

GEOPRO^{3D} - A THREE-DIMENSIONAL GIS TOOL FOR THE VISUALIZATION AND ANALYSIS OF THE WATER TABLE AND HYDROGEOLOGICAL PROFILES

Désirée Hilbring
Institute for Photogrammetry and Remote Sensing
University of Karlsruhe, Germany
hilbring@ipf.uni-karlsruhe.de

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ABSTRACT

This article discusses briefly the issues for developing 3D GIS Tools, which can be used for developing 3D GIS Applications. Further it introduces a ready to use three-dimensional example application, called GeoPro^{3D}. GeoPro^{3D} visualizes and analyses the water table and hydrogeological profiles relating to proposed construction sites. It is implemented using a 3D GIS Tool written with Java3D. This paper will show the successful integration of a low cost virtual reality in a GIS Application, which is meant to serve users with no or little GIS experience.

1 INTRODUCTION

Besides the visualization of 2D data, the visualization of 3D data has continued to grow in importance. This is because with three dimensions it is possible to display complex spatial information.

Disy Informationssysteme GmbH and the Institute of Photogrammetry and Remote Sensing of the University of Karlsruhe are developing a GIS Framework (GISterm) for implementing Geoinformation Systems [GISterm]. GISterm is meant to serve users with no or little GIS experience and a low budget for special applications, as for example, German local authorities. In order to achieve platform independence and web acceptance GISterm is implemented entirely in Java.

Further, considering the growing importance of 3D data, a 3D Extension (3D Service) using Java3D is currently under development. Using this 3D Service an application programmer shall be able to implement a three-dimensional GIS application without any knowledge about 3D graphics programming. That means the 3D Service provides tools for including a virtual reality into GISterm (Figure 1). The means of the 3D Service include basic functionality generally needed for 3D GIS applications. These features include:

- Creating a virtual reality and including it into the 2D GIS.
- Managing 3D object content.
- Managing several properties influencing the whole 3d scene, like lighting or shading.
- Providing means for navigation and orientation in the virtual reality
- Providing basic interaction techniques, like picking objects or clipping parts of the 3D scene.

Taking into account that GISterm is implemented in Java, the use of Java3D, which is an extension of Java was evident. Java3D uses OpenGL or DirectX, is free of charge and capable of distributing information over the world wide web [Java3D].

The 3D Service is an optional extension of GISterm, so goals considered by GISterm should be considered by the 3D Service as well. Due to that fact the 3D Service should use familiar 2D GISterm features and should be as self-explanatory as possible.

GeoPro^{3D}, the 3D GIS application, is itself another extension of GISterm and employs the means provided by the 3D Service. It displays data stored in a ground water database.

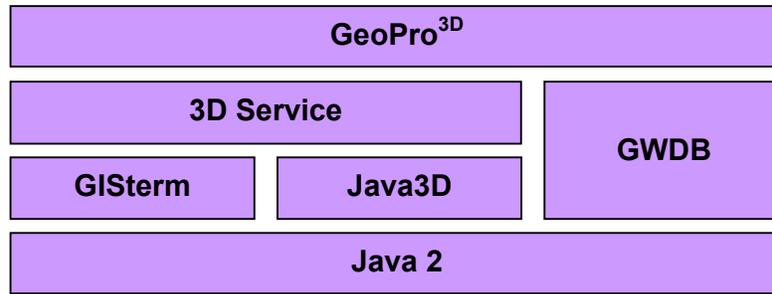


Figure 1. Correlation between Java, GISterm, the 3D Service and GeoPro^{3D}

2 TASK

The "Landesanstalt für Umweltschutz Baden-Württemberg" (LfU) (a local authority concerned with environmental protection) is acquiring ground water values and hydrogeological profiles in a ground water database called "Grundwasserdatenbank (GWDB)" [GWDB]. Currently this data is analyzed manually to detect conflicts between the ground water table and proposed construction sites. The goal of GeoPro^{3D} is to ease the work for the user by visualizing three-dimensional data digitally, so that detecting critical locations is fast and easy. In accomplishing this target a virtual reality with the following content is created:

- Several layers with different water levels (minimum, average, maximum)
- Several layers containing the hydrogeological profiles
- One layer containing all ground water measurement points
- One layer containing the proposed construction site

The potential users of GeoPro^{3D} application are employees of local authorities, they know GISterm and the GWDB, but they have no experience with 3D graphics visualization. The effort for training is too high, so the basic "How to use GeoPro^{3D}" questions are covered in the online help.

