Multi-scale representations for scalable and dynamic 3D geoinformation services

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1. Introduction

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 (wireless) Internet. The handling and dynamic visualisation of truly scalable 3D landscape models in a web-based environment raise a variety of multi-scale representation issues.

In terms of multi-scale representation there a number of differences between 2D and 3D geoinformation solutions. A common denominator is the presence and simultaneous use of multiple and hybrid data sets, e.g. the integrated use of raster maps at different scales or the combined use of vector and raster representations. The major distinction is the number of representations per spatial view. In 2D geoinformation solutions and services there is always just one scale and one representation per view, or one representation per data type and view. In a scalable 3D geoinformation environment there are as a general rule different levels of detail (LOD), i.e. multiple scales and multiple representations per view. The presence of multiple representations per view also raises the issue of how to handle transitions between different scales and representations within the same view.

2. 3D Landscape Models – Contents and Multi-scale Issues

2.1. Typical Components of 3D Landscape Models

The representation of 3D landscape and city models requires a variety of components and corresponding spatial data types. These include terrain texture (orthoimagery, raster maps), digital height models (DTM, DSM), vector-based 2D geo-objects, 3D objects, object textures, animations and hyperlinks. The spectrum of these components ranges from very large spatial objects to large numbers of complex and possibly dynamic 3D objects. These data types have very different characteristics and requirements in terms of management, visualisation and multi-scale representation.

2.2. Multi-scale Resolution Concepts (and Implementations)

The following short summary gives an indication of the different multi-scale representation issues to be addressed in a 3D geoinformation solution and of some of the main concepts:

- **Terrain texture** – The size of raster data sets in large-scale geoinformation services easily reaches an order of hundreds of Gigabytes to Terabytes. Today there are a number of well-established concepts, such as tiling, multi-resolution pyramids and progressive encoding schemes, which can be used to efficiently exploit very large imagery mosaics in a 2D and 3D environment (Nebiker, 2001).The use of multiple and discrete representations, e.g. of multiple raster maps at different scales, which is common in 2D geoinformation solutions, is usually not suited for a 3D environment where these multiple representations have to co-exist and graphically 'harmonise' in the same spatial view.
- **Digital terrain models** – The interactive visualisation of large terrain surfaces requires multi-resolution tessellation strategies. The common goals of all strategies are to optimally represent the terrain surface with a minimum number of meshes per view and to progressively load and improve the terrain model in a dynamic environment. There are a variety of approaches using regular or irregular, rectangular or triangular tessellations (Pajarola, 1998), (Aasgard, 2002), (Nebiker, 2001).
- **2D objects** – Vector-based 2D data will play an important role in 3D geoinformation solutions, since they constitute the vast majority of existing geodata and are often readily available for large areas. As pointed out earlier, efficient multi-scale representation solutions are required, which also address the aspects of scale or representation transition within the same spatial view. It is expected that upcoming solutions for 3D environments will greatly benefit from the past and current research activities in the two-dimensional domain.
- **3D objects** – The management and visualisation of large numbers of 3D objects in a distributed environment raises a number of issues: different representations for different levels of detail (simplified block models, generalised 3D models, detailed CAD models), possibly hierarchical geometry models which can progressively be built-up, automatic generalisation and aggregation of 3D objects, integration of 2D and 3D geoinformation environments etc. A number of these issues are being addressed in the DILAS project.

3. The DILAS Project

3.1. Introduction

The goal of the dilas project is to identify the main requirements in 3D geoinformation services and to develop a prototype system for the management and visualisation of very large 3D landscape and city models. DILAS is an applied research project with an emphasis on feasibility and on an evolutionary approach. One of the design goals, for example, was the use and possible extension of existing standards and state-of-the art technologies, such as the OpenGIS Simple Feature Specification (Open GIS Consortium, 1999), XML and object-relational DBMS technology (currently Oracle 9i). The dilas project succeeds the GRIDS project, (Nebiker and Relly, 1999), which addressed the DBMS-based management of very large raster databases, and builds on the since commercialised GRIDS Server (GEONOVA, 2001).

