CityGML goes to Broadway

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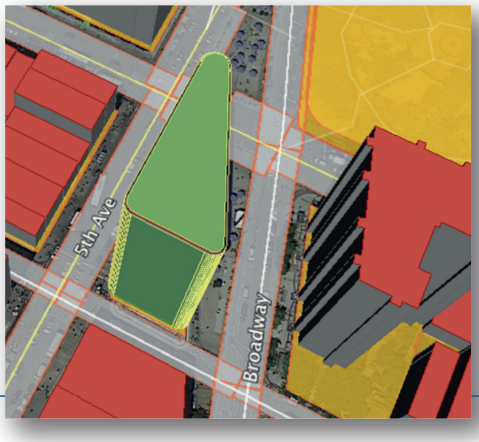
Photogrammetric Week 2015,
Stuttgart



The New York City Open Data Portal

- Data is provided by different departments of NYC administration; most datasets are regularly updated
  - free use of datasets, but NYC remains owner
- Many 2D and 2.5D geospatial datasets are available
  - e. g. building footprints, road centerlines, land parcels, water bodies
  - raster based DTM with 1 ft. resolution
  - land cover classification map
- Thematic data on value assessments, ownerships etc.
- **But: no 3D data;** no uniform coordinate reference system; no common feature definition or exchange format

City Geography Markup Language – CityGML

Application independent Geospatial Information Model
for semantic 3D city and landscape models

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

3D Decomposition of Urban Space in CityGML

- City is decomposed into meaningful objects with clear semantics and defined spatial and thematic properties
  - buildings, roads, railways, terrain, water bodies, vegetation, bridges
  - buildings may be further decomposed into different storeys (and even more detailed into apartments and single rooms)
  - application specific data are associated with the different objects

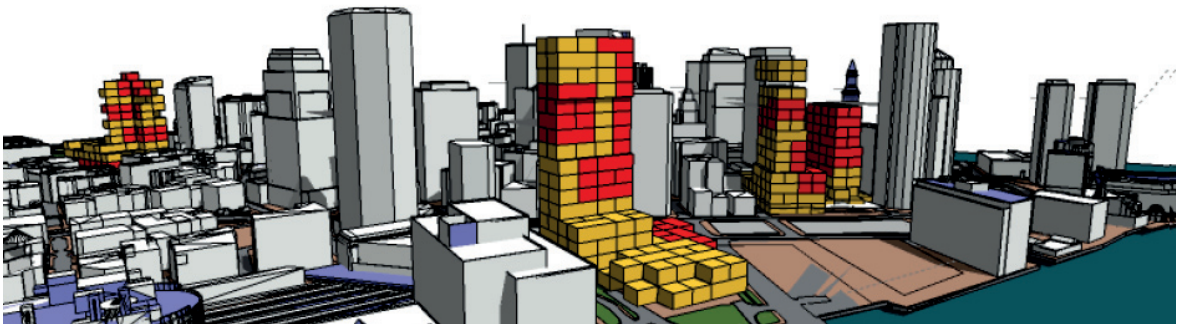
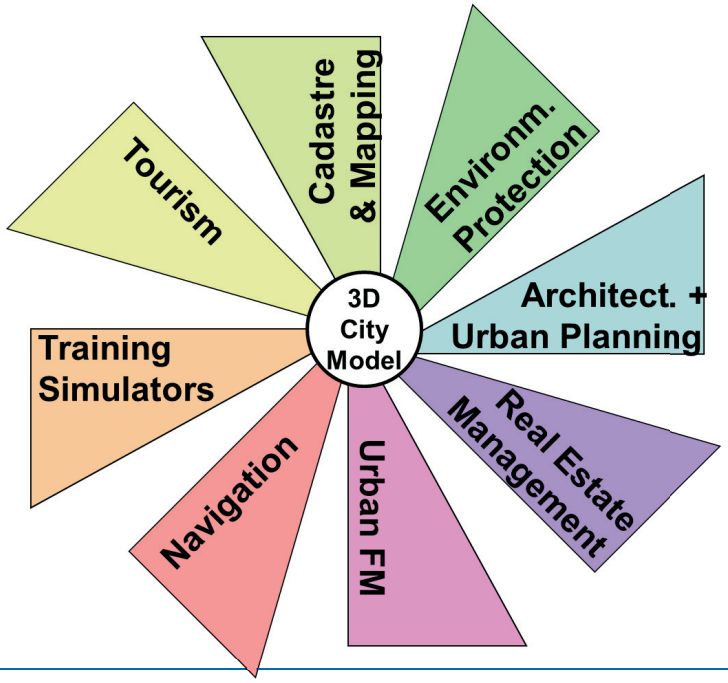


