APPLYING THE 3D GIS DILAS TO ARCHAEOLOGY AND CULTURAL HERITAGE PROJECTS – REQUIREMENTS AND FIRST RESULTS

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ABSTRACT:

The original aim of the 3D GIS project DILAS (Digital Landscape Server) was the efficient generation, management and visualisation of large 3D landscape and city models. Thus, the primary focus was placed on 3D objects with often generalised geometry and on medium to small scale representations. The result of the first project phase was an operational prototype of a 3D GIS based on an object-relational DBMS. This prototype system has since been commercialised and is now used in applications such as regional or city planning. Among the emerging application areas for 3D GIS are archaeology and the preservation of cultural heritage. This paper highlights some of the domain-specific requirements and illustrates how these requirements have been addressed in DILAS. The requirements include a strong support for object semantics, for complex object geometries and photo-realistic textures, for the integration of existing databases and for temporal aspects.
3D object support in DILAS is based on an object-oriented topological 3D data model. This model is automatically mapped between an object representation in Java and an XML representation which is stored in an object-relational DBMS (Oracle 9i). DILAS provides a rich semantic support at the object level and at the element level. DILAS is built on top of a spatial DBMS architecture (Oracle Spatial) and can make use of spatial indexing and querying functionality available in typical 2D GIS. This architecture has now been extended to support complex 3D objects, e.g. buildings consisting of their exterior hull and of different types of interior objects (rooms, hallways, caverns etc.).
The following two projects served as case studies and test beds for the new features. In the first example DILAS was applied to the generation of a high-resolution, reality-based 3D model of the castle of Wildenstein, BL (Switzerland). The complex model incorporates the interior and exterior of the castle including its surroundings. The second project is the 3D reconstruction of the roman city of Augusta Raurica (Switzerland) and the modern city of Augst, which is partially built on top of the historic site. Both projects demonstrate the benefits of applying 3D GIS to archaeological and cultural heritage projects by integrating all required types of information into a single system environment. It is also shown, that a 3D GIS serves as an ideal platform for generating web-based 3D geoinformation services, in this case by using the high-performance viewer technology G-VISTA.

1. INTRODUCTION

1.1 Motivation

Cultural monuments have an inestimable value. But often this is only recognized once the cultural monuments are endangered or already destroyed. The fire of the famous Kapellbruecke of Lucerne (Switzerland) or the deliberate destruction of the large Buddha statues in the Afghan Bamiyan called this only too clearly in memory. With the use of virtual 3D models it is possible to renovate or – in the worst case – to reconstruct such cultural heritage objects. In addition to the long-term digital preservation the production of virtual 3D models has further concrete reasons. The provided 3D models, for example, serve as basis for preservations or for interactive presentations.

1.2 Current Status and Activities

DILAS (Digital Landscape Server) is one of the first commercial 3D GIS systems available on the market. DILAS enables the efficient generation, management and visualisation of large 3D landscape and city models. DILAS also serves as a research and development platform at the Basel University of Applied Sciences (FHBB) where it is being applied to different application areas. One of them is the digital 3D reconstruction of cultural heritage, a long-term project initiative of the FHBB. The results of this project initiative are an increasing number of interactive, digital 3D models of important historical buildings and objects in the area. In a first project DILAS is applied to the generation of a high-resolution, reality-based 3D model of the castle of Wildenstein, BL (Switzerland). The complex model incorporates the interior and exterior of the castle including its surroundings. The second project is the 3D reconstruction of the roman city of Augusta Raurica (Switzerland) and the modern city of Augst, which is partially built on top of the historic site. Both projects demonstrate the benefits of applying 3D GIS to archaeological and cultural heritage projects by integrating all required types of information into a single system environment. It is also shown, that a 3D GIS serves as an ideal platform for generating web-based 3D geoinformation services, in this case by using the high-performance viewer technology G-VISTA.

