anwendung notwendig, während die Funktionen der zweiten Kategorie ein weites Feld spezifischer Funktionen umfassen. Die anwendungsspezifischen Funktionen sind schwer zu verallgemeinern und müssen für jeden einzelnen Fall entwickelt werden. Dieser Artikel zeigt Beispiele für die erste Kategorie anhand eines 3D Software Entwicklungssystems und Beispiele für die zweite Kategorie anhand einer spezifischen 3D GIS Anwendung.

## 1. INTRODUCTION

Besides the visualisation of 2D data the visualisation of 3D data has continued to grow in importance. One reason is, that it is possible to display virtual scenarios in an appearance similar to the real world. Another reason is, that the third dimension helps in displaying complex spatial information for visual analysis tasks. It is possible to present data in a way, which combines realistic world objects (e.g. a terrain shape) with abstract objects (e.g. a 2D topographic map). The familiar look of well known objects helps the viewer to concentrate on the analysis problem.

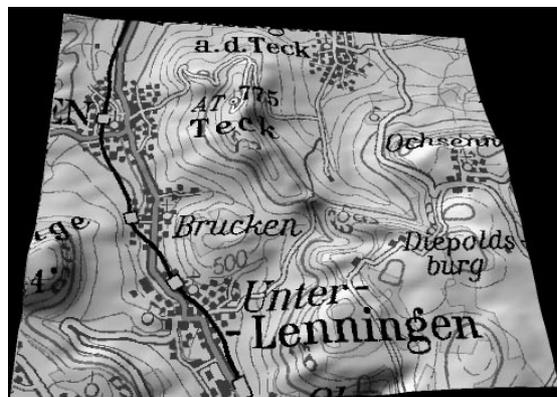


Figure 1. Digital elevation model with topographic map texture

To create such a scenario it is necessary to combine a GIS with a virtual reality for the visualisation of 3D data. But the sole visualisation of the given data is often not enough. The generation of a fundamental analysis from the given data needs interactive techniques to extract the bits of information needed to solve the problem.

For the intervention of the user into the virtual world some kind of devices are needed. Devices like Head-Mounted Displays, data gloves etc. have been popularised in the entertainment media and are recognised by the public as symbols of virtual reality. Here we are at the high end of experiencing a virtual world. On the other hand, an example definition of virtual world is: "Virtual reality is the simulation of a real or imagined environment that can be experienced visually in the three dimensions of width, height, and depth" [Whatis]. That means it is also possible to create a virtual reality with a "low" personal computer. That is the kind of virtual world this article is referencing to. The user views the virtual world at the monitor. To intervene into the content of the displayed virtual world it is possible to restrict the interaction devices to the well known mouse and keyboard.

## 2. INTERACTION

The intervention of the user in software applications is not restricted to the intervention with 3D content. Commonly the intervention is called user interaction. "Interaction is when the imagery changes in response to user action" [Interaction]. Thus user interaction is a well known task in universal software development. This article concentrates on typical

GIS interaction types applied by the user to intervene into the scene. This envelopes a wide range of activities. We want to name and categorise some GIS interactions into different types, valid for both 2D and 3D GIS scenes.

## 2.1 Classification of Universal Interaction Types

One classical interaction type is the navigation through the GIS scene. Commonly addressed as navigation is here the change of the view due to user interactions. Typical GIS interactions are:

- Panning
- Zooming
- Zoom to extent

To analyse the scene content the user often needs to select one object for further activities. This is another interaction category mostly referred as “picking”. Picking includes the click of the user on an object and the resulting selection. The object has then focus for further action. The following actions are performed directly on the object and can include:

- Moving the object
- Change the shape of the object
- Change the appearance of the object
- Display further information about the object
- ...

Picking is an interaction category, which is performed on special object content.

Another interaction type is the appearance manipulation of the scene. In this category all interaction functions changing the entire scene are included:

- Changing the scale
- Changing the background color
- Changing the appearance of all objects in the scene
- ...

