May 2012
Oracle Spatial User Conference
May 23, 2012
Ronald Reagan Building and International Trade Center
Washington, DC  USA
Javier Herreruela
Institute for Geodesy and Geoinformation Science
Technical University of Berlin

Joint work with T.H.Kolbe, C.Nagel, G.König, A.Lorenz, B.Naderi
Deploying 3D City Models for Urban and Metropolitan Planning
OVERVIEW
• The 3D City Database is a free 3D geo database to store, represent, and manage virtual 3D city models on top of the Oracle Spatial relational database. The database model contains semantically rich, hierarchically structured, multi-scale urban objects facilitating complex GIS modeling and analysis tasks, far beyond visualization.

CHALLENGES / OPPORTUNITIES
• The growing popularity of 3D city models and their fields of application like Urban Information Modeling create an increasing demand for tools that can handle and manage large amounts of data in OGC’s CityGML format.
• Usage of 3D city models not only means visualization. Many complex questions in areas like energy assessment and urban planning for smart cities can now be answered with the help of the 3D City Database.

SOLUTIONS
• The 3D City Database is an object-relational schema for storing large and complex 3D city models described in CityGML built on top of Oracle Spatial as a product.
• It works with Oracle Spatial 10g R2, 11g R1 and 11g R2

RESULTS
• The 3D City Database makes comprehensive use of Oracle Spatial features. It allows Oracle Spatial to support storage and management of CityGML contents – with CityGML being the leading standard for semantic 3D city modeling – in an almost native way.
• The software is open source, released under the terms of the GNU Lesser General Public License v3 (LGPL)
Program Agenda

• CityGML Short Introduction
• 3D City DB Overview, CityGML Support
• 3D City DB KML/COLLADA Export
• 3D City DB in Action
CityGML Short Introduction
Modeling Urban Spaces

**Application-independent Geospatial Information Model**
for virtual 3D city and landscape models

- CityGML defines an **ontology of the urban space**
  - Facilitates urban information modeling
  - Comprises **different thematic areas** (buildings, water, terrain, etc.)

- **Adopted international OGC standard** since 08/2008

- **CityGML represents**
  - 3D geometry, 3D topology, semantics and appearance
  - in 5 discrete scales (Levels of Detail, LOD)
CityGML Short Introduction

CityGML vs. Graphics Formats

- Hierarchically structured feature model
- Spatio-semantic coherence
  - Geometric entities know WHAT they are
  - Semantic entities know WHERE they are and their spatial extents
- Facilitates sophisticated semantic and spatial analyses
CityGML Short Introduction

CityGML vs. Graphics Formats

**CityGML:**
Complex semantic objects with structured geometry

**KML, X3D, VRML, etc.:**
No or little semantics, just (unstructured) geometry
Program Agenda

• CityGML Short Introduction
• 3D City DB Overview, CityGML Support
• 3D City DB KML/COLLADA Export
• 3D City DB in Action
3D City DB Overview, CityGML Support

Background: 3D City model of Berlin

550,000 buildings, reconstructed from 2D-cadastre and LIDAR-data

Textures automatically extracted from oblique aerial images

Semantic information based on cadastre data

Model structured according to CityGML

www.3d-stadtmodell-berlin.de
Motivation for a 3D geo database in Berlin

• Repository for the official 3D city model
  – Complete representation of city topography and landscape
  – Data from various sources (cadastre, architecture, utility networks, etc.)

• Usage of 3D city model for applications like
  – City and Urban Planning
  – Energy assessment for smart cities
  – Political Issues and Consulting, Civic Participation

• Basis for the Berlin 3D Spatial Data Infrastructure
  – Access through OGC Web Services, Google Earth (KML), online streaming
  – Implemented using Oracle Spatial 11g
3D City DB Overview, CityGML Support
Tools - www.3dcitydb.net

3DCityDB v2 is a free and Open Source 3D geo database to store, represent, and manage virtual 3D city models.

