Real-Time Visualization of big 3D City Models

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Abstract

Virtual Reality based geographic information systems (VRGIS) are successfully employed today for real-time visualization in such diverse fields as urban planning, city planning, and architectural design.

Today a VRGIS based software solution has to facilitate the interactive visualization of high-resolution 3D terrain data over inter- and intranet. Due to advanced software technology and innovative data management concepts, large amounts of data may be processed in real-time. Digital elevation models, high resolution orthophotos, satellite images, 3d buildings and vector data provide the real time application with the information to display excellent high quality representations of complex terrains and landscapes.

1. Introduction

Over the past three years, 3D PC graphics systems have achieved stunning performance gains and experienced growing acceptance in visual simulation applications.

VRGIS applications enable the real estate sector to visualize houses and objects within a three-dimensional terrain and support the corresponding marketing and management activities. Furthermore, industrial sites and factory premises with large production equipment and units can be visualized interactively with full details.

3D internet streaming applications can give an opportunity to the tourism sector to present their region and services in the internet, with links to further corresponding information, depicting landscape, hiking, ski and tourism areas as well as hotel and restaurant sites.

Different 3D database paging formats [Terrex03][TerraSim03] provide open, scalable solutions to one of the last remaining limitations of PC based visual systems: database and texture size constraints.

Technologies like adaptive triangulation and paging of digital terrain models, level of detail (LOD) management of texture data and volumetric rendered clouds help to generate most accurate 3D real-time graphics. With different VRGIS applications we will show real time rendering of big 3D city models whose data is streamed over inter- and intranet.
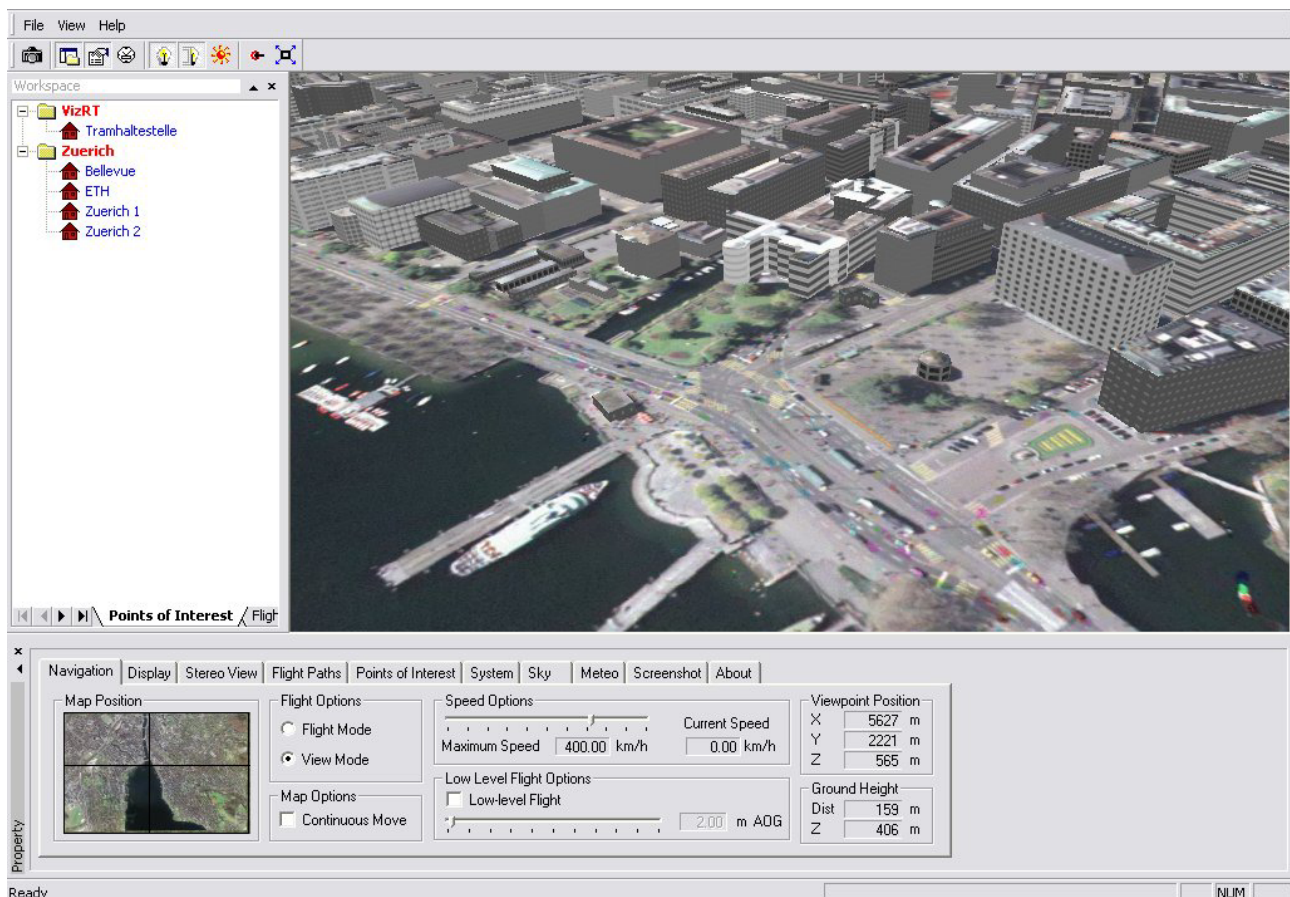

Figure 1: City model of Zurich rendered with TerrainView

2. VR System Architecture

The architecture of a modern VRGIS application should be able to explore large geographical areas e.g. Switzerland, Germany, Europe, in high resolution on a standard PC using a standard operating system[Beck99].