Image: Paul Cote, Harvard Graduate School of Design

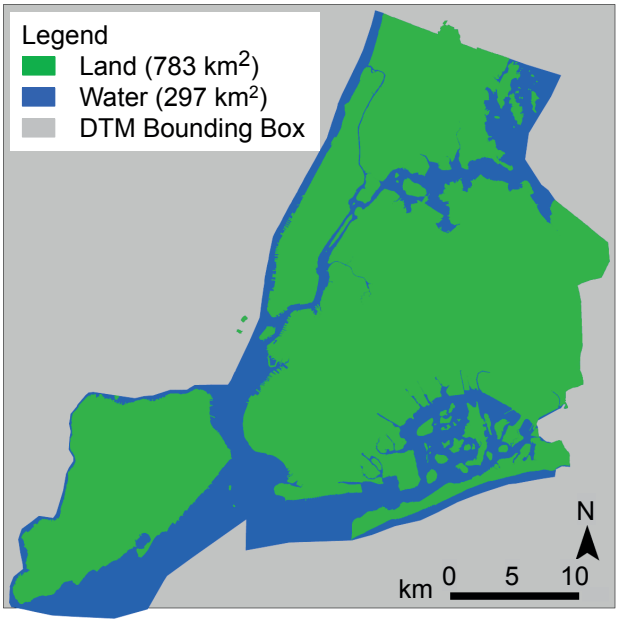
Semantic 3D City Model as Integration Platform



(Inter)national Usage / Availability of CityGML

- **Cities / Municipalities**
  - e.g. almost all German cities with 3D city models; Rotterdam, Zürich, Geneva, Paris, Marseille, Helsinki, Istanbul, Vancouver, Montreal, Kuala Lumpur, Yokohama, Singapore, Abu Dhabi, and many more; **however, few implementations in the USA so far**
- **Organisations**
  - e.g. IGN France, Ordnance Survey, all 16 State Mapping Agencies of Germany, 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

Employed Data Sets from NYC Open Data



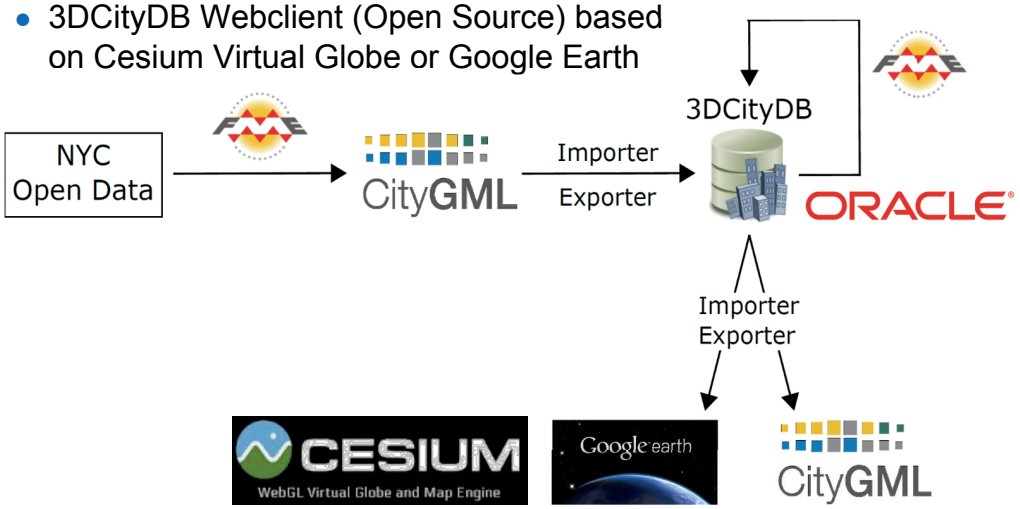
Feature type	Input datasets	Dept.
Addresses	NYC Address Points	DoITT
Buildings	Building Footprints MapPLUTO	DoITT DTM
DTM	1 ft. Digital Elevation Model (DEM)	DEP & DoITT
Lots	MapPLUTO	DTM
Parks	Mèmèkas Meadow Parks Properties	DoITT DPR
Streets	LION Geodatabase	DCP
Trees	Street Tree Census	DPR
Waterbodies	Hydrography	DoITT
Waterbody Structures	Hydrography-structures	DoITT
Zoning	Zip Code Boundaries Census Tracts 2010 Borough Boundaries	DoITT DCP DCP

