

DILAS - The Digital Landscape Server for the Generation and Management of Large 3D City Models

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ABSTRACT

The generation and visualisation of large 3D landscape and city models have received significant attention over the last few years – both in the scientific and the commercial community. Recent progress in 3D data capturing and web-based visualisation technologies are opening up new possibilities for a wide-spread use of these 3D models as a basis for new and exciting geoinformation applications. However, with the rapidly increasing size and complexity of the 3D models being acquired, a pressing need for suitable data management solutions has become apparent.

The Digital Landscape Server DILAS™ presented in this paper is one of the first commercial 3D GIS solutions. It is the result of a joint research project of GEONOVA AG and the Basel University of Applied Sciences (FHBB). DILAS combines object-relational database and XML technologies for the integrated management of very large 3D landscape and city models. The system provides a comprehensive support for colour, transparency, texture as well as animation and view control. This support for reality-based 3D models within a 3D GIS environment enables the automated generation of web-based 3D scenes with user-defined contents and appearance. The paper concludes with the presentation of projects from various application areas illustrating the potential of the DILAS 3D GIS technology.

1. INTRODUCTION

1.1. Motivation

Increasingly efficient 3D data capturing methods are boosting the creation of city-wide, regional or even national 3D landscape and city models. These 3D models provide an ideal basis for future spatial information and entertainment services in the (wireless) Internet (Nebiker, 2001a). The landscape and city models, which enable these services, are reaching an enormous size and an increasing complexity. Thus, the efficient management and web-based visualisation of such large 3D models incorporate a number of major challenges. One is the maintenance and updating of very large 3D geodatabases, another is the streaming and visualisation of 3D data over networks with still limited bandwidths.

1.2. Research Status and Activities

In the geospatial domain reality-based 3D models have received considerable attention from a number of perspectives, namely 3D data capturing, 3D visualisation, 3D data modelling and management.

3D Data Capture – There has been a lot of research work and considerable progress in the field of 3D data capture. Some 3D data capturing methods, such as the automatic generation of terrain models from aerial imagery or laser scanning, are now fully operational. The reconstruction of 3D objects, namely buildings, has reached a semi-automated level with reasonable production rates. Ongoing work is focussing on the integration of multiple sensors, namely aerial imagery and laser scanning in order to further increase the robustness and productivity of the 3D data acquisition process. An increasingly important aspect is the efficient acquisition, correction and assignment of object textures. (Haala and Brenner, 2001), (Grün et al., 2002)

3D Geovisualisation – There has been significant progress in the visualisation of landscape and city models. Over the last couple of years we have seen the emergence of first operational web-based solutions for the visualisation of very large landscape models. Advanced software solutions together with powerful 3D graphics on standard PCs and gradually increasing network bandwidths have turned geovisualisation from a specialist to a mass market application. Some of the ongoing developments are focussing on the streaming of very large numbers of 3D objects, such as encountered in large city models, and on enabling high-performance 3D visualisations on mobile devices. (Kraak et al., 2002), (Nebiker, 2001b), (Müller, 2003).

3D Data Modelling and Management – Over the last few years we have seen an increasing amount of work in the field of modelling and managing geospatial 3D objects. A number of projects were focussing on the modelling and management of complex 3D objects – in a primarily relational DBMS environment, e.g. (Pfund, 2001), (Wang, 2000). However, the relational model is not well suited for managing complex spatial objects and does not provide the scalability required to efficiently manage and serve large numbers of 3D objects as they are typically encountered in regional or national 3D landscape models. Some ongoing projects employ object-relational concepts to address the issues of topology (Oosterom et al., 2002) and integrated 3D geodata management within a 3D GIS framework, e.g. (Nebiker, 2002a), (Zlatanova et al., 2002), (Billen and Zlatanova, 2003).

