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Earth, Landscape, Biotope, Plant. Interactive visualisation with Biosphere3D

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1 ABSTRACT

In this paper, we discuss the Digital Earth concept and scale issues regarding landscape planning visualisation, and we present the interactive visualisation system Biosphere3D. The visualisation system supports multiple scales on a virtual globe, and is focussing on real-time rendering of vegetation, similar to the predecessor Lenné3D-Player. In this paper we describe the visualisation system from a user's perspective. We provide detailed information about the available import and export data formats, the rendering capabilities and the required hardware. Additionally we will give a quick overview over the interfaces that allow the creation of custom software modules and possible applications.

2 THE GEO BROWSER IS NOT ENOUGH

AL GORE (1998) said in his legendary speech on 'The Digital Earth: Understanding our planet in the 21st Century': "I believe we need (...) a multi-resolution, three-dimensional representation of the planet, into which we can embed vast quantities of geo-referenced data." As early as in 1995, Art+Com anticipated somewhat of Al Gore's foresight presenting TerraVision (MAYER et al. 1995, 1996). The figures show examples of TerraVision's graphical user-interface (1), the tangible globe interface (2), and interactive terrain rendering (3). Long before of hardware-accelerated consumer graphics cards, and broadband Internet access, the world was not ready for this prototyp requiring a SGI graphics super computer. Meanwhile, the rapid development of hard- and software for interactive visualisation has been triggered by the fast growing market of computer games and paid by millions of enthusiastic computer game players.

Figure 1-3: TerraVision (http://www.artcom.de)

Since the advent of Google Earth, 'geo browser', 3D GIS and digital globes have become popular tools and topics in both consumer and professional world. Many other software vendors, and open source projects offer such programs, e.g. ESRI ArcGlobe, and ArcGIS Explorer, NASA World Wind, Viewtec TerrainView-Globe, SkylineGlobe, Microsoft Windows Live Local (Virtual Earth), vWorld vieWTerra, and Virtual Terrain Project Enviro.

Geo browsers have in common that they focus on geographic, especially remote sensor data, and cartographic data, i.e. predominantly 2D or 2 ½ D map data draped on the terrain. Some products support 3D city models but none of the digital globes are currently focussing on the visualisation (visual simulation) of landscape scenery, forests or gardens. Do landscape architects, and environmental planners need specialised 3D real-time and 'global' landscape visualisation solutions? Or should we just rely on established geo browsers?

3 VERTICAL RESOLUTION

ORLAND (1992) claims that visualisation techniques for environmental management must include analysis and modelling tools, and should support multiple scales, i.e. detailed change at the local level within the framework of coarse-grained data sets. TerraVision already supported level-of-detail rendering of large terrain with draped image data, and 3D objects.

Tools like Google Earth and a fast Internet connection enable smooth zooms from 15,000 kilometres down to the ground surface. While resolution of orthophotos and satellite imagery is still increasing, this progress is of limited advantage when it comes into the local level, e.g. at “tree-by-tree scale” (ORLAND 1992), first- or third-person-view. In 2006, Microsoft announced a 16 times increase in terrain detail of Flight Simulator X compared to the previous version. In Flight Simulator 2004, 256 x 256 pixel covered 1 square kilometre of terrain, i.e. a resolution of roughly 4 meters per pixel. In a blog [6] the difference is described as the difference between “wearing glasses and not wearing glasses”. Nevertheless, the blogger concludes “… that the future doesn't lay in increased texture resolution, but rather in increased 3D res: Rather than making the flat have more pixels, lets see more ‘vertical’ polygons”. These ‘vertical’ or truly 3D objects are especially landscape elements (ERVIN 2001) like structures (including architecture and infrastructure), animals and people, and vegetation but also waterfalls, and atmosphere.

Nonetheless, Microsoft’s Virtual Earth initiative aims to establish an aerial photo based geo database of the global land area with 144 m km2 and a resolution of 15 cm, which will require about 22 PetaBytes of storage (Franz Leberl, Microsoft-Vexcel, pers. comm. March 28, 2007). This number is still beyond our imagination. Anyhow it is an (very large, delayed) aerial photography of the world. It will neither show a forest’s understorey nor permit a glimpse of the future.