2. REQUIREMENTS

2.1 Object semantics

In archaeological and cultural heritage projects object semantics are typically just as important as the actual geometry. Thus, it is a key requirement to assign thematic information to entire objects and to individual geometric elements. This also makes it possible to select, analyse or edit the geometry and the appearance of objects based on semantic criteria.

2.2 Object geometry

Cultural heritage objects often have a very irregular complex geometry. Thus, a good digital reconstruction requires a very detailed 3D model with a lot of geometry elements. So there are two main requirements to a 3D GIS. The first one is a support for the acquisition and handling of large amounts of complex and non-planar 3D geometry. The second one is the visualisation of these objects which consists of a lot of geometry elements.

2.3 Photo-realistic texture

For realistic virtual 3D models object textures are needed. It must be possible to assign aerial or close-range imagery to the individual geometry elements. Ideally, the resulting texture information should also be managed within the 3D GIS. Major challenges include the full automation of the texturing process and the visualisation of objects with high-resolution texture information.

3. THE DILAS 3D GIS

3.1 Overview

DILAS (Digital Landscape Server) 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 and is now a commercial product line of GEONOVA AG (www.geonova.ch).
The next 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.

3.2 DILAS Concepts

3.2.1 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 3D geometry model 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).

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

The concept for the DILAS 3D object model already incorporates visualisation-related features such as viewpoints and lighting information. In addition the model has been explicitly defined to easily cater for future extensions, such as animation paths etc.

3.2.2 Multi-Representation and Multi-Resolution – Two key issues in the efficient management and visualisation of large 3D models are multiple representations and multiple resolutions. 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 (Nebiker, 2002c). The first two representations are essential for efficient query operations and are automatically derived from the main 3D representation.

3.2.3 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 large object based (LOB) object storage.
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.

3.2.4 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.

3.3 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 system is using an Oracle 9i DBMS. The DILAS system consists of the modules DILAS Server, DILAS Manager, DILAS 3D Modeler and DILAS Scene Generator (Nebiker, 2002b).

3.3.1 DILAS Modules

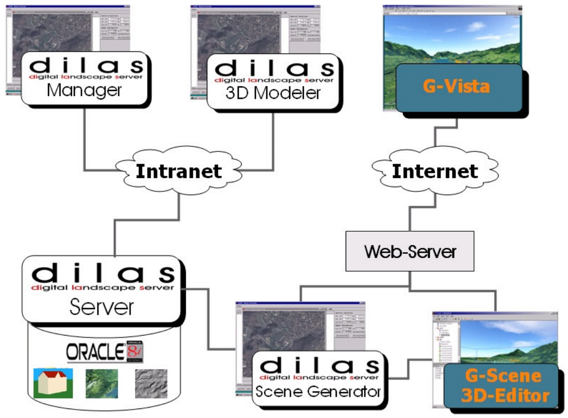

Figure 1: DILAS System Architecture

The Server and Manager modules make up the core components of the system. They 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 CAD of Bentley Systems. The 3D Modeler module performs the mapping 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 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.

3.3.2 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

3.4 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. DILAS provides a comprehensive support for 3D object appearance, including colour, transparency and object textures (Wüst, 2002). 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.

3.4.1 Texture Editor – DILAS incorporates a tool for the assignment and editing of object textures (Figure 2). After selecting one or several 3D objects from the database, images can interactively be assigned to the object geometry. It is also possible to assign textures semi-automatically to the object geometry. First it is necessary to convert the image orientation parameters in an XML-based orientation file. After that the XML file can be imported in the texture editor tool. Then the images can automatically be assigned to the object geometry. The assigned imagery is subsequently 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.

