Automated Transformation of 2D Vector-Based Plans to 3D Geovirtual Environments

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1 Introduction

During the last decades enormous advances have been made in landscape visualization. At present it is possible to create detailed and photorealistic visualizations of virtual landscapes. An increasing number of these visualizations can be classified as geovirtual environments, which are built from geo-referenced data and which can be operated in real-time. A wide variety of research projects in the fields of landscape and urban planning are concerned with construction issues of geovirtual environments and the use of these models in planning processes (e.g., APPLETON & LOVETT 2003; SCHROTH ET AL. 2005; WARREN-KRETZSCHMAR & TIEDTKE 2005). Surprisingly few examples exist that apply geovisualization techniques in an urban context on large-scale projects, such as the design of gardens, parks, and open space.

In our contribution we introduce an approach for the automated mapping of 2D vector-based plans to geovirtual environments based on built-in transformation rules. This approach offers an intuitive method for the construction of detailed geovirtual environments usable for large-scale projects. The approach has been implemented on top of LandXplorer, a real-time 3D geovisualization system for complex geovirtual environments (3D Geo 2006). In a case study, we applied the transformation approach to an historic area in the city of Potsdam in the context of an urban redevelopment plan.

2 Applications and Requirements in Landscape and Urban Planning

Currently, geovirtual models are primarily applied in public participation processes for the presentation of planning scenarios. On landscape scale, these models are frequently used in research projects (e.g., WERNER ET AL. 2005; WARREN-KRETZSCHMAR & TIEDTKE 2005; STOCK & BISHOP 2005). On the scale of single town, quarters or parks, there are only few examples. LANGE & HEHL-LANGE (2005), NICHOLSON (2002), and PETSCHEK (2003), for example, use photorealistic, static 3D models or animations built from geodata and survey data in specialized modeling tools. Real-time rendering of such models is possible by specialized 3D graphics systems (e.g., game engines, VRML viewers, 3D Studio Max), which efficiently handle pre-built 3D scenarios. However, these systems are limited with respect to the interactive manipulation of individual 3D scene objects (e.g., editing ground plans of buildings, positioning of vegetation objects, etc.) and visual exploration and analysis (e.g., selecting trees of a given specie). Furthermore, the creation of 3D scenes involves enormous manual modeling and design work. DANAHY (2005) presents two projects where real-time visualizations were applied in an urban context as well. Both
projects are primarily concerned with the arrangement of buildings and finding optimal building heights and, therefore, do not include high streetscape detail; the 3D objects used in these models are directly linked to databases. These projects have been proven to be helpful tools in the participation process. WAREN-KRETZSCHMAR & TIECKE (2005) also show that especially interactivity in the sense of editing a scene and integrating new planning ideas are questioned features for the future. Moreover, the ease of scene creation should be enhanced to support flexible visualization techniques that allow planners to develop the specifics of the planning measures with the citizens. A prerequisite for the implementation of interactive model creation and data manipulation methods is to increase the intelligence of objects by providing built-in transformation rules. They allow users to intuitively create new objects and control geometric and appearance parameters. In addition, geovirtual environments rarely appear to be applied in open-space planning because plans for large-scale projects are traditionally generated by CAD software, and designers are often less familiar with GIS software. This traditional disjunction between GIS and CAD is increasingly vanishing though, and design plans in CAD formats can be converted to geodata formats and vice versa.

3 Automated Transformation of 2D plans to 3D Geovirtual Environments

Key elements in landscape architecture and open-space design plans are the layout and arrangement of ground-structuring objects, vegetation/plants and other artificial objects, such as streetlights, benches, bus stops, and sculptures. Buildings, which are dominant structures in urban areas, are included in these plans as well. Their design, however, is not subject of open-space planning and, therefore, simple representations of buildings are often sufficient.

The key idea underlying our approach is to provide specialized transformation methods for each of these elements to ease the model creation process. For this, 2D features are enhanced by additional attributes specifying 3D details and appearance. The resulting geovirtual environment resembles the underlying 2D data in 3D and maintains direct references to it. The basic element in geovirtual environments is the terrain on which further objects can be positioned. At site scale, especially in urban areas, the terrain represents a patchwork out of various ground-structuring objects, such as streets, pavements, kerb stones, walls, stairs, and flower beds - they form an ‘artificial terrain’. For modeling and representing the artificial terrain BUCHHOLZ ET AL. (2006) have introduced Smart Terrain Models (STM). They support the creation of detailed 3D street-space and green-space models from 2D or 2.5D vector-based input data by providing specialized transformation algorithms for typical ground-structuring objects such as ground areas, stairs or walls. To create a STM, input polygons or polylines have to be classified into the supported object classes. Each class requires a set of additional attributes that refer to configuration options and parameters of built-in 3D transformation rules. From the geometry and the corresponding attributes 3D objects are constructed automatically. Currently the algorithms support the creation of terrain models from well-defined ESRI shapefiles with referenced textures. The general model concept envisions that any vector-based geo-referenced data can be used as base input data. Configuration options and
transformation parameters can be assigned interactively in the geovirtual environment. Figure 1 depicts the transformation process for the data used in the case study.