Challenges in the Generation of the 3D City Model

- only 2D and 2.5D data given → generation of 3D geometries
  - volumetric building and tree models
  - all other feature types mapped onto the terrain
  - special treatment of road geometries to include different height levels
- data heterogeneity
  - different coordinate reference systems
  - different exchange formats (Shapefiles, ESRI GeoDB, Excel etc.)
  - no standardized semantic data model / ontology (each department defines their own data structures)
  - 1:1, 1:n, and n:m mappings required
- huge data volume
  - large area with > 1 million buildings; big DTM; in total about 4 million objects

Processing Workflow and Employed Tools

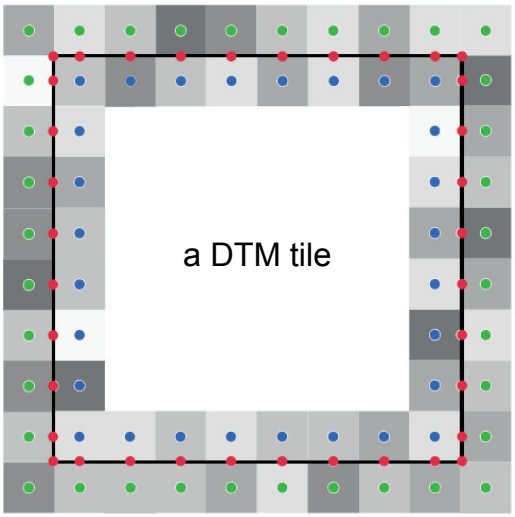
- Implementation is based on
  - 3DCityDB (Open Source) running on Oracle Spatial
  - Feature Manipulation Engine (FME) → 24 different workspaces
  - 3DCityDB Webclient (Open Source) based on Cesium Virtual Globe or Google Earth

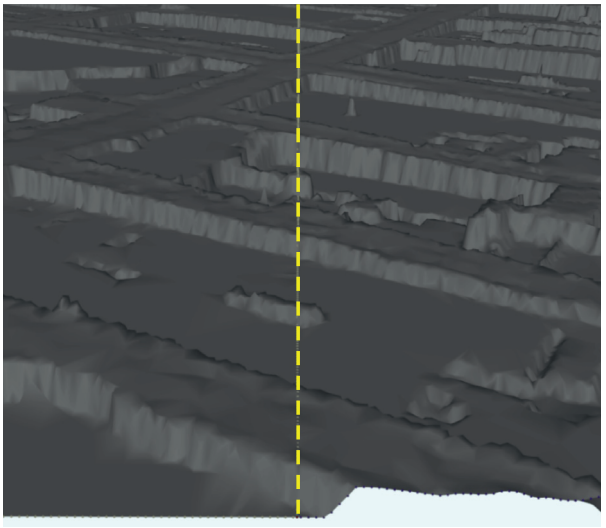


Digital Terrain Model (DTM)