3 INFORMATION PROCESSING AND SOLUTION

Before we can have a look at the three-dimensional scene it is necessary to gather several bits of information. The GWDB stores the terrain data, data about hydrogeological profiles and groundwater data (heights of measurement points and measured values). However, the user needs to specify which measurement points (holding the information) should be included in the analysis, and he/she should specify the time interval, which is critical for the analysis (Figure 2). That means only measurements within the given time interval are considered for the groundwater table. For the analysis of the groundwater table regarding the construction site information about the location and size of the construction site are needed as well.

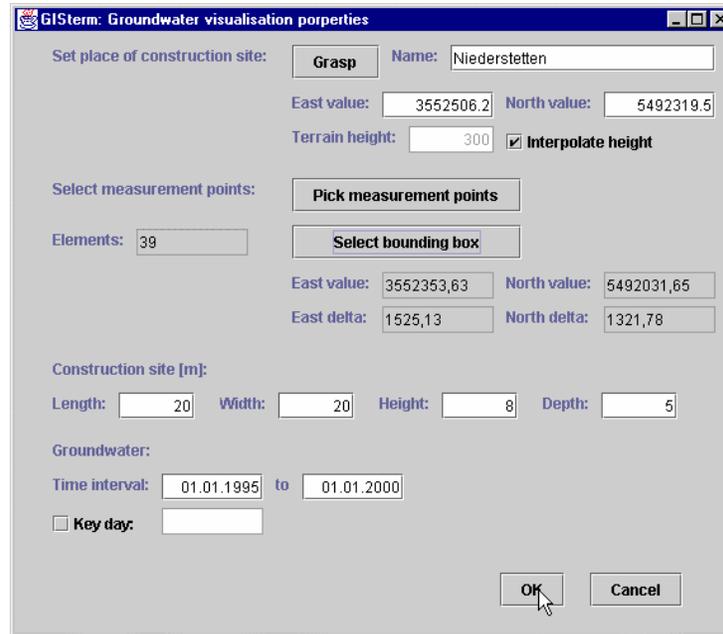


Figure 2. User dialog for specifying the information about measurement points and the construction site

The task of GeoPro^{3D} is to process the given information, create the resulting 3D objects, and display them in a virtual reality. The virtual reality is created by means of the 3D Service. The objects are held in several 3D layers managed by the 3D Service. The content of a 3D layer, which can be compared with a 2D layer well known from many GIS, belongs semantically together. Basic layer functions, like “setVisible (true/false)”, “Remove Layer”, “Zoom To Layer Extent” or “Zoom To Selection” are included in every 3D Service layer and work in the same manner as in 2D GISterm. GeoPro^{3D} refines the 3D layers by including specific content and loads them into the virtual universe. The following layers are created by GeoPro^{3D}:

- All selected measurement points including terrain data are used for the triangulation of the terrain. The currently used triangulation algorithm is a Delaunay Triangulation from the class library VisAD [VisAD]. The result is a triangle mesh layer representing the terrain.
- Analogically the groundwater layers are created with the same algorithm. The result is a layer for each ground water level stored in the GWDB.
- Analogically the data that depict hydrogeological profiles from each selected measurement point is processed the same way, resulting in several hydrogeological layers. For each profile there will be created one layer.
- The 3D object representing the construction site is a cuboid constructed from dimensions specified by the user. This cuboid consists of several boxes, while each box has the thickness of one meter. Boxes above the terrain are colored in different shades of gray, while boxes below the terrain are colored in different shades of blue.
- One created layer contains all measurement points, illustrated by several cylinders. Each cylinder representing a borehole consists of several hydrogeological strata. This layer includes a legend displaying the names of the hydrogeological strata.
- Additionally two text layers are created, which are label the measurement points with the point identification number and the terrain height of each point.