1.3. Limitations and Challenges

Despite the considerable progress in the above mentioned research areas, there are still a number of limitations, namely in the fields of integration and usability of 3D city models. Some of the main limitations include:

- the lack of multi-user support and interoperability in 3D production and exploitation environments
- a primarily graphics-oriented modelling functionality and a limited or missing support for semantics
- a lack of support for managing and exchanging reality-based appearance information and animations in the prevailing CAD formats and platforms
- a missing or inefficient re-usability of 3D city models

1.4. Background and Aims of the DILAS Project

The DILAS™ system presented below is one of the first commercial 3D GIS systems available on the market. It is a comprehensive 3D GIS platform for the integrated management of regional to national 3D landscape and city models and for the generation of web-based geoinformation services (Nebiker, 2002a). DILAS is the result of a joint research project under the same name between GEONOVA AG (www.geonova.ch) and the Basel University of Applied Sciences (FHBB). The goal of the DILAS project was to identify the main requirements in 3D landscape management and to develop a system integrating these diverse and contrasting requirements into an operational and truly scalable solution. The project has received several awards, including the "Swiss Technology Award 2002".

2. DILAS CONCEPTS

This section highlights some of the key concepts of DILAS: a flexible 3D object model, a multi-representation and multi-resolution approach for the different object types, a storage concept for 3D and raster objects and XML-based process rules.

2.1. 3D Object Model

One of the core concepts of DILAS is a generic, fully object-oriented model for 3D geo-objects. This object model incorporates a 3D geometry model (Figure 1) which is based on a topologically structured 3D boundary representation and which supports most basic geometry types (points, lines, planar and non-planar shapes as well as a number of geometric primitives). It incorporates the capability for multiple levels of detail (LOD) as well as texture and appearance information. The 3D object model is suitable for representing any spatial topic (e.g. buildings, bridges, power-lines, construction projects or even aeronautical corridors and approach paths).

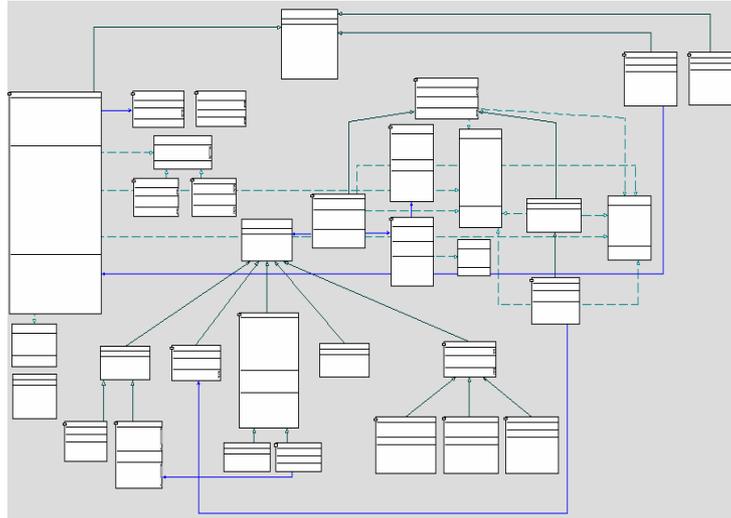


Figure 1: DILAS 3D object model (overview of UML class diagram).

The DILAS 3D object type is supplemented by a number of spatial data types used for representing very large mosaics of high resolution terrain and texture data:

- raster maps
- orthoimagery
- terrain and surface models (regular grids)
- terrain and surface models (irregular point clusters), e.g. for managing very large laser scanning height data sets

2.2. Multi-Representation and Multi-Resolution

Two key issues in the efficient management and visualisation of large 3D models are multiple representation and multiple resolution. Different multi-representation strategies were developed for the spatial object types used in DILAS. The original multi-resolution approach for managing very large raster mosaics (Nebiker, 1997) was further refined and extended to all mosaic types listed above. 3D objects are represented by 3D bounding boxes, 2D object boundaries and the actual 3D geometry. The first two representations are essential for efficient query operations and are automatically derived from the main 3D representation.

