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Javier Herrruela
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
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
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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 standardized OGC Web Services, Google Earth (KML), online streaming
# 3D City DB Overview, CityGML Support

**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

Tools - www.3dcitydb.net
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
Development cycle of the 3D City Database

**CityGML**
- XSD Schema
  ```xml
  <xs:complexType name="CityModelType">
    <xs:extension>
      ...
    </xs:extension>
  </xs:complexType>
  ```

**UML Model**

**Model simplification**

**Simplified UML Model**

**Mapping classes to tables**

**Relational schema**

**SQL DDL statements** (JDeveloper)

**Java binding** (JAXB)

**Schema-derived classes**

```java
public class CityModel {
  ...
}
```

**SQL queries** (Imp/Export Tool)

**Import data**

**Export data**

**Database creation**

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**3D City DB Overview, CityGML Support**
3D City DB Overview, CityGML Support

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
  – 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

- **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)

- **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
  - 5,202,499 individual textures associated with geometries (202 MB)

<table>
<thead>
<tr>
<th>Import and export times</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>
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<tr>
<td>Import w/o texture (1 file)</td>
<td>16 min</td>
<td>2754 feature/sec</td>
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<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

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

### Import and export times

<table>
<thead>
<tr>
<th></th>
<th>Time</th>
<th>Features/Sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Import (1 file)</td>
<td>25 min</td>
<td>704 feature/sec</td>
</tr>
<tr>
<td>Export (7.8GB)</td>
<td>5 min 10 sec</td>
<td>3406 feature/sec</td>
</tr>
</tbody>
</table>
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3D City DB KML/COLLADA Export

3D Visualisation of CityGML Models

- **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

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, DENKIMALRT, EIG_KL_PV, EIG_KL_ST, FOLIE, GE_LoD2_zOffset, GMDE, H_First_Max, H_First_Min, HNR, H_Trauf_Max, H_Trauf_Min, 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"
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New Application: Energy Atlas Berlin

Heat emission

Solar radiation

Utility network

Image: Hoegner / Stilla, TU München

Heating energy estimation

The CityGML Database

3D City DB

Geschätzter Energieverbrauch [kWh/a]

Solar potential
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
  - Comprehensive documentation

- **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