All 3D layers together with the virtual universe form the 3D scene. The 3D Service provides the navigation functions (Figure 3). The user can change the view by moving the mouse. The left mouse button rotates the view, the middle mouse button zooms the view, and the right mouse button pans the view. During navigation in a 3D environment the user often gets lost. The “Zoom To Last” button can be used to move back one step, while the “Zoom To Extent” button moves back to the original view. Additionally the coordinate axes of the

virtual universe are displayed in an “Orientation Window”, helping the user in locating the location of the viewer.

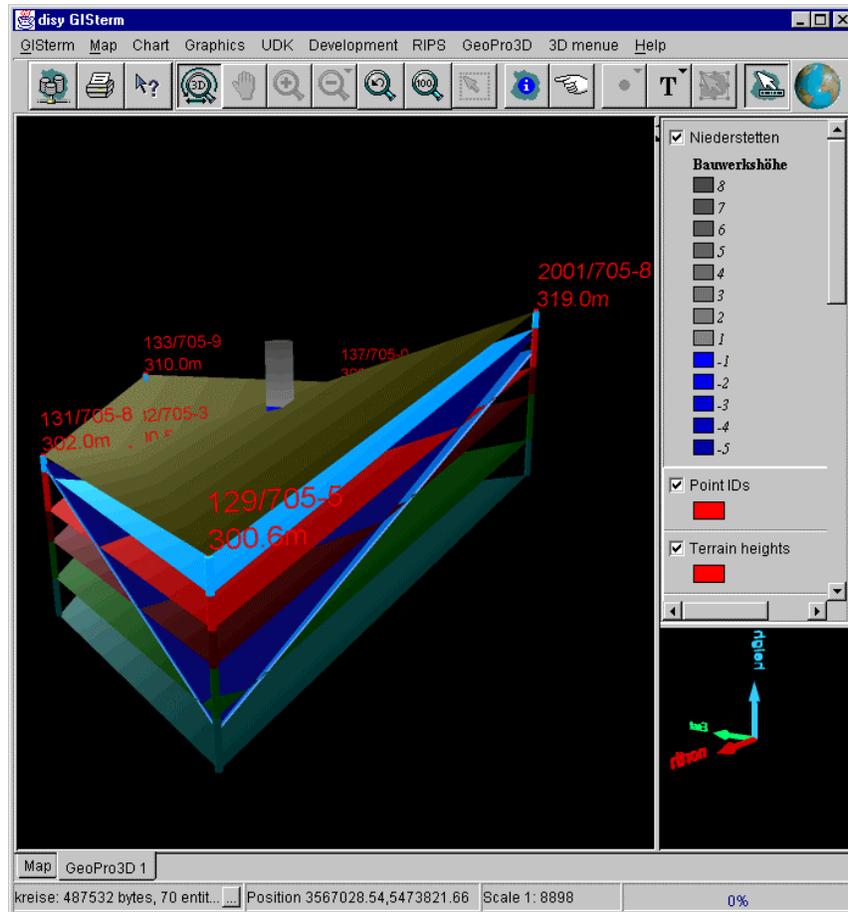


Figure 3. GISterm with the 3D scene created by GeoPro^{3D}

Now we come back to the original task: detecting conflicts between proposed construction sites and the ground water table. That means one priority lies in the visual analysis of the construction site layer. Using the “Zoom To Layer Extent” feature of the constructions site layer moves the view of the 3D scene towards the construction site box. It is possible to clip the currently unnecessary parts of the 3D scene. Due to the different colors of the construction site boxes it is possible for the user to detect the height below ground, at which a special layer is intersecting with the construction site cuboid.

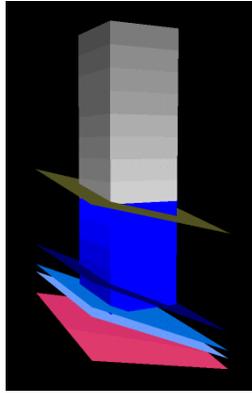


Figure 4. Analysis of construction site

In Figure 4, one can see, that the lighter (grey) parts of the construction site are lying above ground, while the darker (blue) boxes are representing the parts below ground. One can see the darkest layer clipping the construction site by a depth of approximately 4 meters.

A second analysis task, that GeoPro^{3D} is capable of, is the visual analysis of the run of hydrogeological strata below the surface. Using the basic 3D Service function “Picking” it is possible to select several boreholes. Using “Zoom To Selection” afterwards moves the view nearer to the range of the selected boreholes for further visual analysis of the strata in that part of the 3D scene.