### 3D City Database
- Semantically rich, hierarchically structured model
- Five different Levels of Detail (LODs)
- Appearance data in addition to flexible 3D geometries
- Complex digital terrain models (DTMs)
- Management of large aerial photographs
- Version and history management
- Matching/merging of building features
- Works with Oracle Spatial 10g R2, 11g R1, and 11g R2

### 3D City DB Importer/Exporter
- Full support for CityGML 1.0 and 0.4.0
- Exports of KML/COLLADA models
- Generic KML information balloons
- Reading/writing CityGML instance documents of arbitrary file size
- Multithreaded programming facilitating high-performance CityGML processing
- Resolving of forward and backwards XLinks
- User-defined Coordinate Reference Systems
- Coordinate transformations for CityGML exports
3D City DB Overview, CityGML Support
Where is it already in operation?

3D City DB used in production systems
• State Mapping Agencies in Saarland, Rheinland-Palatinate, Baden-Württemberg, Hesse, Bavaria, Thuringia, Saxony
• Cities: Berlin, Potsdam, München, Nürnberg, Kempten, Zürich (Switzerland)

Used in products by commercial partners
• virtualcitySYSTEMS
• M.O.S.S
• Autodesk LandXPlorer

Trial period
• SOM Chicago, TU Delft, Autodesk Paris, Rotterdam
3D City DB Overview, CityGML Support
Development cycle of the 3D City Database

CityGML
- XSD Schema
  `<xs:complexType
    name="CityModelType">
    `<xs:extension ...`
- UML Model

Simplified UML Model

Model simplification

Java binding (JAXB)

Schema-derived classes
`public class CityModel { ...

SQL queries (Imp/Export Tool)

Mapping classes to tables

Relational schema + SDO_GEOMETRY

SQL DDL statements (JDeveloper)

Import data

Export data

Database creation

Oracle Spatial User Conference 2012
Oracle
Main features

- **Standalone Java client for import/export of CityGML models**
  - Support for CityGML files of arbitrary file size (>> 4GB)
  - High-performance CityGML processing through multithreading using Oracle Spatial’s Java API
  - Resolving of forward and backwards Xlinks

- Support for different CRSs and coordinate transformations (based on Oracle Spatial functionality)

- **Exporting data as KML/COLLADA visualization models**

- **Open Source and released under the terms of the LGPLv3**
3D City DB Overview, CityGML Support

Some performance facts

- **3D City DB server**: 4x Intel® Xeon® QuadCore, RedHat EL 5, 56GB RAM, 4 SAS disks (146GB), 16 SSD RAID array (á 64GB), Oracle 10G R2 (default installation)

- **Berlin 3D City Model**
  - 534,357 buildings in LOD2 / LOD3 (file size: 11GB)
  - 2,109,496 thematic boundary surfaces (roof, wall, ground)
  - 9,083,266 surface geometries (3D Polygons given as SDO_Geometry)
  - 5,202,499 individual textures associated with polygons (202 MB, ORDImages)

### Import and export times

<table>
<thead>
<tr>
<th>Import/Export</th>
<th>Time</th>
<th>Feature/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Import with textures (11000 tiled files)</td>
<td>9 h 30 min</td>
<td>77 feature/sec</td>
</tr>
<tr>
<td>Import w/o texture (1 file)</td>
<td>16 min</td>
<td>2754 feature/sec</td>
</tr>
<tr>
<td>Export with textures (11GB + 202MB)</td>
<td>28 min</td>
<td>1574 feature/sec</td>
</tr>
<tr>
<td>Export w/o textures (7.9GB)</td>
<td>5 min 20 sec</td>
<td>8262 feature/sec</td>
</tr>
</tbody>
</table>
3D City DB Overview, CityGML Support