2.3. Storage Concept for 3D Objects

The goal for handling and manipulating 3D objects was to provide an optimum modelling flexibility in combination with an excellent object query and retrieval performance. The developed concept is based on the following components:

- a 3D object representation in Java and XML

- a 3D object serialisation and de-serialisation
- a persistence framework built on top of the DBMS
- spatial data types for 3D and raster objects within an object-relational environment

A number of these mechanisms are adapted from modern object-oriented programming environments. The object serialisation approach, for example, permits to map very complex objects to a simple, but highly efficient storage mechanism. The storage mechanism is based on a type extension for 3D objects which encapsulates the actual XML-based object storage. With the combined use of object serialisation and XML for storing 3D objects the expensive object reconstruction process inherent to the relational model can be avoided. This leads to a performance improvement in the order of magnitude.

The persistence framework developed in DILAS adapts concepts from the Java Data Objects (JDO) extension. It permits a fine-grained control over changes to the 3D object properties.

2.4. XML-based Process Rules

The processes of importing, structuring, generating, validating and exporting 3D city models are quite complex and typically differ from organisation to organisation, e.g. different level assignments, exchange of geometry only versus exchange of actual 3D objects etc.

The goal of accommodating these diverse requirements led to the development of a mechanism using 'XML-based process rules'. The benefits of this rule-based approach are:

- The possibility of formally specifying valid processing options (e.g. data import options) through the means of different XML Schemas.
- The simple adaptation of process rules or the creation of new process rules by a project leader or system administrator and the possibility of easily integrating these rules into the user interface.
- A rigorous validation of user-defined process rules by means of standard XML tools and mechanisms.

3. DILAS SYSTEM ARCHITECTURE

One of the design goals for DILAS was to rely on state-of-the art commercial database technologies. The current system is using an Oracle 9i DBMS. The DILAS product line consists of the modules DILAS Server, DILAS Manager, DILAS 3D Modeler and DILAS Scene Generator (Nebiker, 2002b).

3.1. DILAS Modules

The Server and Manager modules make up the core components of the system, which address the aspects of storage management, 3D scene management and querying, representation mapping as well as 3D scene export and import.

The 3D GIS editor component DILAS 3D Modeler is built into MicroStation V8, the latest CAD version of Bentley Systems. The 3D Modeler module performs the mapping between the DILAS 3D object model and the MicroStation V8 geometry model. DILAS 3D Modeler has full access to the CAD geometry model and to the abundance of construction and import/export functionality available within MicroStation V8. Currently, DILAS 3D Modeler incorporates functionality for the editing of 3D objects, the automatic generation of 3D buildings from roof models or 2D map data and for the interactive texturing of 3D objects.

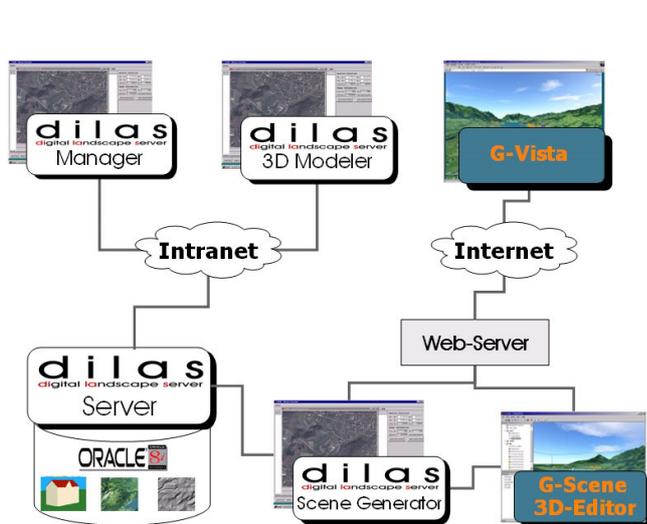


Figure 2: DILAS System Architecture.