![Transformation of 2D input data of terrain structures and buildings to 3D representations](image)

Plants and vegetation areas are another key element in open-space planning. Vegetation areas within urban areas, such as parks, lawn, or wasteland, are represented by the STM as ground areas with high-resolution textures and additional 3D plant models. Site-scale design plans usually contain exact plant positions, which can be utilized to position 3D plant models within the geovirtual environment by assigning attributes to the point positions. To control the scale and rotation of the models, a configuration interface is provided, which allows the system to read this information from additional attributes. Furthermore, it is possible to assign a vertical offset, which controls the exact position in the third dimension. This can be useful for, e.g., positioning plants on roof gardens. In the case where manual positioning of plants is not applicable, algorithmic-based plant distribution can be used. The creation of convincing, realistically looking vegetation covers by algorithmic-based distribution is addressed by DEUSSEN (2003), WERNER ET AL. (2005), and RÖHRICH (2005).

In addition to plants and vegetation, artificial objects such as sculptures, benches, street, and streetlights are often used to create a recognizable design of an area. In CAD block models (prototypes) of such objects are created and inserted at anchor points. This method is similar to the positioning of plants, and the approach for the positioning of 3D plants can be used analogously.

High building density is formative for urban areas, and buildings should be included when designing open space. In some cases 3D building models can be taken from existing virtual 3D city models. If no such model exists, simply textured block buildings can be automatically constructed by extruding buildings footprints based on external height information and textures of the buildings (Fig. 1). If available, additional roof type classifications can be used for the creation of standard roof geometries (FELKEL & OBDRMALEK 1998; LAYCOCK & DAY 2003). These simple building models are sufficient for many planning tasks. If more building detail is required, two strategies exist: manual 3D modeling or conversion of simple block buildings into Smart Buildings (DÖLLNER & BUCHHOLZ 2005). Manual modeling of 3D buildings is very common in architecture and if
available, models in standard 3D formats can be implemented. Smart Buildings, on the contrary, allow us to incrementally refine building models in the geovirtual environment, which can be useful in public participation processes concerned with building density and height.

4 Case Study

The introduced modeling approach was applied to a historic site in the city of Potsdam in the context of an urban redevelopment plan. For the current state, the city’s agency for surveying provided data from the digital municipal town map. The data origins from ground survey, has high accuracy and offers detailed information about buildings, ground cover, vegetation, and artificial objects. It is organized in layers and primarily consists of polylines and points. Hence, the data had to be pre-processed. A detailed description of the data preparation for the terrain model is given in Ross & Kleinschmit (2005). The footprints of the buildings within the research area were included in the creation process of the terrain model and, thus, no inconsistencies between the terrain and buildings appear. With the terrain model and textured block building models as base layers, a representation of the spatial infrastructure is achieved. Trees, hedges, and flower beds, which are stored in the original data as point symbols or line symbols without additional information about species, were then added to the model. In a field survey the plants were classified and their height was estimated. This information was directly stored in ESRI shapefiles on mobile GIS devices and later linked to the plant library of the Lenné3D project. Finally, exemplary 3D objects were modeled, which were then linked to respective points of the original dataset. Fig. 2 shows a screenshot of the resulting geovirtual environment.

The urban redevelopment plan envisions a reorganization of the study area based on the former historic arrangement of buildings and structures. Major changes include the reconstruction of the historic town channel, the church ‘Garnisonskirche’ and rearrangement of public open space. At present no detail plans are available and thus only the rough concept digitized from a redevelopment study was visualized so far. To give an idea of the possible future design some exemplary areas were modeled in detail. Fig. 3 shows a comparison of the actual state and one possible future design.
Fig. 2: Combination of Smart Terrain model with Smart Building models, 3D objects and plant layer

Fig. 3: Comparison of the actual situation (left side) and one possible scenario (right side)
5 Conclusions & Outlook

The presented approach for the automated transformation of 2D plans to 3D geovirtual environments combines several data handling and model creation methods. Especially the use of Smart Terrain Models for the representation of typical urban surfaces, such as street space and green space, offers an intuitive and efficient approach for the creation of an object-oriented terrain layer usable for large-scale projects as well as interactive selection and data manipulation of ground objects. Simple buildings, which are often sufficient for open space planning purposes, can be automatically constructed from the buildings’ footprints and external height information. Furthermore, continuous level-of-detail modeling of buildings can be utilized by the use of Smart Buildings. These two procedural approaches for the creation of 3D objects are combined with static 3D models inserted at point positions, which can be taken from existing datasets or, if no such data is available, can be created interactively in the geovirtual environment. The transition from static models to more intelligent and editable geovirtual environments offers an opportunity to enhance their usability for participation and planning purposes as well. Therefore, we extend the STM approach by an interactive 3D editor that allows for creating and modifying ground-structuring objects of geovirtual environments. Additionally, the collection of built-in transformation rules and their ability to interact with adjacent objects will be extended. This approach will enable users of geovirtual environments to interactively change existing or create new designs on demand.

6 References

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