- A DTM with 1 ft. resolution is given in the Open Data Portal
  - one large image file of 140 GB
- Initial processing steps:
  - resampling to 1m resolution
  - reprojection to the compound 2D+1D coordinate reference system *NAD83 New York State Planes, Long Island, Meter* (horizontal), *NAVD88 height*, *Meter* (vertical)
- Generation of tiles with 250m x 250m extent
  - determination of a 3D boundary ring for each tile; this ring fixes the height profile along the four tile borders (C0 continuity only)
  - constrained triangulation (boundary rings used as break lines)
  - generation of CityGML ReliefFeature objects
  - import into the 3DCityDB geodatabase

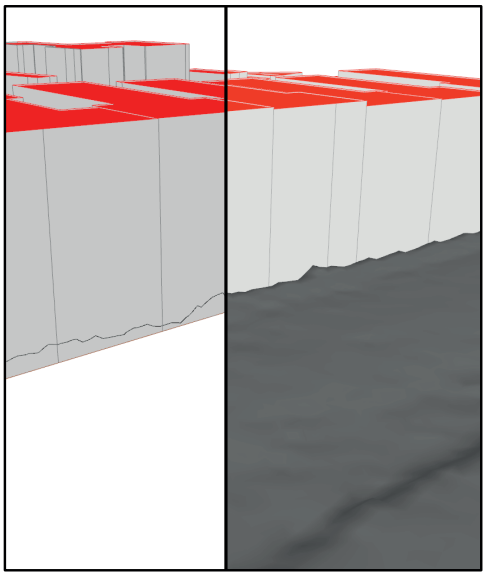
DTM Tiling → Seamless Border Transitions





- Result: 35,153 tiles of 250m x 250m in CityGML

3D Building Models



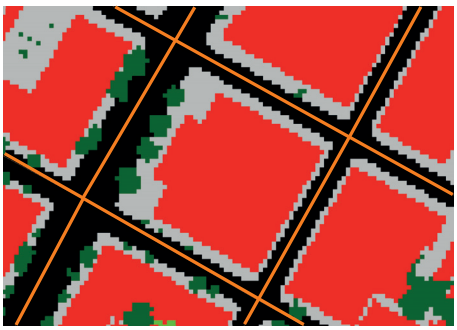
w/o DTM with DTM

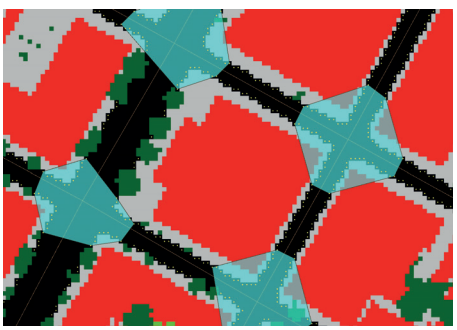
- 2D building footprints come with
  - a building height (in ft.)
  - a number of thematic attributes
  - building identification number
- generation of 3D solids by extrusion (CityGML LOD 1)
- adjustment of the base heights according to the DTM
- integration of address data
- integration of MAPPLUTO data

3D Road Models

- Usable data from the NYC Open Data Portal:
  - LION file geodatabase with 2D road center lines (vector data with thematic attributes like road name, traffic directions, snow removal priority etc.)
  - land cover classification map (raster data)
- CityGML represents roads spatially
  - in LOD 0 as a 3D geometric complex / graph with embedding in 3D
  - in LOD 1 by the street surfaces → road widths required!
- 3D road generation process:
  - determination of road widths for each road segment
  - mapping of center lines and road polygons onto the DTM
  - further height corrections according to qualitative height levels (in order to map elevated roads and complex motorway junctions)