In a survey of APPLETON and LOVETT (2003), searching for a level of realism for visualisations of rural landscapes that is “sufficient” for environmental decision-making, one respondent suggested that there might be a “lowest common denominator” effect, whereby the low-detail elements distract from or appear inconsistent to the rest of the image. Their findings do not show evidence of a sufficient level of realism, but they do reveal that, depending on the scenery, some elements are more important than others, e.g. foreground vegetation and the appearance of the ground surface have a significant effect on the ratings for realism of landscape visualisations.

A greater degree of detail can call into question the accuracy and validity of the basic data and the assumed planning scale of e.g. 1:10,000 (PAAR et al. 2004, PAAR and REKITTKE, 2005). In particular, photo-realistic visualisations from eye-level view, that are based on typical environmental and planning data, are coming into conflict with conventional scales used for representation of community landscaping. ERVIN (2001, p. 62) writing about abstraction, states that “(...) we landscape modelers must also remember the valuable roles of abstraction in both cognition and communication, and not believe that ‘photo-realism’ – or even ‘physical realism’ – is the be-all, end-all of digital modeling. We make models to make explorations or to convey messages, and the infinite variety of explorations and messages will surely yield an equally boundless variety of digital landscape models”.

4 LANDSCAPE VISUALISATION ON LOCAL AND GLOBAL SCALE

While architects, landscape architects and urban planners construct 3D models as a matter of routine, landscape and environmental planners in practice have relied on abstract, two-dimensional representations (LANGE 1999). In the history of landscape architecture, REPTON (1803) may be regarded as an exception and early pioneer in the area of landscape visualisation (LANGE, 2001). In his ‘Red Books’, he invented a technique of perspective representation for landscape designs that is not dissimilar to current digital methods.

In landscape and urban planning, public participation, interactivity, and virtual reality become more and more an issue. At present, landscape visualisations seem to have been widely adopted for use in the assessment of controversial or large-scale projects, for simulating landscape changes, and for research purposes (PAAR, 2006). HAKLAY (2002) surveyed the number of research projects worldwide in the field of GIS and virtual reality (VR) between 1993 an 1998. He found that there was a rapid increase in 1994 and a steady increase through to 1998, after which there was a sharp decrease. Haklay attributed this decline to the integration of VR into standard software, which reduced the justification for specialized research projects. Conventional VR models and infrastructure have been too expensive to use in ordinary planning processes. In practice, landscape visualisations have, up until now, primarily been used to present, explain and market landscape planning scenarios, rather than being used to provide a meaningful contribution towards improving final results (ORLAND, 1992, LANGE, 1999, PAAR, 2006).

[6] http://blogs.technet.com/pixelpoke/archive/2006/01/21/417847.aspx [site visited on March 19, 2007]

Real-time virtual 3D landscapes represent communication tools that allow experts as well as non-experts to use, explore, analyse, and understand landscape information (V. HAAREN and WARREN-KRETZSCHMAR, 2006).

TRESS and TRESS (2003), summarising a case study of scenario visualisation for participatory landscape planning, point out: “It would be ideal to have a powerful and photo-realistic GIS-based visualization tool with dynamic characteristics that would show landscape from the perspective of a moving observer” (p. 173). APPLETON et al. (2002) conclude that there is no “universal landscape visualisation solution”, and that current technology forces users to make trade-offs in detail and interactivity. They see a market gap for a visualisation tool that can be used in combination with GIS, and predict that future visualisation technology will move towards the combined goals of availability, geographic detail, realism and interactivity. ERVIN (2001) remarks that digital landscape models are often homogenized to a degree that was once necessary due to technical limitations but is no longer required.

Two years ago, we asked ourselves what would be the maximum extent of a landscape and therefore the basic terrain model? To the horizon? But what if free navigation is permited? Then the user will somewhere arrive to finis terrae. The curvature of the earth is usually irrelevant from first person (eye level) view landscape perception apart from application in visibility analyses, e.g. for (off-shore) wind turbines. However, what if I like to navigate from one landscape to the neighbouring? It is the notion of spatial context, the surrounding of a site, which is essential for orientation, and assessment of a project.