These categories are still missing the really interesting part, in which all kind of interaction techniques can be imaginable for developing analysis techniques for problem solving. These interactions envelope a wide range themselves and can be very specific.

Thus there are some common interactions, useful for every displayed image scene and otherwise there are application specific interactions for problem solving.

## 2.2 Common 3D-GIS Interactions

Until now, only universal GIS interaction categories were discussed. In the following this article will have a closer look at common 3D GIS interaction types.

Navigation through the virtual world is necessary for exploring 3D content from several viewing positions. The 3D-object content of a virtual world is displayed on a 2D device, the monitor. Thus additionally to panning and zooming the user needs the possibility to rotate the object content. In the cases described by this article the user has only a 2D device to interact with the virtual reality, the mouse. But it is possible to use the normal mouse for 3D navigation. One technique is to allocate each mouse button with one navigation type: one for zoom, one for pan and one for rotation. The rotation is managed by the combination of a click into the 3D scene, which defines a starting point, with the direction of the mouse movement. This technique is the default navigation technique for simple Java3D applications. Other techniques are including virtual input devices for the navigation functions into the program.

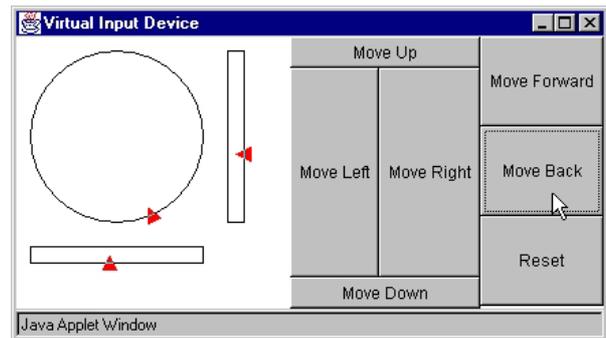


Figure 2. Example of virtual input device

The realisation of the navigation in the virtual world is independent from the transmission way of the user input. It is possible to fulfil that in two different ways. The first approach is changing the actual co-ordinates of the 3D object content, every time the user performs a navigation task, while the second approach actually changes the position of the viewing platform, from which the virtual observer views the 3D scene. The first approach is often used in CAD-Systems and the second approach is often used for large virtual realities including terrain data. Thus the second one is the choice for an interaction type in a 3D GIS.

One big issue during the navigation in a virtual environment is the orientation of the user. It often happens that the viewing platform gets lost in space and the user only sees dark space. For this case the common 2D interaction “Zoom to extent” is helpful, but the orientation in the virtual world can be improved. The following images show an overview window in which the entire 3D scene is displayed. The user can change the view, from bottom to side, so that it is possible to extract the position and height of the viewing platform (represented by the camera) in the virtual universe.

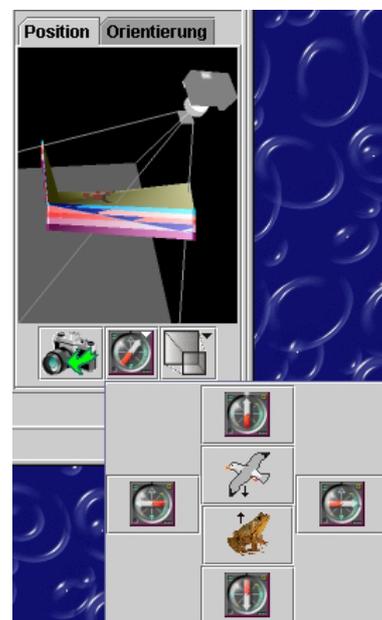


Figure 3. Overview window viewing the scene from the south direction with panel for change of viewing direction

The overview window shows additionally a pyramid frustum which borders the 3D content. Only 3D content inside the so called “view frustum” is displayed in the main view. Thus the user can see always, where the 3D scene is being clipped.