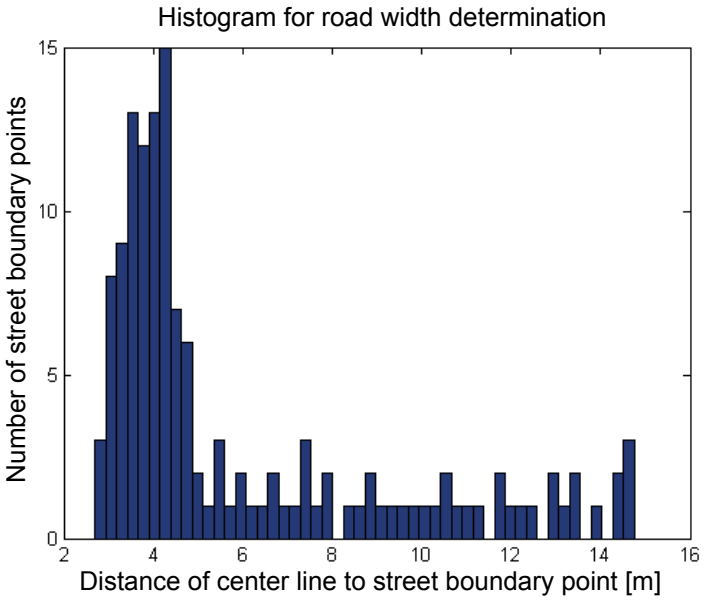
Estimation of Road Widths (1)



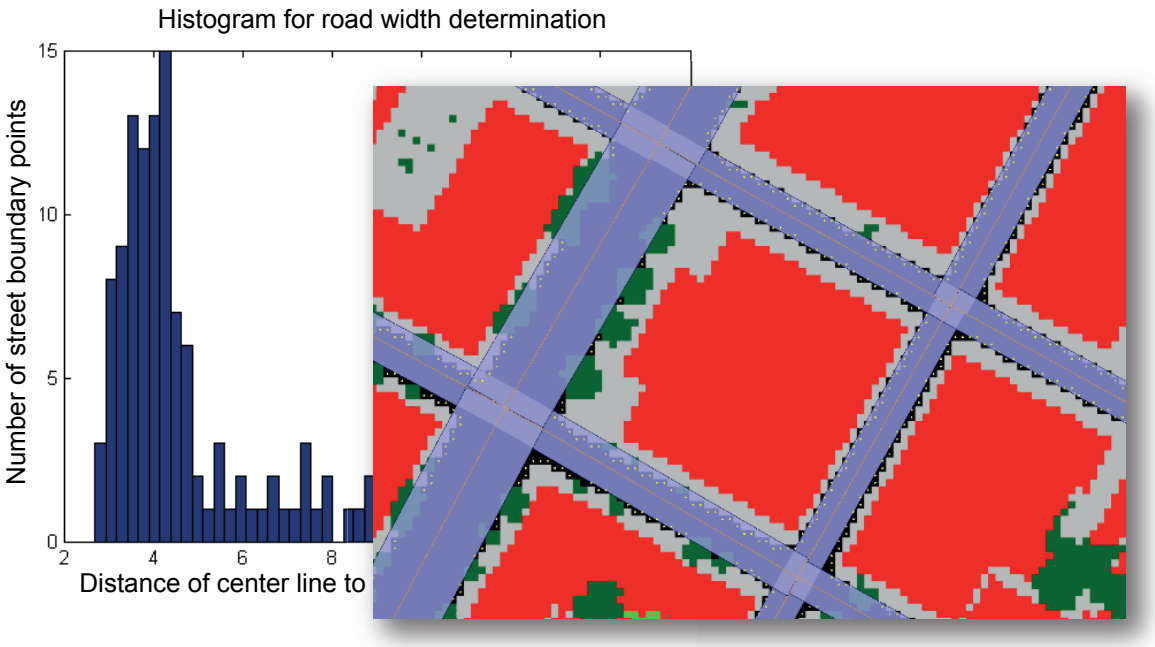


- road centerlines (orange) overlaid onto the land cover classification map
- identification of crossings
  - areas have to be excluded from road with estimation
- for each individual segment
  - determination of the distances from the center line to the first cell not classified as ‘road‘
  - accumulation of distances in a histogram
  - selection of the mostly occuring width; buffering of the line