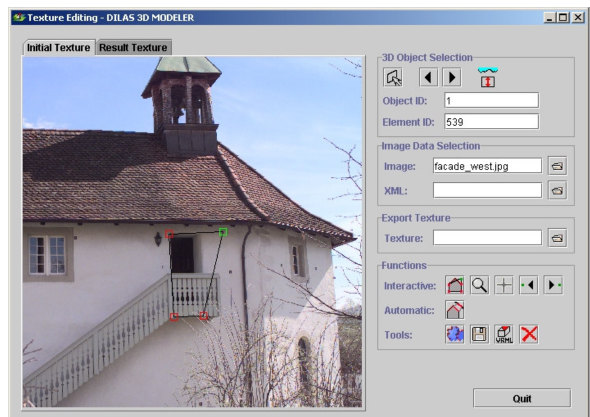

Figure 2: DILAS 3D Modeler – Texture Editor

The semi-automatic texturing tool was developed in a diploma thesis at FHBB (Knabl, 2003). To test this texturing tool a 3D model of the chapel of Zwingen (Switzerland) was used. The constructed CAD model (Figure 3) consists of about 1800 geometry elements. For the texturing approximately 300 elements were used. The integrated support for semi-automatic texturing is an essential tool in the process of texturing complex objects.

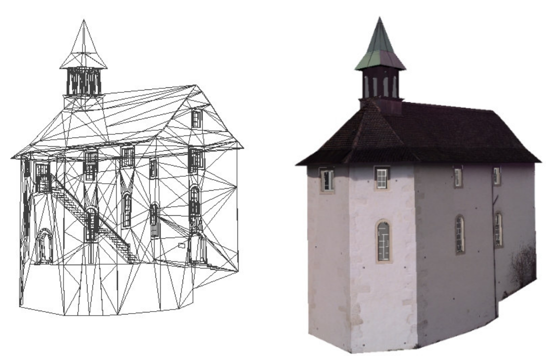

Figure 3: CAD model and fully textured 3D model of the chapel of Zwingen

4. APPLICATIONS AND RESULTS

The following cultural heritage projects were carried out using the DILAS 3D GIS in order to assess its suitability and to gain valuable information for further developments and investigations.

4.1 3D model of the castle of Wildenstein, BL (Switzerland)

A recent project at FHBB addressed the acquisition and modelling of the castle of Wildenstein, BL (Switzerland). This castle is the only preserved height-castle in this region. The tower of the castle was built around 1293. The other parts of the castle were built later around 1693.

Figure 4: Castle of Wildenstein, BL (Switzerland)

As shown in the photograph above the acquisition and modelling of the castle was very difficult due to its exposed location and complex form. Thus, a range of technologies were used for the surveying of the castle. The exterior hull of the castle, for example, was surveyed by means of helicopter-based digital close-range photogrammetry using a Nikon D100 camera. The interior of the castle was surveyed using reflector-less tachymetry and terrestrial laser scanning. A precise geodetic control network was established to tie these different surveys to a common reference system. The comparison between the two methods revealed some interesting results. While laser scanning is unbeatable in terms of data acquisition rate, it proved that current laser scanning processing software is still ill suited to the modelling and construction of irregular 3D objects and that operators typically reverted to the combination of tachymetry and CAD construction. The integrated result of these surveys was a 3D CAD model of the castle of Wildenstein.
The DILAS 3D GIS was subsequently used to manage the 3D model of the castle.