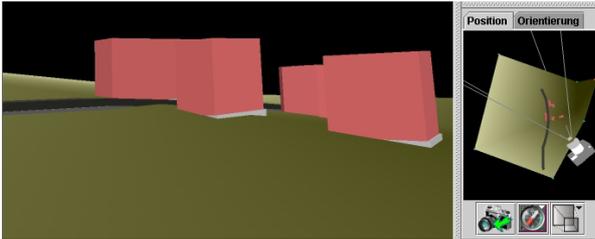


Figure 4. Left: main scene; right: overview window viewing the scene from top with camera south east of buildings in main scene

Picking in a 3D GIS is very similar to picking in a 2D GIS. The mode of operation is the same, while the implementation is different. To find the sighted object in the virtual scene a ray from the users eye is sent into the scene and selects the first, or all objects, intersected by the ray.

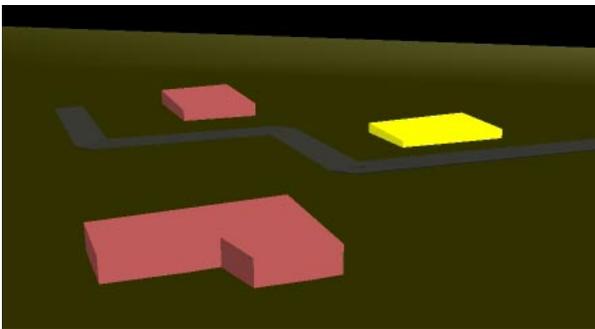


Figure 5. The picked object is highlighted with yellow.

The appearance manipulation for a 3D GIS envelopes activities well known from 2D GIS, and additionally contains classic 3D graphic approaches:

- Objects in a 3D scene can be illuminated with different 3D graphic techniques, like “Gouraud Shading” or “Flat shading”. Sometimes the original colour can be useful as well for identifying objects in the scene.
- Important is also, that it is possible to change the position of the sun, ensuring best lighting for any scene.
- Another technique, which changes the appearance of objects, is the scaling of co-ordinate axes. Considering that a 3D GIS displays real world data (for example digital elevation models or geological layers), where the analysis of topographical characteristics is necessary, the scaling of the height axis disband objects and helps to analyse the 3D scene.

Common 3D GIS Interaction techniques are necessary to provide the user with a flexible environment suitable for their specific needs. A number of these techniques are realised in the Geographic Information System GISterm. The project is included in the “Umweltinformationssystem Baden-Württemberg” an environmental GIS project and funded by the “Landesanstalt für Umweltschutz” a local authority concerned with environmental protection [GISterm]. GISterm is developed entirely in Java and is extended by the 3D Service, a service for developing 3D GIS applications. The 3D Service is realised with the means of Java 3D [Java 3D]. The purpose of the 3D Service is to create a virtual reality, include it into GISterm and provide means and methods for the implementation of specific 3D GIS

applications. Among other things the 3D Service includes the following interaction techniques:

- 3D GIS navigation featuring rotation with a 2D mouse using the Java 3D approach
- Orientation window for the orientation of the user in the scene
- Manipulating appearance aspects of the entire view with the help of a property dialog
- Picking 3D objects for displaying further attribute information

### 2.3 Application Specific Interactions

Application specific interactions are hard to categorise. They are including all kinds of activities, like:

- Creating “Fly Throughs”
- Analysing specific parts of a 3D scene
- Postprocessing of created object content
- ...

In the following some examples for specific application interactions are given, featuring GeoPro<sup>3D</sup>, a special 3D GIS application, realised with the means of the 3D-Service as another extension of GISterm, for visualising and analysing the ground water table and hydrogeological profiles [GeoPro<sup>3D</sup>].