Estimation of Road Widths (2)

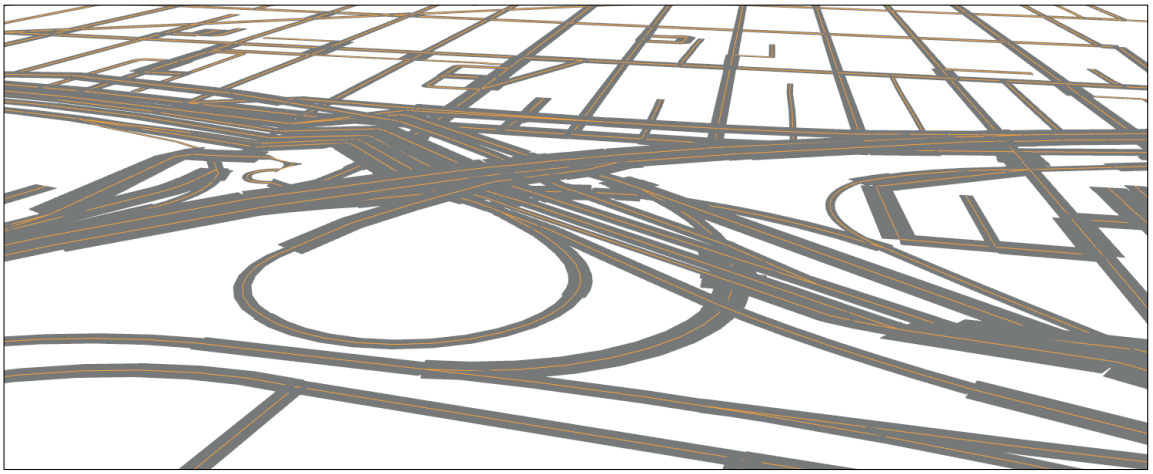


Estimation of Road Widths (2)



Generated 3D Street Geometries (2)

- Complex motorway junction with many different height levels
  - 3D embedded graph usable for routing applications has been created



Generated CityGML Objects for NYC (1)