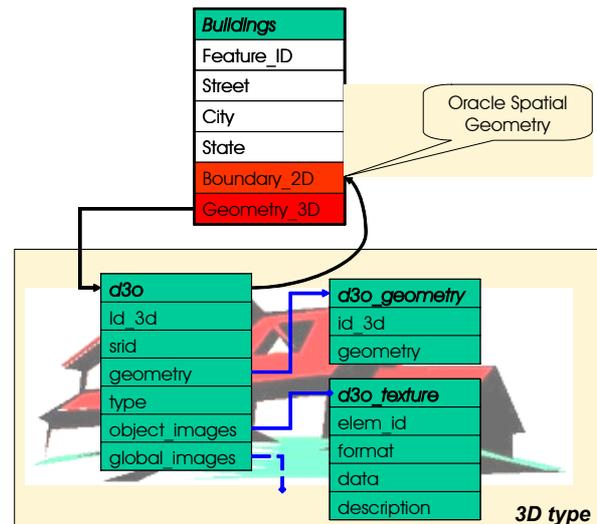


Figure 3: Feature table 'Buildings' with a DILAS 3D object attribute of the type 'd3o'.

The DILAS Scene Generator plays a key role in enabling the web-based visualisation of very large landscape and city models using GEONOVA's high-performance 3D-visualisation software G-VISTA. DILAS Scene Generator generates web-based multi-gigabyte 3D scenes with large numbers of 3D objects and 2D vector objects.

3.2. Integration of 2D and 3D

An important factor in making 3D city models and landscape models a technical and commercial success will be the integration of 3D landscape management solutions with existing 2D GIS environments. In DILAS this 3D-2D integration is achieved by adapting the OGC Simple Feature data model and by extending it with the spatial data types listed in the previous section. Figure 3 illustrates the extension with the DILAS 3D type. The chosen approach yields a number of benefits:

- the vast amounts of existing 2D geodata can also be accessed and exploited in 3D
- the 3D geometry, for example, can be treated as a spatial attribute of a conventional 'GIS feature'
- the 2D representation and all attributes of a 3D object or a multi-Terabyte orthoimage mosaic are visible in any OGC SF compliant GIS

3.3. Support for Visualisation and Animation in DILAS

In addition to the broad range of 'standard' GIS functionality, DILAS also provides a number of features, which specifically support or facilitate the visualisation and animation of reality-based 3D models (Nebiker, 2003).

Support for 3D Object Appearance – DILAS provides a comprehensive support for 3D object appearance, including colour, transparency and object textures. These appearance attributes can be assigned to any geometric element within the 3D geometry model. All appearance information is stored within the Oracle 9i database.

Semantic Colour Editor – Since all geometric elements of a 3D object may also carry semantic information, e.g. about the type of element (e.g. roof or façade) or the type of material (e.g. glass or aluminium), this attribute information may be used for controlling and editing the object appearance. The DILAS 3D Modeler incorporates a powerful colour editor which uses spatial and seman-

tic predicates for manipulating colour and transparency of entire city models, of individual 3D objects or specific parts thereof.

Texture Editor – DILAS also incorporates a tool for the assignment and editing of object textures. After selecting one or several 3D objects from the database, images can interactively be assigned to the object geometry. The results of this assignment and the imagery are stored in the database as part of the 3D object model. The texturing process is supported by additional tools for the verification and correction of normal vectors and by an integrated 3D viewer which enables the immediate verification of the texturing results.

4. APPLICATIONS AND RESULTS

The following projects and case studies were carried out using the DILAS™ 3D GIS. They illustrate the potential and benefits of such an integrated 3D geodatabase environment.

4.1. Management and Generation of Large 3D Landscapes

In June 2001, GEONOVA and the DILAS project team launched one of the first interactive web-based visualisation of a nation-wide 3D scene with resolutions down to the sub-meter level (Gibbs, 2001). The 3D scene for this "Flight through Switzerland" was generated using an early version of DILAS Scene Generator. Since then a number of new 3D geoinformation services have been generated using the DILAS system. The service shown in Figure 4 features a web-based 3D visualisation of the 2002 Winter Games in Salt Lake City – embedded in a 3D landscape of the entire State of Utah. Key components of the DILAS project are now used to manage and generate web-based 3D scenes with texture and height data in the range of hundreds of Gigabytes in size.