The dilas architecture consists of a number of data management modules (dilas Server, Manager, Scene Generator and 3D Modeler) and the web-based viewer component (G-Vista) (Nebiker, 2002).

In the following section a number of multi-scale resolution concepts which have been implemented as part of the DILAS project are highlighted:

- a 3D object model with integrated support for LOD
- the handling of multiple representations of 3D objects within the OGC SFS framework
- a quadtree-based multi-resolution access structure for 3D objects

3.2. 3D Object Model and Data Type

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 for 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).

Two different representations of the 3D object model are used within dilas: a Java-based and an XML-based representation which are transformed using object serialisation and de-serialisation mechanisms. The combination of these two representations provides an optimum modelling flexibility, an excellent object query and retrieval performance in a commercial DBMS framework and a self-documenting mechanism for data exchange.

3.3. Multiple Representations of 3D Objects

In addition to the object-internal support for LOD, DILAS also supports – and exploits – multiple representations of the 3D objects. Each object is represented by a 3D bounding box, a 2D object boundary and the actual 3D geometry. The first two representations are essential for efficient query operations and are automatically derived from the main 3D representation.

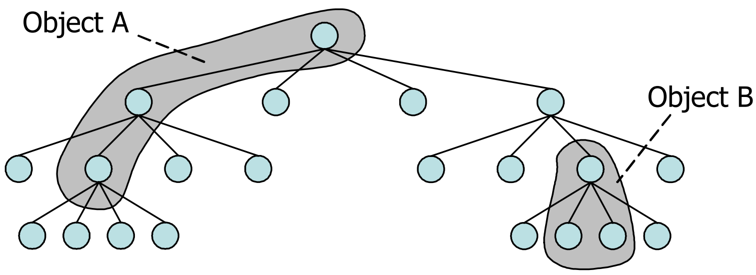
It is expected that one of the key factors in making 3D landscape models and 3D-GIS a technical and commercial success will be their compatibility with existing 2D GIS environments. In dilas this 3D-2D integration is achieved by adapting the OGC Simple Feature Specification and by extending it with a new 3D spatial data type. 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 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 SFS compliant GIS

3.4. Quadtree-based Multi-Resolution Access Structure for 3D Objects

Regional to national 3D geoinformation services incorporate large numbers of 3D objects and 'location-based' hyperlinks, which need to be accessed in a dynamic mode over low-bandwidth connections.

In the DILAS environment hyperlinks and 3D objects are organised in a hierarchical quadtree-based data structure (see below) which supports levels of details (LOD) and multi-representations. Upon entering a 3D service the G-Vista viewer accesses the root node and all the globally visible objects assigned to that node. Additional nodes are loaded depending on the viewers current position. The appearance of objects in the MR-quadtree depends on their position and on their visibility settings (min. and max. distance). A hyperlink with local significance (object B) will appear on lower levels than a 'high-level' label or hyperlink which should be visible throughout the 3D-scene (object A).



4. Conclusions and Outlook

The multi-scale representation concepts presented above are currently being integrated into the first commercial version of the DILAS system. Several feasibility studies and tests had previously demonstrated an excellent performance and flexibility. First results of the project had already helped to launch one of the first nation-wide 3D geoinformation services in Summer 2001 (www.geonova.ch).

Large-scale 3D landscape models and web-based 3D geoinformation services are a new but rapidly evolving field. It is typical for such an early phase that with each step solved new issues are starting to show up. Among the unresolved issues related to MR are:

- Optimal integration of 3D objects (e.g. bridges or buildings) with multi-resolution terrain models
- Transition between different representations, particularly for 2D vector data
- The handling of inter-object topology in multi-scale representation 3D geoinformation environments

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