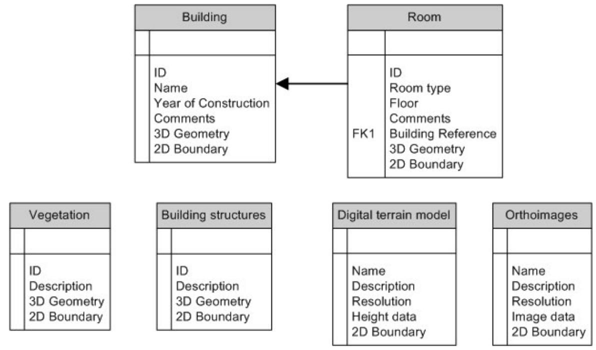

Figure 5: Data model of the castle of Wildenstein

The data model for this application is shown in Figure 5. In this case the data model is relatively simple and consists of buildings and their rooms. However, the objects themselves can be highly complex and can consist of a lot of geometry elements with different semantics (e.g. wooden facade or concrete ground etc.). To manage this so called element thematic it was necessary to attach thematic attributes to all geometry elements. This can be done using XML-based import rules which, for example, assign element attributes based on CAD levels before storing the 3d objects in the database.
The project revealed a number of advantages of the 3D GIS over the CAD file-based solution. One was the possibility to selectively load one or more rooms or building parts from the database based on different predicates such as floor number, room type or building material. Another advantage was the multi-user support which allowed several different teams of students to simultaneously work on the same 3D model.
Following the generation of the complete 3D model in DILAS which also included the digital elevation model and the orthoimagery of the area, an interactive 3D scene was created (Figure 6). This 3D scene can be displayed with the viewer technology G-VISTA.

Figure 6: 3D model of the castle of Wildenstein, BL (Switzerland)

G-VISTA is a high-performance 3D viewing technology which enables the interactive visualisation of very large 3D landscapes – either from CD/DVD or via the Web. The web-based capability significantly extends the range of users and applications for such cultural heritage projects. In our case the 3D model is not only used for the digital preservation of the castle of Wildenstein but also for the presentation and exploitation of this important historical site via the Internet, e.g. for educational purposes.

4.2 3D reconstruction of the roman city of Augusta Raurica (Switzerland)

Augusta Raurica was a roman city ten kilometres east of Basel. The city was inhabited by some 20’000 people in the first centuries A.D. Many monuments are well preserved and the historic site attracts more than 120'000 visitors annually (www.augustaraurica.ch).

The aim of first diploma thesis at the FHBB was to create a realistic virtual 3D model of the modern city of Augst, which was partially built on top of the ruins of Augusta Raurica. The base data consisted of aerial imagery and ground planes of the buildings. The 3D city model was generated using interactive digital photogrammetric restitution and the automatic city model generation functionality provided by DILAS. The results of the project consisted of a digital terrain model, orthoimages and a CAD-based 3D city model of Augst (Figure 9).

In a second project a 3D model of the ancient city of Augusta Raurica was generated (Salathé, 2001). The basis for this project was an existing wooden 3D model at a scale of 1:500 which had been established around 1960 (Figure 7). The model is based on an abundance of archaeological evidence and had thus gained a certain level of acceptance. This was an important pre-requisite for using this model as a basis for the digital reconstruction.

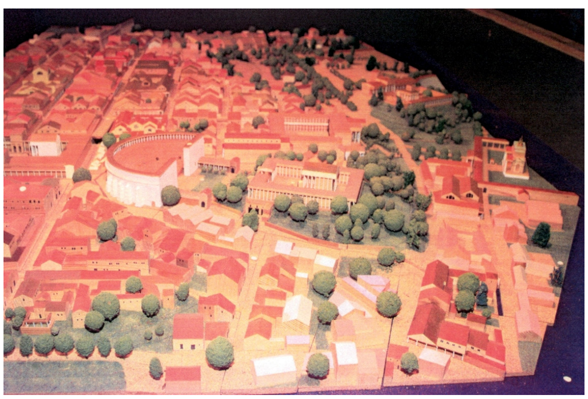

Figure 7: Wooden 3D city model of the ancient city of Augusta Raurica (original scale of 1:500)

The ancient city model was reconstructed using close-range digital photogrammetry. One result of the project was the 3D CAD model of the ancient city of Augusta Raurica (Figure 10). The ancient digital elevation model was also reconstructed using archeological data sets.

