Motivations and Challenges of 3D City Modeling

A rapid transition of urban areas towards energy efficiency and the adaption to challenges posed by climate change are highly required...

- 3D city modeling can play an essential role for energy planners and municipal managers, supporting them with:
  - energy diagnosis of the present situation
  - Coordination of strategies to decrease building energy demand
  - ...and increase sustainable energy supply concepts
  - development of strategies for sustainable transport

- A common, flexible and open city modeling standard is needed to:
  - deal with different levels of details and data availabilities/qualities
  - store and exchange numerous and miscellaneous urban data on a unique support
  - provide a visualization of results

From 2D to 3D

<table>
<thead>
<tr>
<th>Standard: CityGML</th>
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<td>2007</td>
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<tr>
<td>CityGML 0.4.0</td>
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3D Citymodels based on CityGML

- Standardized (OGC) open data model for virtual 3D Citymodels
- Based on ISO 19139 Standard GML (XML based), extended for urban structures
- Spatio-semantic Model, linking geometry, topological relationships, semantic data and design property (for visualization)

Strengths
- open standard, regularly updated
- already wide-used (at least in Germany)
- XML based and extendable
- many possibilities of spatial analysis
- modeling with 4 possible Level of Details (LOD)

3D geospatial data infrastructure
Simulation of district heating energy demand

Data collection
- Generation/Import and quality control of a 3D City model (CityGML LoD1/LoD2)
- Development of an integrated process of district heat demand calculation

1. Generation/Import and quality control of a 3D City model (CityGML LoD1/LoD2)
2. Automated calculation of building envelop thermal characteristics
   - Use of national building libraries (building types/ages)
   - Updated with additional information (precise U-values, refurbishment etc.)
3. Geometrical Analysis of 3D Model, pre-processing with building parameters
4. Heat demand calculation for each building through the monthly energy balance method (EN ISO 13790)

Analysis of 3D City model

- Building classification
- Volume Calculation
  - Tetraeder decomposition
- Extraction adjacent walls
- Window extraction from textures

Geometrical data processing

The heated volume, wall, cellar wall and window areas must be corrected between the 3D Model and the thermal building model, particularly if:
- Cellar type = heated/non-heated
- Attic storey type = non-heated
- Usage ALKIS = commercial-residential building

Thermal Data processing

- Building attributes
  - Calculation
  - Building library (IWU etc.)
  - Updated building state (photo, observation in-situ)

Results Visualization

© European Institute for Energy Research, 3D-Print of Stuttgart (1km x 1km)
2D GIS – Heat demand in Grünbühl
3D Visualization – Heat demand in Grünbühl
Software development at HFT

CityEnergy3D

- Input 3D spatial database of CityGML file
- Simulation of energy demand and scenarios
- PV analysis and shadow calculation
- Standardization: OGC services and CityGML ADE
- Extension to other aspects of urban planning

District Heat Demand Calculation – Case studies

Two case studies of District Heat Demand Calculation, with different level of details and input data qualities
- District Grünbühl, in Ludwigsburg
- District Rintheim, in Karlsruhe

Case study 1: Ludwigsburg – Grünbühl

Case Study 1: Post-war district
Ludwigsburg – Grünbühl
- Living area: 77,000 m²
- Energy supply: mainly Gas boilers
- 3D model: LoD1 (roof area from laser scanning)
- U-values deduced from building age and types information, updated with outside observations

Data collection
- For apartment dwellings: building data collected from owner companies
- For private buildings: on-site observation (survey)

Integration of a „facade damage index“ (0 - 5) in the 3D Model dataset
- Used for the infiltration rate assessment
- Potential use to define refurbishment priorities in a refurbishment scenario

Outside facade state of post-war buildings

GEB_ID
STRAẞE_NAME
STRAẞE_NR
NUTZ_ALK nach ALK Definition (Whs; Wghs; Schule …)
WOHNTYP nach IWU Definition (EFH; RH; MFH; GMH…)
GEBALTKLASSE nach IWU Definition (A; B;…; J )
VOLLGESCHOSSE
DACHGESCHOSS_TYP
KELLER_TYP
SANIERUNGSJAHR
FASSADE_ID
WRICHTUNG
WDAEMD
WDAEMLAMBDA
WUWERT
FUWERT
FSCHATTEN
WSCHAD
ANTEIL
"1 - 5"
"1 - 5"
"1 - 5"
"1 - 5"
"1 - 5"
Case study 1: Ludwigsburg – Grünbühl

Building and refurbishment year
• 1/3 post-war buildings
• Since 1990, 1% of the district living area is refurbished yearly

Heat demand calculation
• Average: 106 kWh/m²/yr
  • from 30 for newly refurbished buildings to 216 kWh/m²/yr for old leaky buildings

Comparison with gas consumptions* (average over the last 6 years)
Global Deviation: 18%

Use of 3D City Model for urban planning
• Refurbishment scenario and energy saving potentials
• Definition of refurbishment priorities, temporal planning of the urban renewal
• Calculation of refurbishment investment/global energy costs

Case study 2: Karlsruhe – Rintheim

Case Study 2: partly refurbished Apartment dwellings
Karlsruhe – Rintheim
• Living area: 65,000 m² (36 Buildings – 1/3 refurbished)
• Energy supply: Gas boilers
• 3D model: Karlsruhe LoD2 model (roof area from laser scanning)
• Precise information on u-values (building classification in 6 types)
Case study 2: Karlsruhe – Rintheim

Individual building comparison – Simulated and measured heat demand*

- Average gas consumption over 3 years
- Total district deviation: 6.7%
- Standard deviation: 18%

* Assumptions: domestic hot water: 20 kWh/m²/yr; Gas boiler efficiency: 88%

Building type comparison – Simulated and measured heat demand*

- Building types II - V match well (deviation ~5%)
- Low-energy building type VI – 18% underestimated heat demand
- Non-refurbished building type I – 32% over-estimated heat demand

* Assumptions: domestic hot water: 20 kWh/m²/yr; Gas boiler efficiency: 88%

Impact factors

Simulation model
- Dynamic
- Monthly energy balance
- Heat loss due to transmission
- Based on Typology

Attribut data
- Detailed Attributes per building
- Based on statistics

Geometric detail

Open issues

What do we gain with LoD 3 models?

LoD2 + facade geometry

Pilot Scharnhauser Park, Ostfildern, LoD 3

What do we gain with LoD 3 models?

LoD2 + facade geometry

Pilot Scharnhauser Park, Ostfildern, LoD 3

Open issues

How do we get better attribute data?

Crowd sourcing

Crowd Sourcing: Open Street Map 3D

Heilbronn

Crowd Sourcing: Open Street Map 3D

Prof. A. Zipf, Universität Heidelberg, http://www.osm3d.de/
Open issues

Measure / Enhance data quality

- CityGML model
- Model requirements
- Validation
- Validation Report
- Certificate
- Improved Model
- Healing Report

http://citydoctor.hft-stuttgart.de/, Förderung durch das BMBF

Standardization: Interfaces

3D-spatial data infrastructure

OGC 3D Portrayal interoperability experiment

Interoperability of OGC drafts W3DS and WVS specifications

http://www.opengeospatial.org/projects/initiatives/3dplc

Summary

3D city modeling can already play an essential role for energy planners and municipality managers

Challenges:
- enhance attribute data (crowd sourcing approach)
- enhance / manage data quality of 3D city models
- develop standard interfaces for 3D spatial data structure
- investigate the use of highly detailed facade geometry

Hochschule für Technik Stuttgart

3D-SDI
A long way to go!