# DESIGN AND IMPLEMENTATION OF THE HIGH-PERFORMANCE 3D DIGITAL LANDSCAPE SERVER 'DILAS'

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**ABSTRACT:**

Recent advances in the fields of 3D data capturing, storage capacities, database technologies and web-based 3D-visualisation are gradually enabling the establishment and exploitation of large 3D landscape and city models on a regional or even national scale. These landscape models will enable exciting new information and entertainment services in the Internet. However, there is a lack of solutions for managing, updating and serving such large 3D worlds. The research project dilas (Digital Landscape Server) presented in this paper addresses these issues.

This paper presents concepts addressing the vastly contrasting requirements of very large spatial objects, on the one side, and large numbers of complex and possibly dynamic 3D objects on the other. The chosen modelling concept for 3D objects combines a versatile 3D object model, multi-representation and object serialisation. This information is managed in a commercial object-relational DBMS using a hybrid data model. The results of the research project are currently being integrated into the commercial version of dilas – one of the first fully scalable solutions for the management and visualisation of very large 3D landscape models.

**KURZFASSUNG:**

Fortschritte in den Bereichen 3D-Geodatenerfassung, Speicherkapazitäten, Datenbanktechnologien und in der webbasierten 3D-Visualisierung ermöglichen mittlerweile den Aufbau regionaler bis nationaler 3D-Landschaftsmodelle und Stadtmodelle. Diese virtuellen Landschaftsmodelle werden eine Reihe neuer Informations- und Unterhaltungsdienste im Internet ermöglichen. Zur Zeit fehlen jedoch noch Lösungen zur effizienten Verwaltung und Nachführung derart grosser 3D-Landschaftsmodelle.

Die in diesem Beitrag beschriebenen Konzepte ermöglichen Lösungen für die stark unterschiedlichen Anforderungen sehr grosser Geoobjekte einerseits und sehr vieler, komplexer 3D-Geobjekte andererseits. Das vorgestellte und erfolgreich implementierte Lösungskonzept für 3D-Geoobjekte kombiniert ein leistungsfähiges 3D-Objektmodell mit einer Mehrfachrepräsentation und einer Objektserialisierung. Für die Speicherung dieser 3D-Geoobjekte kommt ein kommerzielles, objekt-relationales Datenbankverwaltungssystem Einsatz. Die Forschungsergebnisse werden zur Zeit in die kommerzielle Version von dilas integriert – einer der ersten voll skalierbaren Systemlösungen zur Verwaltung und Visualisierung beliebig grosser 3D-Stadtmodelle.

## 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, 2001). 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 net-works with still very limited bandwidths.

The representation of 3D landscape and city models requires a variety of spatial data types. These include orthoimagery and terrain data, vector-based 3D and 2D geo-objects, object textures, 3D scene objects, animations and hyperlinks. These data types have very different characteristics and requirements in terms of management and visualisation. The spectrum ranges from very large spatial objects, such as orthoimagery and high-resolution DTM data, with data volumes in the order of Terabytes to large numbers of complex and possibly dynamic 3D objects.

### 1.2 Related work

A number of ongoing research projects in the field of landscape management and 3D-GIS are either focussing on the management of very large imagery and DTM databases, or on the modelling and management of complex 3D objects, e.g. (Pfund, 2001), (Zlatanova and Tempfli, 2000) or (Wang, 2000). The latter projects address the aspects of 3D modelling and 3D topology, but they typically revert to conventional data

management concepts based on relational database models. 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.

### 1.3 Aim

The goal of the dilas project is to identify the main requirements in 3D landscape management and to develop a prototype system integrating these diverse and contrasting requirements into an operational and truly scalable solution. The dilas project succeeds the GRIDS project (Nebiker, 1997), (Nebiker and Relly, 1999) and builds on the since commercialised GRIDS Server (GEONOVA, 2001). The "dilas" project is funded by industry partners and by the Swiss Federal Office for Professional Education and Technology.

## 2. DILAS CONCEPTS

### 2.1 Overview

The following section highlights some of the key concepts developed and implemented as part of the dilas project: 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.

### 2.2 3D Object Model

One of the key concepts of the dilas project is a generic, fully object-oriented model for 3D geo-objects. This object model incorporates a topologically structured 3D geometry model, which supports most basic geometry types. The geometry model is based on a 3D boundary representation. It incorporates the capability for multiple levels of detail (LOD) as well as texture and appearance information required by 3D visualisation packages. The 3D object model is suitable for representing any spatial topic (e.g. buildings, bridges, power-lines).

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

### 2.3 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.

### 2.4 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 LOB-based object storage. Attributes which are frequently queried and accessed are automatically extracted from the serialised objects and stored in relational or object-relational form. With the combined use of object serialisation and LOBs 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.