Figure 4: 3D geoinformation service featuring the 2002 Winter Games of Salt Lake City (www.sports-3d.com)

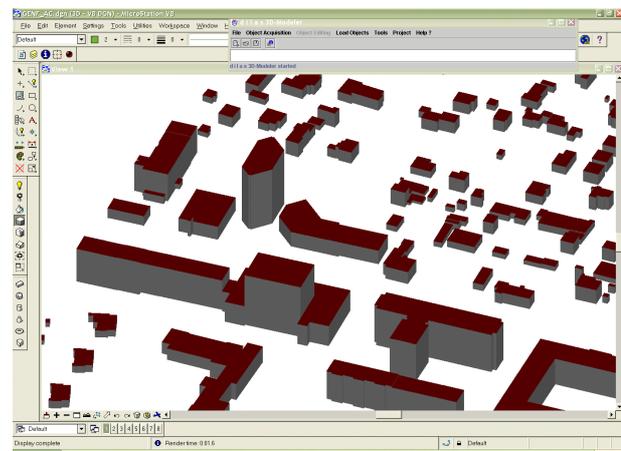


Figure 5: DILAS 3D Modeler with section of a 3d city model which was automatically derived using ground plane data together with a DTM and DSM (source data: Service des systèmes d'information et de géomatique (SSIG), Genève)

4.2. Management and Generation of 3D City Models

The fact that DILAS integrates all data into a single DBMS environment offers a range of new possibilities in the efficient generation of 3D city models. The following building generation strategies are supported at the moment:

- automatic building model generation based on 3D roof geometry information and on a digital terrain model

- identical approach with the incorporation of ground plane information, ensuring the correct position and shape of building facades and roof overhangs
- automatic building model generation using building ground plane information (e.g. 2D building outlines from cadastral data sources) together with a digital surface model and a digital terrain model

The latter approach permits a highly efficient and fully automatic generation of large city models in cases where surface models, typically from airborne laser scanning, are available (see Figure 5).

4.3. Town Planning and Local 3D Geoinformation Services

A recent study addressed the integration of a 3D GIS into the town planning environment of the city of Rüslikon in Switzerland. Among the investigated aspects were potential applications, data products, work flows and the 2D-3D GIS integration. As part of the investigations CAD-based building projects were integrated into the 3D GIS. Subsequently a range of 3D products were generated directly from the DILAS system environment including VRML scenes (Figure 6) with different appearance options, hardcopy 3D-prints (Figure 7) and interactive web-based 3D scenes for the G-VISTA viewer environment (Figure 9).

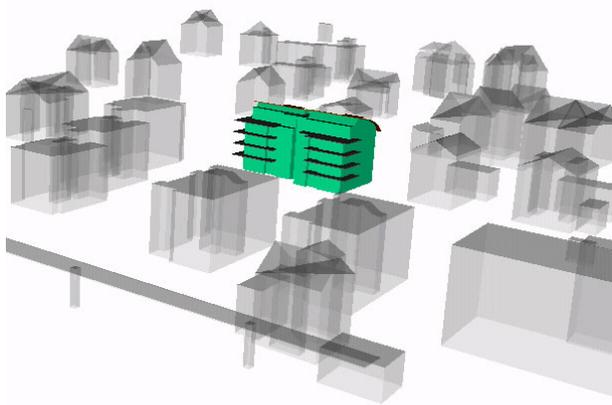


Figure 6: Highlighted construction project with semi-transparent city model.



Figure 7: Hardcopy 3D city model of the same area exported from the 3D GIS and produced with a 3D plotter.

4.4. Web-based 3D Geoinformation Services

Reality-based 3D models are playing an increasingly important role in the communication and assessment of infrastructure projects. One of the upcoming major construction projects in Switzerland will be a new railway tunnel crossing the Jura mountain range south of Basel. The access route to this new tunnel will lead through densely populated areas and has led to heated political discussions in the past. A comprehensive digital 3D model of the access corridor with thousands of 3D objects is playing an important role in the current planning and communication strategy. DILAS was chosen as a project platform, also because of the long-term character of the project and the need to gradually refine the 3D model over time. Figure 8 shows a small extent of this large and highly detailed regional 3D scene.