### 2.4 Illustration for Application Specific Interactions in an Example 3D-GIS Application GeoPro<sup>3D</sup>

In contrast to the 3D-Service GeoPro<sup>3D</sup> implements only specific interactions. It is creating a 3D scene with object content from data stored in a ground water database [GWDB]. The user loads the ground water measurement points into GISterm for the region to be analysed. Then he specifies the relevant points for the calculation of the water table and indicates a time interval for the calculation of the ground water table. With this information GeoPro<sup>3D</sup> triangulates three ground water layers: minimum ground water layer, medium ground water layer and maximum ground water layer. Each measurement point includes the terrain height, from which GeoPro<sup>3D</sup> can produce the terrain layer. Some measurement points in the ground water database additionally include hydrogeological stratum information GeoPro<sup>3D</sup> is using for creating hydrogeological layers. The purpose of GeoPro<sup>3D</sup> is to detect conflicts between these created layers and proposed construction sites. GeoPro<sup>3D</sup> can handle two different kind of construction sites: buildings (single or groups of buildings) and routes (roads or railway routes). The user digitises the shapes of the objects in the 2D map and gives further information about the dimension, for creating 3D objects. The following picture shows a virtual reality scene created with GeoPro<sup>3D</sup>.

For the specific analysis of this example scene the user needs application specific interactions.

The main task for the user is to find out, where the construction sites are cutting the ground water table. Thus the clipping from construction sites from the overall scene is one example for application specific interaction. The function combines the universal interaction “picking” with the clipping of the picked construction site from the scene, so that the observer can analyse the near range of the construction site.

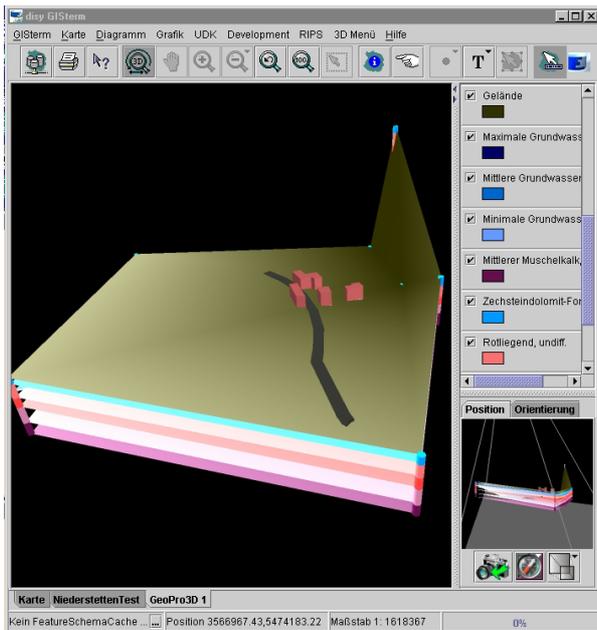


Figure 6. Virtual reality created by GeoPro<sup>3D</sup> and included into GIStern with terrain layer, ground water layers, hydrogeological layers and construction sites

The function needs to distinguish between buildings, which can be clipped the way shown in the following picture and routes needing further analysis functions.

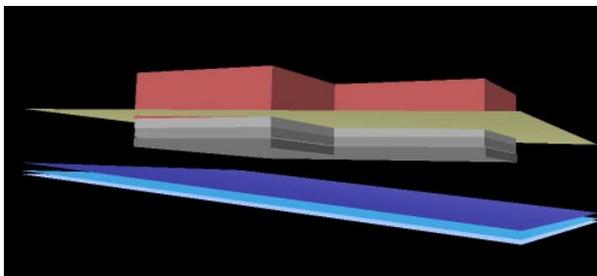


Figure 7. The overground parts of the building (red) are separated by the terrain (green) from the underground parts (grey). There is no conflict between the building and the ground water table (blue).

To analyse routes, the best way is to analyse 2D cross direction profiles along the roads. The user positions a slice through the 3D scene and moves the slice along the run of the street. This application specific interaction will be implemented in future, using the basic specific interaction of creating 2D hydrogeological cross direction slices.

For creating universal 2D cross direction slices the user needs to specify the place of the slice. In activating this functionality the 3D scene is clipped in the middle by a vertical slice. This slice can be positioned using the cursor keys.

