Semantic 3D City Models for Urban Information Fusion and City Lifecycle Management

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Who are we?

Institute for Geodesy and Geoinformation Science (IGG), Chair of Methods of Geoinformation Technology

- Team consisting of 7 researchers / PhD students, 3 techn. staff

Main research areas:

- Spatio-semantic modeling, analyses and databases
- 3D object recognition, interpretation, and 3D geovisualization
- Strong focus on Virtual 3D City and Landscape Models, Urban Information Modeling & Fusion
- Indoor Navigation (spatial modeling, localization methods, orientation support)
- Originator and leader in the development of the international standards CityGML, Web 3D Service, IndoorGML of the Open Geospatial Consortium
City Lifecycle Management

- (in analogy to product lifecycle management) is about the **conception, design, construction, usage, maintenance, and disposal** of urban assets
  - many assets are directly related to physical objects in the real world (e.g. buildings, bridges, roads, technical infrastructures, trees)

- requires a comprehensive documentation of the status of (and plans about) the assets
  - indicators, indexes, operation and maintenance status
  - relations to other assets (e.g. aggregations, dependencies)
  - covering many different thematic aspects from different domains (e.g. economic, environmental, energetic, and social indicators)

- assets to be modeled and represented in such a way, that allows to fuse these urban information from different domains / disciplines
Challenges in Asset Modeling / Data Provision

How should **assets be modeled and represented**?
- How to ensure that data from different disciplines can be associated / related to each other?
- Problem: indicators / parameters from different domains can only be related in a sensible way, if they are referring to the (almost) exact identical entities
- Thus: different domains need to have a coherent understanding of the urban assets

What is an appropriate **granularity** of urban asset models?

Who is defining / giving a **reference model**?

Who can / will provide the **data about the urban assets**?
- In a sustainable and reliable way?
- With full coverage of all (relevant) entities of the urban space?
many urban assets are directly related to physical objects

physical objects occupy space in the real world
- partitioning of the occupied real world space \(\rightarrow\) discrete objects
- criteria for subdivision: thematic classification into different topographic elements like buildings, roads, trees, water bodies etc.

**spatio-semantic representation** of the relevant geoinformation
- modeling of the city & its constituents
- objects are categorized
- spatial properties location, shape, extent

different, discrete scale levels (LODs)

real world space is 3D \(\rightarrow\) semantic 3D city models
City is decomposed into meaningful objects with clear semantics and defined spatial and thematic properties:

- buildings, roads, railways, terrain, water bodies, vegetation
- buildings may be further decomposed into different storeys (and even more detailed into appartements and single rooms)
The given structuring of the geodata enables to relate domain specific application data to entities of the real world by linking it with the ID of the corresponding geoobject in an unambiguous way.

- requires that the structuring of the geodata is fitting to (coherent with) the application.
Application independent Geospatial Information Model for virtual 3D city and landscape models

- comprises different thematic areas (buildings, vegetation, water, terrain, traffic, tunnels, bridges etc.)

- Internat ‘I Standard of the Open Geospatial Consortium
  - V1.0.0 adopted in 08/2008; V2.0.0 adopted in 3/2012

- Data model (UML) + Exchange format (based on GML3)

CityGML represents

- 3D geometry, 3D topology, semantics, and appearance

- in 5 discrete scales (Levels of Detail, LOD)
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CityGML for 3D city models

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22. 6. 2012
Example for a Semantic Building Model

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3D-Modell: Stadt Coburg

BuildingInstallation (Dormer)

BuildingPart

BuildingPart

Building surface (WallSurface)

Building
Semantic 3D City Model of Berlin

>550,000 buildings;
- fully-automatically generated from 2D cadastre footprints & airborne laserscanning data.
- textures (automatically extracted from aerial images)
- semantic information (includes data from cadastre)
- 3D utility networks from the energy providers
- modeled according to CityGML

www.virtual-berlin.de
(Inter)national Usage / Availability of CityGML

★ Cities / Municipalities
- e.g. almost all German cities with 3D city models; Rotterdam, Zürich, Geneva, Paris, Marseille, Istanbul, Vancouver, Montreal, Kuala Lumpur, Yokohama, Doha; however, few implementations in the USA (Blacksburg, Boston)

★ Organisations
- e.g. IGN France, Ordnance Survey UK, State Mapping Agencies of Bavaria, BaWü, Hesse, RLP, NRW, BIMTAS in Istanbul, many companies, research institutes, and universities

★ CityGML is **reference model in** the european **INSPIRE** initiative (→ full EU coverage)
- INSPIRE building model is based on CityGML

★ The official national and municipal 3D geoinformation standards of Germany, The Netherlands base on CityGML
Application Example

Strategic Energy Planning
Energy Atlas Berlin

Collaboration project (2.5M€) partially funded by the European Institute of Innovation and Technology EIT

- located within the Knowledge & Innovation Center for Climate Change and Mitigation (Climate KIC)

- Partners:

  **Berlin University of Technology:**
  - Innovationszentrum Energie
  - Institut für Geodäsie und Geoinformationstechnik
  - Institut für Energietechnik
  - Institut für Energie- und Automatisierungstechnik
  - Institut für Architektur
  - Institut für Technologie und Management (ITM)