Specialised landscape software such as E-on Software Vue, Planetside Software Terragen 2 or 3D Nature Visual Nature Studio (VNS) enable 3D modelling of existent or non-existent landscapes aiming to provide photorealism, rendered offline both as still images or animations. VNS supports GIS data, and even the curvature of the earth but lacks real-time rendering. 3D Nature’s NatureView Express viewer offers real-time capability on a lower level of detail.

As most landscapes are covered with vegetation, the representation of plants and vegetation is a prerequisite for realistic visual simulations of landscape sceneries. In 2000, German practice of landscape architecture and environmental planning was dissatisfied with the quality of visualisation of plants and habitats provided by the available software and convincing representations of plants and habitats were the feature most demanded from the next generation of landscape visualisation systems (PAAR, 2003, 2006).

REKITTKE and PAAR (2006) emphasise on the unique, fascinating and complex potential of vegetation as a landscape design element. It “(…) becomes overwhelmingly apparent as soon as one tries to create digital models of vegetation, especially when the aim is to replicate as nearly as possible the mosaic structure, distribution and forms of actual natural herb vegetation communities.”

5 BIOSPHERE3D

The interactive landscape visualisation system Biosphere3D is focussing on real-time rendering of vegetation in different scales. Main target scale of the predecessor Lenné3D-Player was visualizing landscape from an eye-level perspective enabling to wander through the planned or predicted landscape (WERNER et al. 2005). Biosphere3D supports multiple scales on a virtual globe reflecting our thoughts on the maximum extent of a landscape. Unlimited terrain can be visualized due to the spherical terrain model and the efficient data management (CLASEN and HEGE 2007, 2006). Satellite images (fig. 4), raster digital elevation models (DEM), and aerial views (fig. 6) of multiple terabyte can be combined with vegetation plots based on vector shapes (fig. 7) and biological sample data to create photorealistic views, e.g. of planned scenarios and reconstructed historical gardens (fig. 8, rendered with Lenné3D-Player). Since no pre-calculation is required, the data can be edited and reloaded to enable quick development cycles and semi-interactive participation processes. Biosphere3D is compatible to Lenné3D’s plant models, permitting access to one of the largest databases of realistic 3D plants (REKITTKE and PAAR, 2006).

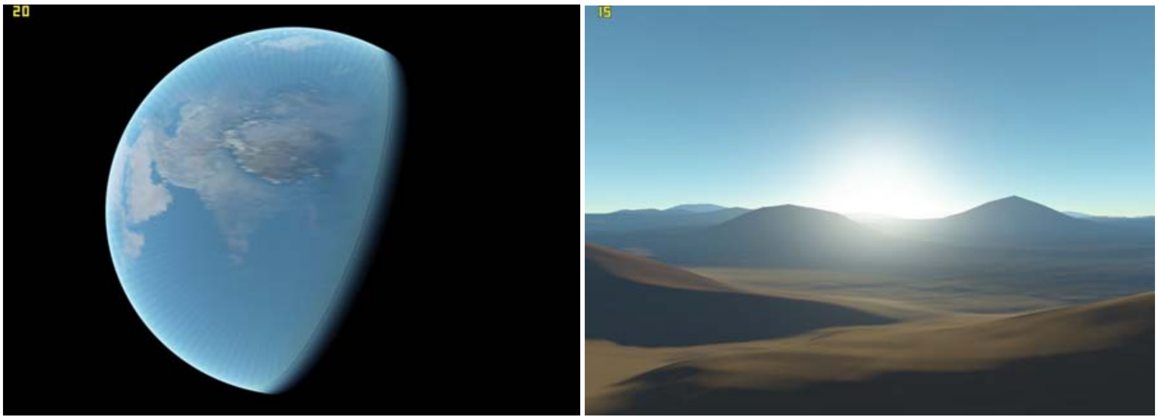

Figure 4+5: Planet Earth from outer space at sunset in Asia; virtual sunrise over the Andes (screenshots: Biosphere3D, 2006; data: NASA SRTM and Blue-Marble)

Figure 6+7: Landscape in Germany; at eye-level planting trees (screenshots: Biosphere3D, 2006; data: NASA SRTM and Blue-Marble, LGN orthophoto, Lenné3D Flora3D trees)

Figure 8: Pot Marigold (Calendula officinalis) in a garden (screenshot: Lenné3D-Player, Flora3D plant models, 2006)

Habitat and land-use data provide the basis for Lenné3D's vegetation modelling; the input of further geographical data allows automatic generation of plant distribution maps (RÖHRICHT 2005). Three-dimensional plant models are assigned to the distribution map and positioned on the terrain model.