To reach these requirements different algorithms are proposed and patented [Terrex03]:
A VRGIS application is developed with application speed in mind. triangles which are pre-stripped and fanned for good performance on OpenGL systems. This is needed to achieve a sustained 30Hz at a reasonable flying speed while paging the database from disk in real time. Realistic and completely natural looking terrain databases must be built using real world imagery, aerial photographs or satellite images.
Level-of-Detail (LOD) switching is the practice of displaying different geometric representations of the same object at different times, less detailed representation when the object is farther away; more detailed when it is closer to the observer. LOD-switching of discrete objects in a simulation (buildings, vehicles, aircraft, etc.) is fairly simple, because you can replace the entire object at once. LOD-switching of terrain is more problematic, because the terrain needs to present the appearance of a continuous unbroken surface and requires different amounts of detail across this surface; more detailed on the ground close to the observer, less detailed far away from the observer.
This effect is normally achieved by dividing the terrain up into a rectangular grid of "tiles". Each tile can have multiple LOD representations and can switch between these representations independently. Tiling schemes come in two versions: "replacement LODs", where all LOD representations for a tile are the same size and "Quadtree LODs", where the current LOD tile is quartered at the next LOD into four smaller tiles. In order for the grid of tiles to appear as a continuous surface, each tile must match its neighbor along their shared edge, even when the neighbor is displaying a different LOD representation. This is typically accomplished by forcing the geometry of the shared edge to remain constant throughout all LOD representations of a tile. If the border never changes, it will always match the neighbors.
This solution comes at the expense of the visual quality of the terrain skin. Because the edges of the tiles must remain the same, the number of points in the edge cannot be appropriate for the coarsest LOD and the finest LOD at the same time. You will either have too many points for the coarsest LOD, or too few points for the finest, or both. This uneven distribution of points and polygons along the edges of the tiles results in odd triangulations that are visible in the final database, thus drawing attention to the boundaries between the tiles.
New technologies in digital photogrammetry guarantee higher quality in 3d models but also require a higher amount of texture memory and number of polygons. Today, a high resolution stereo camera (HRSC) is able to generate high resolution DEMs with less than 2m resolution and orthophotos with a resolution of 0.25m. However, using real world imagery to build terrain databases has been difficult in the past because of two main factors:

- Geospecific terrain databases contained so many phototextures that computer graphics systems quickly ran out of texture memory.
- Images required so much computer memory that processing was terribly slow.

Different paging formats have solved the problem of limited texture memory by permitting textures to be paged in and out of the graphics system's texture memory from disk in real-time. To dramatically reduce the memory space needed to hold and process image wavelet compression (and decompression) technology, while simultaneously and dramatically reducing the time needed to

load and manipulate images. In addition, terrain paging permits loading small segments of a large image, so that work can be completed faster. Loading and processing of segments of images further improves the speed of terrain building. New algorithms applie a "snapshot" of the highest LOD as a phototexture on lower LODs during the terrain generation process. For example, a lake maintains its complex shoreline throughout all Levels of Detail. Textures, materials and models have to be indexed and reference counted centrally. This allows the creation and use of large scale imagery databases as well as more traditional types [Terrex03].

3. Visualization of 3D Building Data

Virtual patterns of towns, agglomerations and tool scenarios are becoming increasingly relevant in the market of geo-data. Different application [ViewTec03][Multigen03][TerraSim03][Terrex03] have import interfaces to various well known 3d formats. The imported data can be manipulated and adjusted to the customer's needs in an easy and comprehensive manner. That means several 3D models can be merged into a single one; the level of detail setting allows full utilization of the available hardware components, still guarantueeing visualization free of any delays. Relative to the viewing distance, various details of 3D objects such as trees, walls and roof textures can be represented. Tools like Cyber City Modeler allow the reconstruction of 3D buildings and city models from aerial images and terrestrial video images. For this purpose, it makes use of advanced image segmentation and 3D reconstruction algorithms [Gruen99].

A few web plugins [ViewTec03] for Internet Explorer application facilitate the interactive visualization of high-resolution 3d terrain and 3d building data directly over the internet or private computer networks. They use standard web server technology with TCP/IP protocols and are optimized for low-bandwidth data transfer. The 3d terrain data size is only limited by the available disk space and the application has to work in conjunction with proxy servers and fire walls. For security purposes all data streams are compressed and heavily encrypted.

Figure 2: City model of Kobe rendered with TerrainView-Web

4. Cloud rendering

Methods to display realistic clouds are proposed. To display realistic images, a precise shading model is required: two components should be considered. One is multiple scattering due to particles in clouds and the other factor to be considered is sky light [Nishita00].

Only a few implementations [ViewTec03] allow interactive visualization of weather conditions in a paged 3D terrain model. With new solutions based on OpenGL functionality, a high amount of freely definable volumetric cloud layers, consisting of 10 different cloud types, can be rendered in real time. Over an intuitive user interface by means of a „dual screen" steering mechanism, wind speed and wind direction may be set for each cloud layer. The software solution is specially designed for highest-quality terrain visualizations and allows, for instance, visualizing different cloud scenarios over Switzerland.

Figure 3: TerrainView: Volumetric Clouds over Switzerland.

5. Conclusion

Different 3d database paging formats provide open, scalable solutions. Technologies like adaptive triangulation of digital terrain models, level of detail (LOD) management of texture data and volumetric rendered clouds help to generate most accurate 3d real-time graphics. We have shown that today, a few VRGIS applications are able to render these complex 3d scenes in internet and intranet.

6. Literature

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