  **Zentrum für Technik und Gesellschaft, TU Berlin**
  - Deutsches GeoForschungszentrum Potsdam (GFZ)
  - Vattenfall Europe Berlin AG
  - GASAG AG
  - Berlin Partner GmbH
  - Berliner Senat für Wirtschaft, Technologie und Frauen
  - Bezirksamt Charlottenburg-Wilmersdorf in Berlin
Planning and Decision Support Tool

Level

Sphere of competence

Political & entrepreneurial level

Design & planning level

Engineering level

Strategic goals, (legal) regulations

Cities – Urban districts
Spatial planning & conceptual design

Buildings – Quarters
Energy efficient components;
Energy sources;
Distribution networks

Spatial Aggregation

Future projects

Starter project

+ Energy-ADE

CityGML

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Scale Levels of the Energy Atlas

City
District
Quarter / Block
Building / Street
Appartement
Room

Generalisation / Aggregation
Resolution / Level of Detail
Correlation Consumption ⇆ Building param’s

Building data

- Volume [m³]
- Floor space [m²]
- Building type
- Building usage
- Year of construction
- (renovation state)
- Number of habitants

Consumption data

- Electricity
- Water
- Gas
- (Remote) Heating

Correlation

What is the relation of consumption with specific building characteristics?

3D City Model
- Geo Base Data

Full coverage of entire cities!

Only available for a few households (detailed data only where Smart Meters are installed)

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20. 6. 2012
Estimated Heating Energy Consumption

Estimated Energy Consumption [kwh/a]

- 5.659 - 84.798
- 84.799 - 175.183
- 175.184 - 277.386
- 277.387 - 426.684
- 426.685 - 670.171
- 670.172 - 1.677.163
- 1.677.164 - 6.985.480
- kein Wohngebäude
Energy Demand Estimation (I)

3D City Model + Geo Base Data

Correlation function

Estimation of the individual energy demand for every single building

Aggregation

Quarter level

District level

City level
Energy Demand Estimation (II)

GIS
3D City Model + Geo Base Data

Correlation function

Estimation of the individual energy demand for every single building

Energy Demand Estimation (II)

Changes to the city model according to planned / possible measures

Impacts on the energy demand can be directly estimated and compared with the current status

Estimation of the energy demand

Quarter level

District level

City level

Aggregation
The energy production potentials for photovoltaics and solar thermal heating, the required investments and achievable CO2 reductions have been computed for each of the 550,000 buildings on the level of roof surface segments and were added to the 3D city model.
Aggregating Energy Indicators for Districts

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Aggregating Energy Indicators for Districts

CityObjectGroup name:
Hansaviertel

Existing generic attributes (mouseOver for values):

- AGGR_SOLAR_SUM_AREA_P_EK1
- AGGR_SOLAR_SUM_AREA_P_EK2
- AGGR_SOLAR_SUM_AREA_P_EK3
- AGGR_SOLAR_SUM_AREA_PGES
- AGGR_SOLAR_SUM_AREA_SGES
- AGGR_SOLAR_SUM_CO2_EINSPI
- AGGR_SOLAR_SUM_CO2_ST
- AGGR_SOLAR_SUM_IEST
- AGGR_SOLAR_SUM_INVEST
- AGGR_SOLAR_SUM_STR_ESTR
- AGGR_SOLAR_SUM_WAERMEERTR
Each 3D cell is 500m x 500m x thickness of the rock layer at the respective location.

Currently represented in CityGML as GenericCityObjects with generic attributes.
Virtual Drilling / Well

Parameters: location & depth

Estimation: Sustainably producable geothermal energy; usable energy; costs

1. Determination of all buildings in an area
2. Summing up the heating energy demand of the buildings
3. Comparison with the amount of usable geothermal energy
4. If more energy is available, increase size of region

Estimation of the Berlin underground model and the geothermal potential by J. Sippel, O. Kastner, GeoForschungsZentrum Potsdam
Energy Atlas: Information Fusion

Heat Emission

Solar Irradiation LOD1

Utility Networks

Thermal Remote Sensing

Solar Potential

Geschätzter Energieverbrauch [kWh/a]

5.659 - 8.798
84.799 - 175.183
175.184 - 277.386
277.387 - 426.684
426.685 - 670.171
670.172 - 1.677.163
1.677.164 - 6.985.480
kein Wohngebäude
Ausblick: Stadtsystemmodellierung inkl. sozialräumlicher Dynamik

Kooperation mit SIEMENS Corporate Technologies & Dr. Hempel (Zentrum für Technik und Gesellschaft, TUB)
Conclusions

- **Semantic 3D City Models** (→ Urban Information Models)
  - are an appropriate reference model and data platform to attach/link domain specific information across different disciplines for CLM
  - Semantic 3D city models are provided by authoritative sources (municipal agencies, state & national mapping agencies) → full coverage of the urban space, high reliability, stability
    - Google 3D models, Open Streetmap are not suitable!!
  - allow for 3D visualizations AND thematic analyses
  - facilitate comprehensive analyses on the urban scale in the fields of e.g. energy assessment, environmental simulation, urban planning
  - accumulate knowledge (including analyses results)

- **Interoperability** is key for information integration
  - OGC ‘s CityGML defines the semantic model + exchange format