### 2.5 XML-based Process Rules

The processes of importing, structuring, generating and validating 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 easy 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 of the dilas project was to rely on state-of-the art commercial database technologies. The current prototype system is using an Oracle 9i DBMS. The dilas prototype system consists of the modules dilas Server, dilas Manager, dilas 3D Modeler and dilas Scene Generator (Nebiker, 2002).

### 3.1 dilas Modules

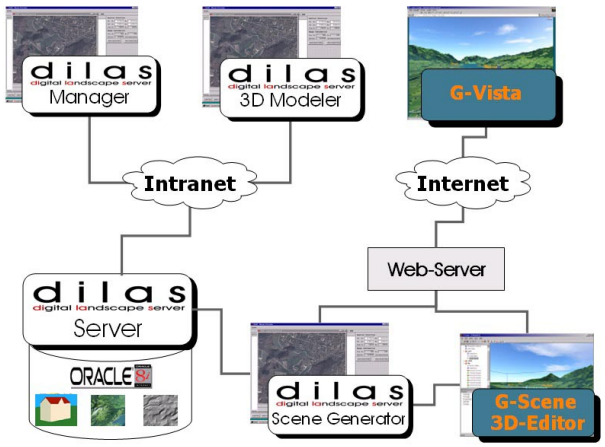


Figure 1: dilas System Architecture.

The Server and Manager module 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 Modeler component is built into MicroStation V8, the latest CAD version of Bentley Systems. The 3D Modeler module maps between the dilas 3D object model and the MicroStation V8 geometry model. Through the MicroStation Java API 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.

The dilas Scene Generator plays a key role in enabling the web-based visualisation of very large landscape and city models using the high-performance 3D-visualisation software G-Vista (GEONOVA AG). dilas Scene Generator generates web-based multi-gigabyte 3D scenes with large numbers of 3D objects.

### 3.2 The Integration of 2D and 3D

One of the key factors 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. This 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 of a 3D object is visible as a read-only attribute in any OGC SF compliant GIS

## 4. RESULTS

### 4.1 Feasibility Studies

The dilas project was preceded by a number of studies by (Eugster and Henz, 2001) and (Schaad and Schärer, 2001) which proved the feasibility of the 'dilas approach' and its superior performance and scalability over conventional data management solutions.

### 4.2 Management and Generation of Large 3D Landscapes

In June 2001, the project team and its industry partners GEONOVA and G-Graphix launched probably the world's 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 the first version of dilas Scene Generator. Since then a number of new 3D geoinformation services have been launched using results from the dilas project.

The service shown in
Figure 2 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 2: 3D geoinformation service featuring the 2002 Winter Games of Salt Lake City (www.sports-3d.com)

### 4.3 Management and Generation of 3D City Models

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

- automatic building model generation based on 3D roof geometry information and on a digital terrain model
- 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 very large city models in cases where surface models, typically from airborne laser scanning, are available (see
Figure 3).

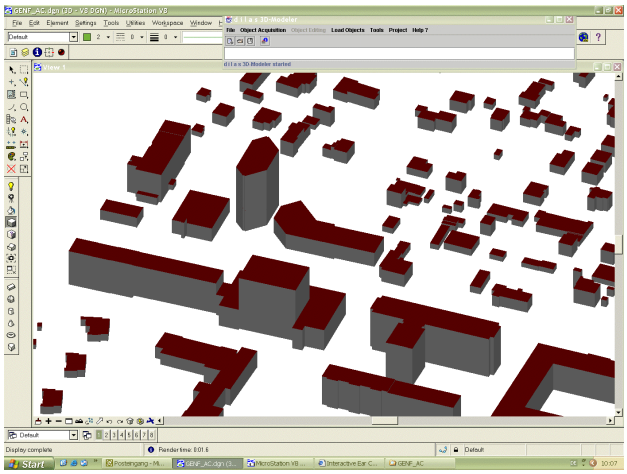

Figure 3: *dilas 3D Modeler* with a section of a 3d city model which was automatically derived using ground plane data together with a DTM and DSM (source data: Service des systèmes d' information et de géomatique (SSIG), Genève)

## 5. CONCLUSIONS

The dilas project has shown that an efficient, flexible and highly integrated management of very large 3D landscape and city models is feasible. The presented prototype system provides an environment supporting all data types required to handle large 3D landscape and city models within a single object-relational DBMS.

The concepts presented in this paper have been evaluated on a number of real-world projects with thousands of 3D objects and very large texture and height data sets. In these projects the feasibility of the 'dilas approach' and its excellent performance and scalability in comparison with conventional data management solutions could be clearly demonstrated. The results of the dilas project are currently being integrated into a commercial 3D landscape server which is expected to be released in Q2/2002.

Ongoing and future research activities are focusing on the streaming of 3D object data to a large number of mobile clients and on the optimal handling of LODs for 3D objects. Further important aspects affecting the dilas project are the future definition of 3D types in the OGC SF framework.

## 6. REFERENCES


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[1] KTI-Project Nr. 5195.1 'dilas – Digital Landscape Server'