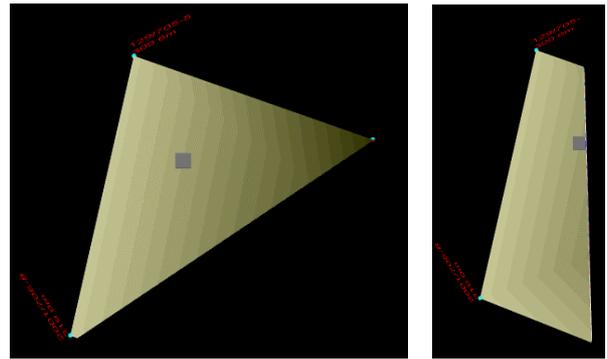


Figure 8. Left: 3D scene viewed from top and cut by vertical slice; right: the slice was moved with the cursor keys to the target place.

If the user has reached the appropriate place of the slice he can activate the cross direction profile function and sees the 2D hydrogeological profile in the display window.

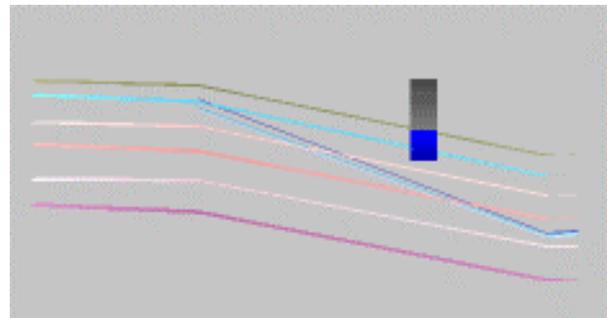


Figure 9. Hydrogeological cross profile from the position in figure 8.

Sometimes the run of the hydrogeological layers GeoPro<sup>3D</sup> is creating includes some errors (measurement points lying within a layer, not including the hydrogeological strata of the layer).

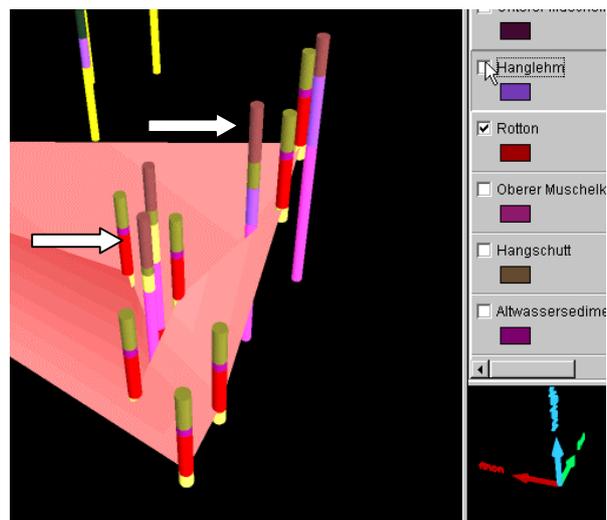


Figure 10. Not every borehole includes the "Rotton" stratum

This is another task which will be solved by a specific interactive technique, the post-processing of the

hydrogeological layers. The user will be able to select points, which should not be included in the triangulation of the hydrogeological layer, and afterwards the layer will be recreated.

Whatis: [whatis.com](http://whatis.techtarget.com/definition/0,,sid9_gci213303,00.html) , virtual reality, [http://whatis.techtarget.com/definition/0,,sid9\\_gci213303,00.html](http://whatis.techtarget.com/definition/0,,sid9_gci213303,00.html) (visited in March 2002).

### 3. CONCLUSION

The investigation in this article shows, that different interaction types are necessary for the user oriented analysis in 3D GIS tools. It is possible to distinguish the interaction types into two main categories: universal interaction types and application specific interaction types. Universal interaction types include navigation and orientation, picking, and changing the appearance while application specific interaction types are hard to be categorised and envelope a wide range of possibilities. Thus development systems for 3D GIS software should include methods for all common universal 3D GIS interactions, because they will be needed in almost all special 3D GIS applications. The realisation of application specific interactions must be done in the special 3D GIS application itself, because they envelope such a wide range of possible functions. In the example of this article the 3D-Service of GISterm is the development system for 3D GIS software while GeoPro3D represents the 3D GIS application.

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