The current alpha version supports the following import formats:

- ERMapper Compressed Wavelets Raster (.ecw)
- ESRI Shapefile (.shp)
- Lenné3D ASCII Ecofile (.eco)
- Lenné3D Flora3D plant files (.flora3d)

Support for 3D objects in COLLADA format (.dae), and KML file format (.kml/.kmz), best known as the geographic interchange and XML based format of the client component of Google Earth, are scheduled for the first beta release in June 2007.

Hardware requirements are moderate: a standard dual core PC with 1-2 GB of RAM and a consumer GPU supporting OpenGL 2.0 are adequate to run the system. Graphics quality and performance will benefit from more cores, more RAM, and faster GPUs.

5.1 LINKING WITH SIMULATION SYSTEMS

Biosphere3D itself is a pure visualisation system. User interaction is currently limited to the rendering settings such as camera position. However, this is no limitation but a design decision: There are many different kinds of applications where Biosphere3D can be used, so if all possible interactions would be integrated in the base system, it would be unnecessary hard to understand and maintain. Therefore, it has been engineered to be used with higher application layers that provide this interactivity. In fact, the data structures used by Biosphere3D require no pre-processing step; so all data can be modified on the fly with minimal turn around times.

One such application could be a forestry simulation tool where the forester can interactively decide which trees is to cut down while the forest develops over time. If Biosphere3D is used for visualisation, there are three interfaces to the application: First, the current forest has to be transferred to Biosphere3D. Second, the user should be able to select trees in the 3D view. Biosphere3D has to report which tree is visible for a given coordinate in the generated image. Third, the application should be able to modify the rendering settings of individual plants to allow highlighting of selected trees.

Figure 9: Forest stand visualisation calculated by the interactive thinning simulator JTragic (HAUHS et al. 2001; screenshot: Biosphere3D, Flora3D tree models, 2007)

If the simulation tool has a front-end that allows replacing the renderer, then Biosphere3D can be integrated as a library. The front-end has to provide an OpenGL window and handle all user commands, just as it does stand-alone. Biosphere3D exposes its domain model where the tool developer select the necessary components from, for example a class that contains individual plant instances as opposed to a class that deals with vegetation plots. Combining a few of these components creates the visualisation. Each component has an interface for direct manipulation, such as adding or removing single trees. Dynamic highlighting can be implemented by creating a second tree container with different render settings and moving instances between them.

If the simulation tool has no reusable front-end, then programmers can extend Biosphere3D's viewer (fig. 9). The viewer already provides basic support for rendering and user navigation. Linking a simulator to Biosphere3D requires at first to determine the best way to transfer the data. Many simulators support reading and writing files. Based on this, programmers can write the current state to a compatible file, call the simulator as an external process, wait for it to finish and read back the resulting data. This limits time dependent interaction to time slices. Either the user says how long the simulator should run before he wants to interact again, or the simulator runs in fixed slices so that the user can decide every virtual month whether he wants to cut down anything or not. The specific interaction has to be implemented in the viewer. Working with simulators that provide database access or web services is similar, although these have the ability to run parallel to the front-end. However, this game-like kind of interaction is rare in professional simulators.

6 DISCUSSION

In his speech, AL GORE (1998) closely predicted the recent and ongoing Digital Earth developments: "Obviously, no one organization in government, industry or academia could undertake such a project. Like the World Wide Web, it would require the grassroots efforts of hundreds of thousands of individuals, companies, university researchers, and government organizations. Although some of the data for the Digital Earth would be in the public domain, it might also become a digital marketplace for companies selling a vast array of commercial imagery and value-added information services. It could also become a 'collaboratory' — a laboratory without walls for research scientists seeking to understand the complex interaction between humanity and our environment."

