Chapter 11
Making Interoperability Persistent: A 3D Geo Database Based on CityGML

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Abstract. Virtual 3D city models are becoming increasingly complex with respect to their spatial and thematic structures. CityGML is an OGC standard to represent and exchange city models in an interoperable way. As CityGML datasets may become very large and may contain deeply structured objects, the efficient storage and input/output of CityGML data requires both carefully optimized database schemas and data access tools. In this paper a 3D geo database for CityGML is presented. It is shown how the CityGML application schema is mapped to a relational schema in an optimized way. Then, a concept for the parallelized handling of (City)GML files using multithreading and the implementation of an import and export tool is explained in detail. Finally, the results from a first performance evaluation are given.

11.1 Introduction

Like many cities in Germany, Berlin is currently establishing a virtual 3D city model. More and more applications require additional height information and object structuring in vertical direction – just think of urban and landscape modelling, architectural design, tourism, 3D cadastre, environmental simulations, radio network planning, disaster management, or navigation. In order to assess the comprehensive 3D geoinformation for a city like Berlin, an appropriate data management component has to be built. Here, data may be collected, compared, adapted, updated, and exchanged. The data is used for urban studies, planning variants, calculation of intervisibility, impacts of vegetation alterations, and semantic data explorations. A necessary precondition is the existence of a standardised data model, ensuring consistent and interoperable data structuring.

CityGML [9] is an international standard for the representation and exchange of 3D city and landscape models issued by the Open Geospatial Consortium (OGC). The
common information model behind CityGML defines classes and relations for the most relevant topographic objects in cities and regional models with respect to their geometrical, topological, semantic and appearance properties. By covering thematic information and structures, CityGML complements 3D graphics formats like KML and X3D/VRML. CityGML is implemented as an application schema for the Geography Markup Language (GML) 3.1.1 [3] of the OGC and the ISO TC211.

Based on CityGML, a 3D geo database for the official Berlin 3D city model was established. The main development objective was to achieve both the efficient storage and fast processing of CityGML. For this reason, the CityGML data model was mapped to a compact relational database schema. Moreover, an import/export tool was realised to facilitate the high-performance processing of CityGML and GML structures. Both aspects are considered integral parts of the 3D geo data management in Berlin. In this paper, we therefore address the modelling and database design of the Berlin 3D geo database as well as the software engineering aspects of the import/export tool.

11.2 A 3D geo database for Berlin

The 3D geo database has been realised as an Oracle 10G R2 Spatial relational database schema. In the first project phase, the Institute of Geodesy and Geoinformation, University of Bonn, built a first version that was confined to a subset of CityGML [1]. In the second phase, we now have redesigned the existing database schema to fully comply with CityGML 1.0.0. For this upgrade, additional support of interior building structures, the new appearance model and the full set of CityGML’s thematic modules is provided.

In detail, the database implements the following key features of CityGML:

- **Complex thematic modelling**
  The description of thematic features includes attributes, relations, and nested aggregation hierarchies (part-whole-relations) between features. Since on the spatial level geometry objects are assigned to features, both a semantic and a geometrical aggregation hierarchy can be employed. The rich semantic information can be used for thematic queries, analyses, or simulations.

- **Five different Levels of Detail (LODs)**
  Following the idea of multi-representation, every geo object (including DTMs and aerial photographs) can be stored in five different LODs. With increasing LOD, objects not only obtain a more precise and finer geometry, but do also gain in thematic refinement.

- **Appearance data**
  In addition to semantic information and geometry, features can have appearances, i.e., information about the observable properties of a feature’s surface. Appearances can represent textures and materials, but are not restricted to visual properties. In fact, appearances can transport any surface based theme, such as infrared radiation, noise pollution, etc.

- **Complex digital terrain models (DTMs)**
  DTMs may be represented in four different ways in the 3D geo database: by regular grids, triangulated irregular networks (TINs), 3D mass points and 3D break