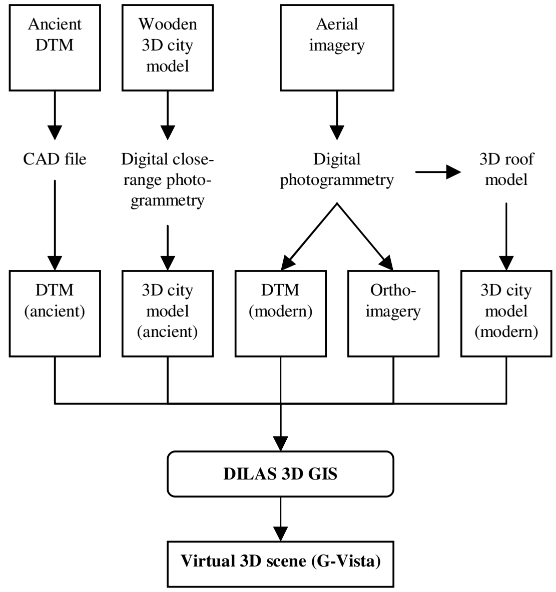

Figure 8: Basic data, analysis and results of the 3D model creation of the modern city of Augst and the ancient city of Augusta Raurica

In the following steps, the different data sets were imported into the DILAS 3D GIS (see Figure 8). In an initial step a common data model had to be defined. Since the data acquisition had taken place much earlier – without considerations for a future 3D GIS – the data model was much coarser than in the case of Wildenstein. After the database import an interactive 3D scene was generated using the DILAS Scene Generator. The different data components and object classes within the 3D scene (see Figure 8) can dynamically be loaded and overlaid.

Figure 9: 3D city model of the modern city of Augst

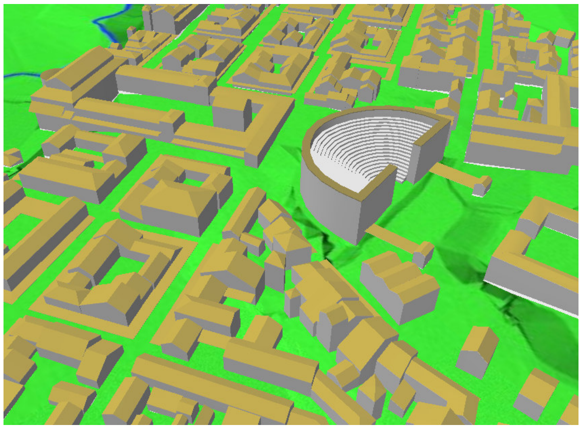

Figure 10: 3D city model of the ancient city of Augusta Raurica

Figure 11: 3D city model of the ancient city of Augusta Raurica with modern orthoimages and height model

In combination with the dynamic visualisation this enables completely new possibilities for exploring and analysing the ancient city as well as potential conflicts between the archeological site and the modern city (Figure 11).

5. CONCLUSION

In the projects presented above it was possible to demonstrate the feasibility and benefits of applying a 3D GIS such as DILAS to cultural heritage projects. There are a number of advantages offered by the use of a 3D GIS for managing reality-based virtual 3D models. Among them are the possibilities of semantically structuring the data, of 3D geometry management and editing based on attribute predicates and the multi-user support which is an important aspect in major projects. But there are also some problems associated with creating 3D models of typical cultural heritage objects. The main problem is the efficient creation of 3D CAD models of the typically very complex non-planar geometry of such objects. The complexity of these real-world objects is generally not yet met by the capabilities of data exchange standards or visualisation tools such as VRML viewers. In the case of the castle of Wildenstein, for example, most facade and building parts have a very irregular geometry which would best be modelled using non-planar geometry. However, in order to ensure the usability of the results with standard tools and viewers, the geometric model had to be limited to planar shapes. For the acquisition of rooms and caverns laser scanning technology would be the ideal solution. Unfortunately, many of the processing tools available do not yet allow the full exploitation of the potential of this technology. For example, the software used had a poor or missing support for non-planar geometry, for constructing hidden objects, for object semantics, and for a selective data reduction. There are further challenges in the field of 3D viewer technologies such as a suitable indoor navigation and visualisation. Particularly in application areas such as archaeology and preservation of cultural heritage it is important to interactively and intuitively explore the interior of these objects. An additional problem is the visualisation of complex 3D objects with large amounts of texture data. A truly scalable 3D GIS such as DILAS provides the basis for handling such large reality-based 3D models in an integrated environment and for enabling new solutions for analysing and visualising such 3D databases.

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