Technology has reached a point where scientists and planners are enabled to use sophisticated visualisation tools, and reach a wide audience. Google Earth found its way to our desktops and it is an exiting and inspiring tool to explore planet earth. Scientists, organisations like NASA are contributing and sharing content on Google Earth.

The raw potential of landscape visualisation continues to accelerate. It is fascinating, but also a good time for a critical reflection of the hype. The possibility to have high-class visualisations is no guarantee for an implementation of the planned landscape. The fundamental issues to be addressed with every visualisation in planning come to the fore: Whom is the visualisation aimed at? What should be shown? What is fundamentally important? What is less relevant? (REKITTKE and PAAR, 2005). ERVIN is clear about the fact that the means must necessarily be derived from the end goal: "[...] there is never a single correct answer to any of the many representational and abstraction problems [...], and so reference to the questions: "What is the purpose?", and "What is the question?", is an important touchstone for understanding visualization tasks and evaluating representations" (2004). Accurate and carefully chosen visualisations support the dialogue on community landscape planning and decision-making.

Current technological developments within computer graphics, videogames, and 3D GIS will certainly assist 3D landscape visualisation tools in fulfilling the specific requirements of landscape planners and environmental managers. ERVIN (2001) recommends that research and development of landscape modeling should be carried out in close cooperation with computer scientists. REKITTKE (2002, p. 121) argues that the profession of landscape planning "(…) must be prepared to keep up to date with current developments in the field of digital technology and, if necessary, develop solutions tailored to its needs". BISHOP et al. (2001) state that we should have our thinking on the application of virtual reality technology to experimental landscape research attuned to the next set of opportunities, not to the past set of constraints. Currently, and this is also true for Biosphere3D, the sheer number of plants of realistic densities still pose a problem for real-time visual simulations. Nevertheless, visual (photo-) realism can save on plant densities almost without visible artefacts. The seamless transition from foreground to middleground, and aerial view to "tree-by-tree scale" remains a task for further research in computer graphics.

Biosphere3D bypasses large, non-freely available datasets of satellite and aerial imagery concentrating on high "vertical resolution", e.g. 3D plant models. Users can add their own or licenced geo data.

7 CONCLUSION AND OUTLOOK

Interactive landscape visualisations on Digital Earth have the potential to be developed into a perceptually efficacious, somehow 'natural' user interface in landscape planning processes. Planners and landscape architects will publish their projects 'on earth' addressing stakeholders and the general public. Currently, mainstream tools and media like Google Earth already offer an easy and wide access to Internet users. Still, the 'digital tool box' lacks support for professional landscape planning processes, and state-of-the-art representation of vegetation.

Second Life is the most hyped of several new virtual reality platforms based on a metaverse concept, a parallel world where users interact as avatars with each other, that uses the metaphor of the real world without its physical limitations, but with a lot of real-life problems and hiccups. These concepts are sociologically and psychologically very interesting, but we doubt that a metaverse landscape is the right platform for real life planners and planning processes. STEINS (2007) compares planning in Second Life as a bit like being in the 19th century, when businesses and the wealthy controlled development." Currently with look and the aesthics of 1990ies computer graphics. Steins thinks, that it "(...) may not be long before we begin to see community design review meetings that take place in a virtual environment like Second Life."

Certainly Digital Earth will evolve, get more community features, links to sensors, and extensions. Hopefully, we don't have to hurry up for our 'claims' with a monthly fee for virtual landowners. Here, fantastic 'metaverses' have the advantage that space (e.g. islands) is theoretically an unlimited resource while space on earth, maybe even on a digital one, is becoming precious. However, 'Google Ads', georeferenced, will conduct us through the digital marketplace, while 'geo spam' might obstruct our view.

Since Biosphere3D shall become open source in mid 2007, it will be available for any kind of application at no cost. We are focussing on collaboration with academic research and teaching. Zuse Institute Berlin (ZIB), the company Lenné3D GmbH, and Leibniz-Centre for Agricultural Research (ZALF) are engaged with the development. ZIB and ZALF are currently developing several modules and using the system to visualize forests in the project SILVISIO funded by the German Federal Ministry of Education and Research.

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