4 PROBLEMS

Several problems are raised during the implementation of GeoPro^{3D}. First, the GWDB stores values sufficiently precise for the height of the measurement points and the ground water, but many measurement points do not hold information about the terrain. This results in a very rough terrain, which can only be solved in using other data sources for terrain construction.

Second, the geographical extent of the region to be analyzed is much higher than the extent in the height direction, resulting in a flattish 3D scene. Addressing this issue a new feature was included in the 3D Service. For a meaningful interpretation the height axis of the entire 3D scene can be scaled by a factor specified by the user, so that the triangulated layers disband, and height differences between the layers can be visualized in the virtual reality.

Third, the analysis of hydrogeological layers shows that the run of the strata is often more complicated, than a Delaunay Triangulation can consider. It happens that several clusters of boreholes have almost the same hydrogeological strata, while holes between these clusters are missing some strata. The currently used algorithm is not considering this problem. For future releases the algorithm should be improved and it should be possible for the user to interactively adjust the run of the strata.

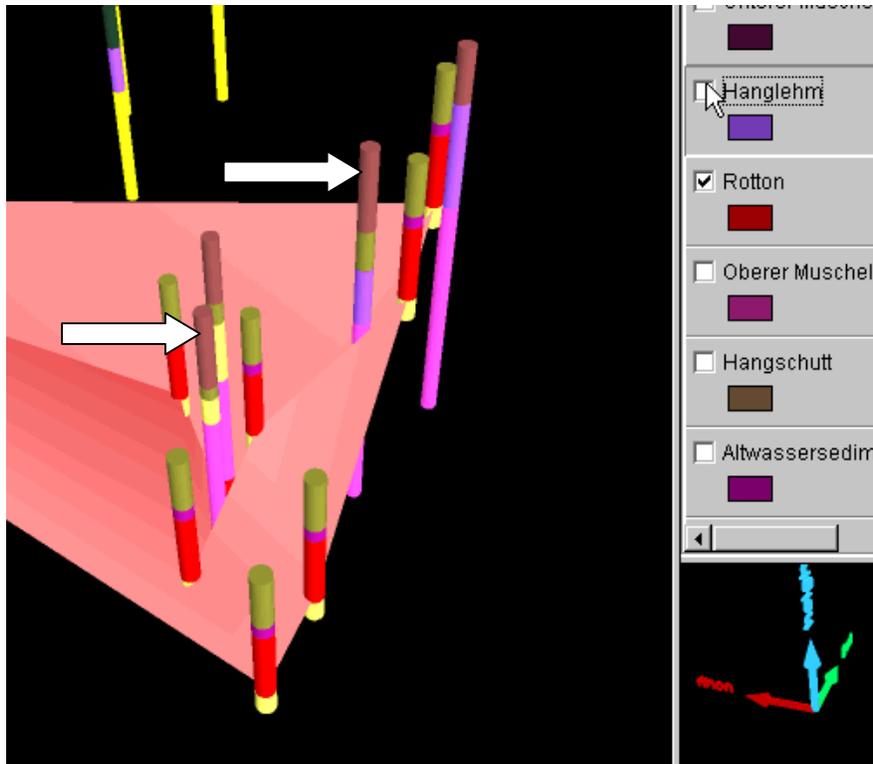


Figure 5. Problem with run of “Rotton” stratum

Figure 5 shows some cylindrical boreholes with several hydrogeological strata. Nine boreholes contain the stratum “Rotton” which is displayed as the shaded hydrogeological layer. The dark stratum in the boreholes is the “Rotton” stratum. The problem is that two boreholes (marked by the arrows in figure 4) not include the “Rotton” stratum, but nonetheless cut the “Rotton” layer.

5 CONCLUSIONS

GeoPro^{3D} is a first step towards a three dimensional GIS application. It connects common 2D GIS assumptions (included in GISterm), means for developing 3D GIS applications (included in the 3D Service of GISterm), Java and Java3D (leaving later web distribution open) with a special task to create a helpful application tool. GeoPro^{3D} is just a prototype and lacks the use of further data sources and better data processing, but it shows that virtual realities can be used to create present and easy to use low cost 3D GIS applications.

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