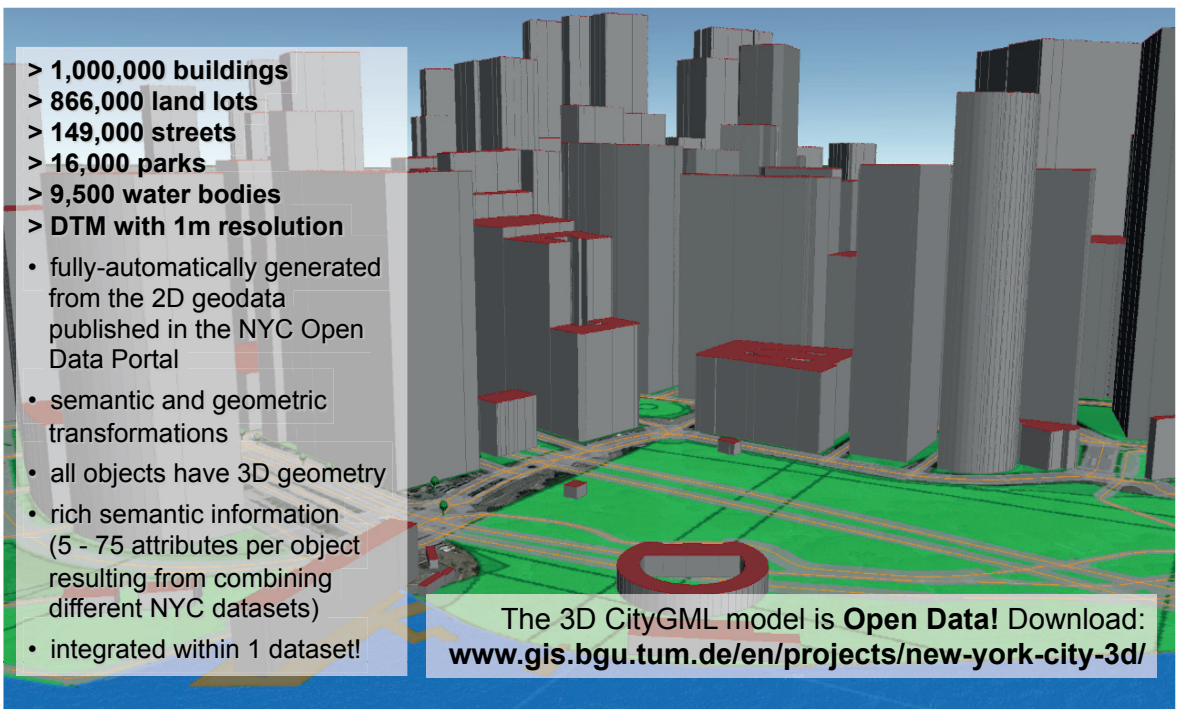
Dataset	Format	Geometry types	Number of objects	Num of attributes	Data size [GB]
Buildings/ Addresses	Shape	2D polygon/point	2,023,531		0.931
	CityGML	3D Solid	2,020,523	20 – 55	11.085
DTM	Raster	Grid	1		121
	CityGML	Tiled TIN	35,153 tiles	–	1,450
Land Cover	Raster	Grid	1		0.2
	CityGML	–	–	–	–
Lots	Shape	2D Polygon	857,853		0.867
	CityGML	3D Polygon	866,853	75	8.021
Parks	Shape	2D Polygon	14,674		0.025
	CityGML	3D Polygon	16,159	10	0.054
Streets	ESRI File gdb	2D Line	212,890		0.128
	CityGML	3D Line+Polygon	149,292	31	0.482
Street Inter-sections	ESRI File gdb	2D Point	125,118		0.128
	CityGML	3D Point	104,754	1	0.055

Generated CityGML Objects for NYC (2)

Dataset	Format	Geometry types	Number of objects	Num of attributes	Data size [GB]
Trees	Shape	2D Point	623,920		0.206
	CityGML	3D tree shape solid	277,108	16	113
Water Bodies	Shape	2D Polygon	1,976		0.01
	CityGML	3D Polygon	9,542	5	0.025
Water Body Structures	Shape	2D Polygon	2,464		0.003
	CityGML	3D Polygon	2,464	3	0.006
Zoning	Shape	2D Polygon	2,436		0.005
	CityGML	CityObjectGroups	2,436	23	≤ 1
Total	Original	2D + 2.5D	**3,864,864**		**123.4**
	CityGML	3D + 2.5D	**3,484,284**		**1,583.7**

- The largest share (1.45 TB) is required by the DTM, due to the XML representation of > 5 billion triangles
- File compression reduces CityGML files to 5% of their original size. The compressed NYC dataset has 79 GB.

Result: New York City in CityGML LOD 0&1



Interactive 3D Visualization & Data Inspection

- Using the Open Source 3DCityDB + the new Webclient
  - www.3dcitydb.net & https://github.com/3dcitydb/3dcitydb-web-map

Summary

- A semantic 3D city model for New York City has been generated exclusively based on 2D/2.5D data from NYC Open Data
  - (to the best of our knowledge) this is the first Open Data 3D City Model based on official city data for a large city in the USA
- Information integration from 26 different datasets into one common and standardized representation (CityGML)
  - DTM, buildings, roads, land parcels, parks, water bodies, water body infrastructures, trees, zoning
  - all objects have rich thematic attributes
  - projection into one common, metric compound 3D CRS
- Interactive exploration of the 3D city model using our Open Source 3DCityDB Webclient


Playing Now
CityGML
CityGML
PHANTOM
Tonight belongs to...
GUEST SUITES
DoubleTree Guest Suites
SHREK THE MUSICAL
JERSEY BOYS
WICKED
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