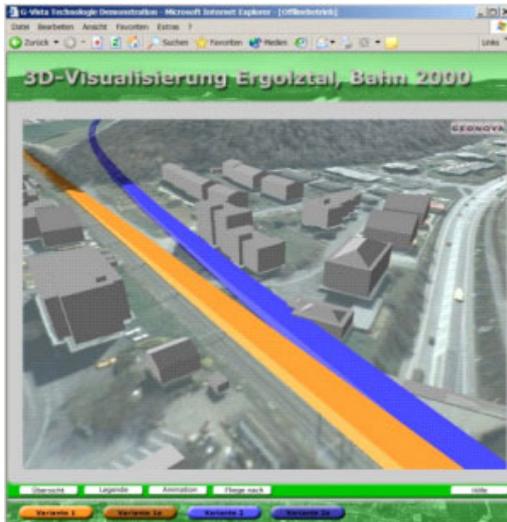


Figure 8: 3D geoinformation service for the Swiss railway project 'Bahn2000'

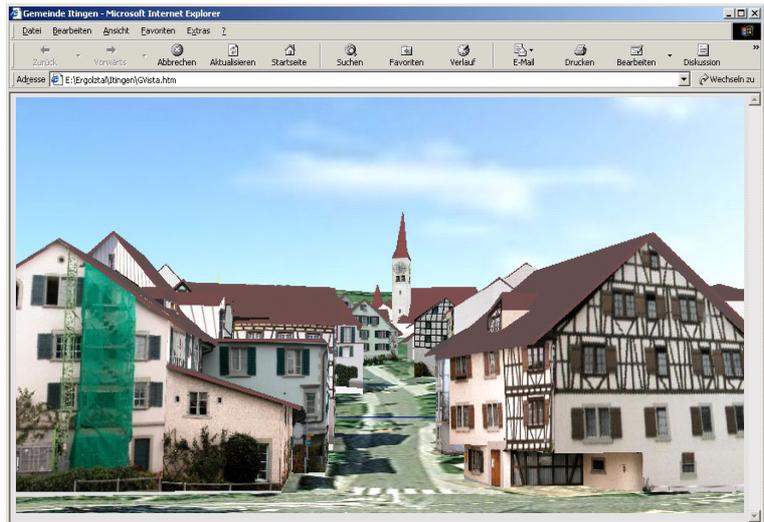


Figure 9: Interactive reality-based 3D model of Rüschtikon (Web-based 3D viewer G-VISTA™ by GEONOVA).

5. CONCLUSIONS

The DILAS project and the resulting commercial 3D GIS demonstrate that an efficient, flexible and fully DBMS-integrated management of very large 3D landscape and city models is feasible. The presented system provides an environment supporting all data types required to handle large 3D landscape and city models within a single object-relational DBMS. Such regional to national 3D landscape models bear a tremendous potential for illustrating spatial phenomenon to professionals and to the general public alike. The author strongly believes that such 3D geoinformation services will play an important role in the emerging mobile information society. Some of the key factors for the commercial success of such 3D services will be:

- the re-usability and integration of existing 3D geodata
- the integration of 2D and 3D geodata
- the inclusion of semantics
- and a comprehensive support for realism and animations

Ongoing and future research and development work at FHBB and GEONOVA is focusing on the streaming of large volumes of 3D object and 2D vector data to a large number of (mobile) clients. Another major challenge will be the enrichment of such 3D geoinformation services with additional spatially related content. For this purpose, the team has just launched the Geo-Roaming™ research project which aims at the development of a software framework for the management, updating and global utilisation of distributed dynamic 3D geoinformation services in the (mobile) Internet.

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7. ACKNOWLEDGEMENTS

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