Some performance facts

- **3DCityDB server**: 4x Intel® Xeon® QuadCore, RedHat EL 5, 56GB RAM, 4 SAS disks (146GB), 16 SSD RAID array (á 64GB), Oracle 10G R2 (default installation)

- **Cologne / Leverkusen 3D City Model**
  - 1,055,951 buildings in LOD1 (no textures, single file size: 7.8GB)
  - 11,511,040 surface geometries (3D Polygons given as SDO_Geometry)
  - 1,056,797 generic attributes

### Import and export times

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Import (1 file)</strong></td>
<td><strong>25 min</strong></td>
<td><strong>704 feature/sec</strong></td>
</tr>
<tr>
<td><strong>Export (7.8GB)</strong></td>
<td><strong>5 min 10 sec</strong></td>
<td><strong>3406 feature/sec</strong></td>
</tr>
</tbody>
</table>
Program Agenda

- CityGML Short Introduction
- 3D City DB Overview, CityGML Support
- 3D City DB KML/COLLADA Export
- 3D City DB in Action
• One 3D City Model
  – may comprise (or link) thematic data from different applications
  – can be stored and exchanged as one CityGML dataset
3D City DB KML/COLLADA Export
Different Display Styles

- Footprint
- Extruded
- Geometry
- COLLADA
3D City DB KML/COLLADA Export
Multiple Styles for Visual Levels-of-Detail
1. No tiling

2. Automatic (fixed tile size) or manual (rows, columns) tiling

3. Each CityObject in its own tile; this mode can be combined with any of the above
3D City DB KML/COLLADA Export

3D Object Interaction and Information

BLDG_0003000f00093e8b

Address:
Straße des 17. Juni 135
Berlin

Available in: LoD2

Appearances: 1
Measured height: 45.78056 m
Existing generic attributes (mouseOver for values): ANZ_LOC, DENK_ID, DENKHALART, EIG_KL_PV, EIG_KL_ST, FOLE, GE_LoD2_zOffset, GMDE, H_First_Max, H_First_Mn, HNR, H_Trauf_Max, H_Trauf_Mn, Kachel, KREIS, LAND, LFD, RBEZ, STR, TexVersion
External reference name: 0003000f00093e8b
3D City DB KML/COLLADA Export
Application Specific Portrayal

• Example: Solar Atlas Berlin

Semantic information (here: estimated solar energy production) is used both to cartographically style the visualization and to fill the „information balloons“
Program Agenda

- CityGML Short Introduction
- 3D City DB Overview, CityGML Support
- 3D City DB KML/COLLADA Export
- 3D City DB in Action
3D City DB in Action
New Application: Energy Atlas Berlin

- Heat emission
- Solar radiation
- Heating energy estimation
- Utility network
- Solar potential

Image: Hoegner / Stilla, TU München

The CityGML Database
3D City DB
3D City DB in Action
Usage of Oracle Spatial Technologies

• 3D geometries + 3D CRS (including 3D coordinate transformations)

• Spatial indexes for fast searching and query processing

• Spatial functions (spatial aggregation, SDO_RELATE)

• Bulk processing of spatial data (during imports / exports)

• GeoRaster, ORDImage

• Comprehensive and multithreaded usage of Oracle Spatial's Java API

• Integrated usage of spatial and thematic data in combination with the Oracle Workspace Manager
3D City DB - Summary

What is available?

http://www.3dcitydb.net

• 3D City Database (current version 2.0.6)
  – Oracle SQL scripts and PL/SQL functions, including documentation
  – Implementation based on Oracle Spatial's 3D capabilities

• 3D City Database Import/Export Tool (current version 1.4)
  – Executable Java binaries, complete source code, comprehensive documentation
  – Supports CityGML (input/output) and KML/COLLADA (output)

The 3D City DB is in practical use in many places all over Europe. In production environments, research institutes, educational centers and at the core of new innovative projects like the Energy Atlas Berlin.
DEMONSTRATION

Energy Atlas Berlin
Q&A