Making 3D City Models Dynamic

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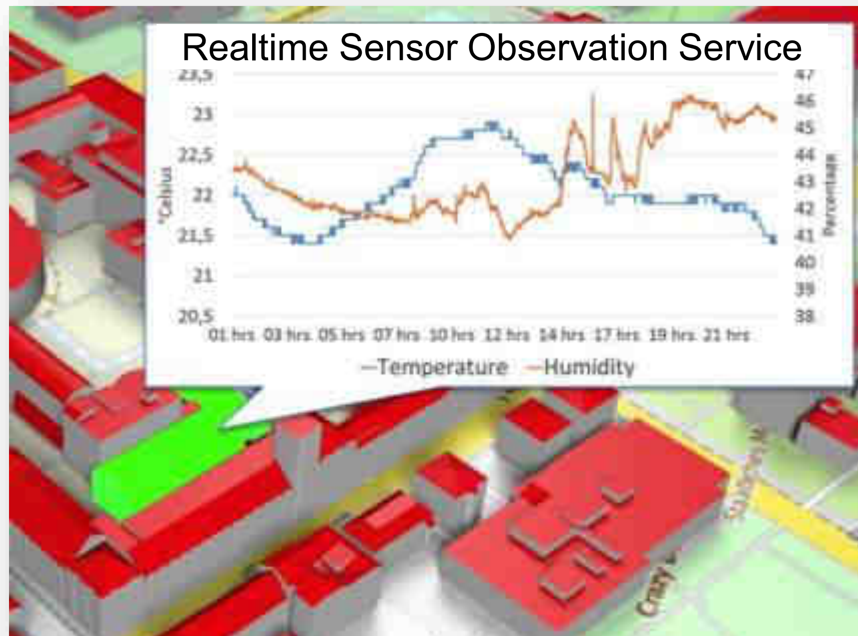
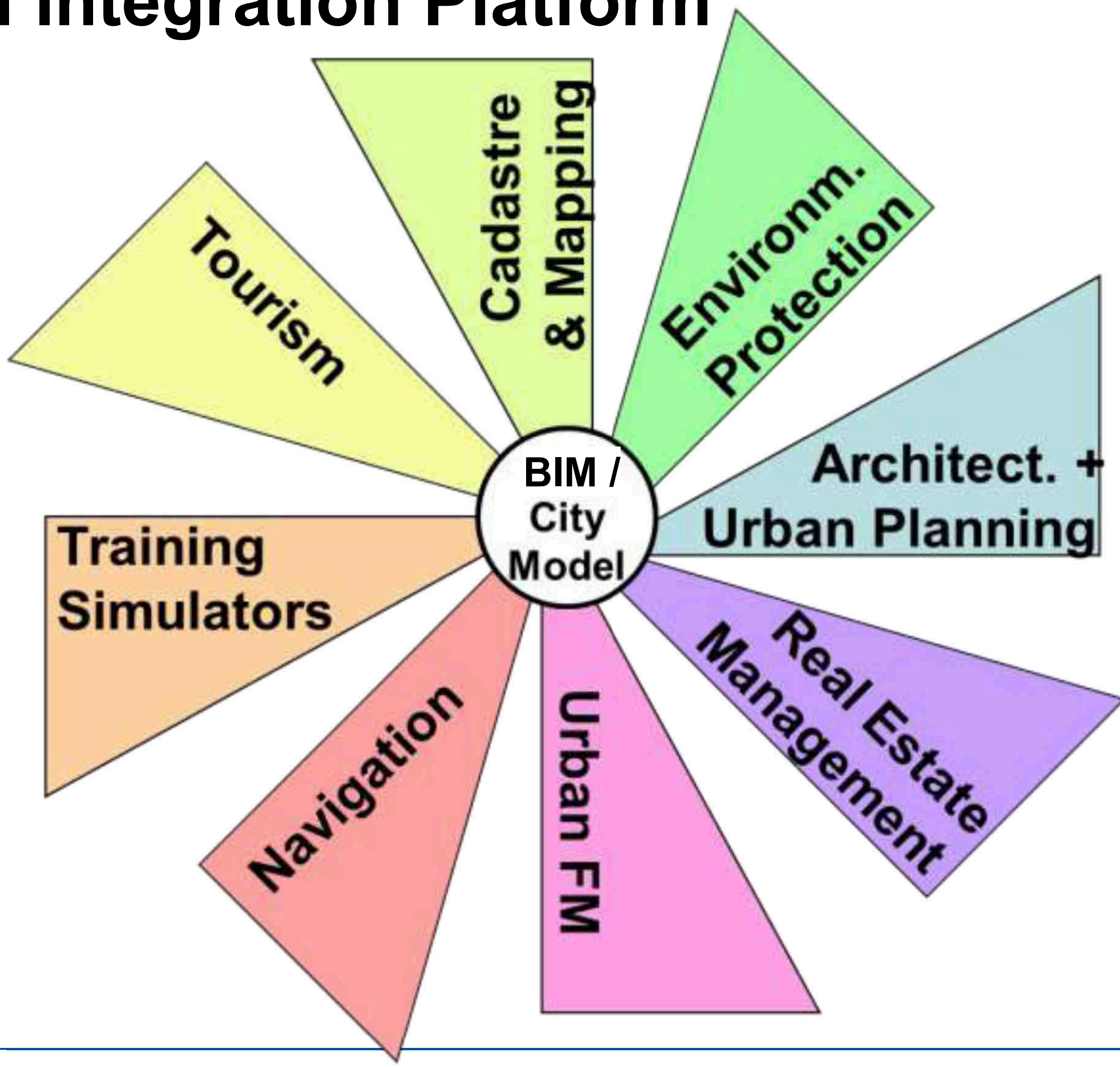
Joint 3D Athens Conference, Greece



Digital Models of the Built Environment

- On the scale of individual sites:
  Building Information Modeling (BIM, IFC)
- On the scale of city quarter up to entire regions:
  Semantic 3D City Models (CityGML)

Semantic Site and City Models as Cross Domain Integration Platform

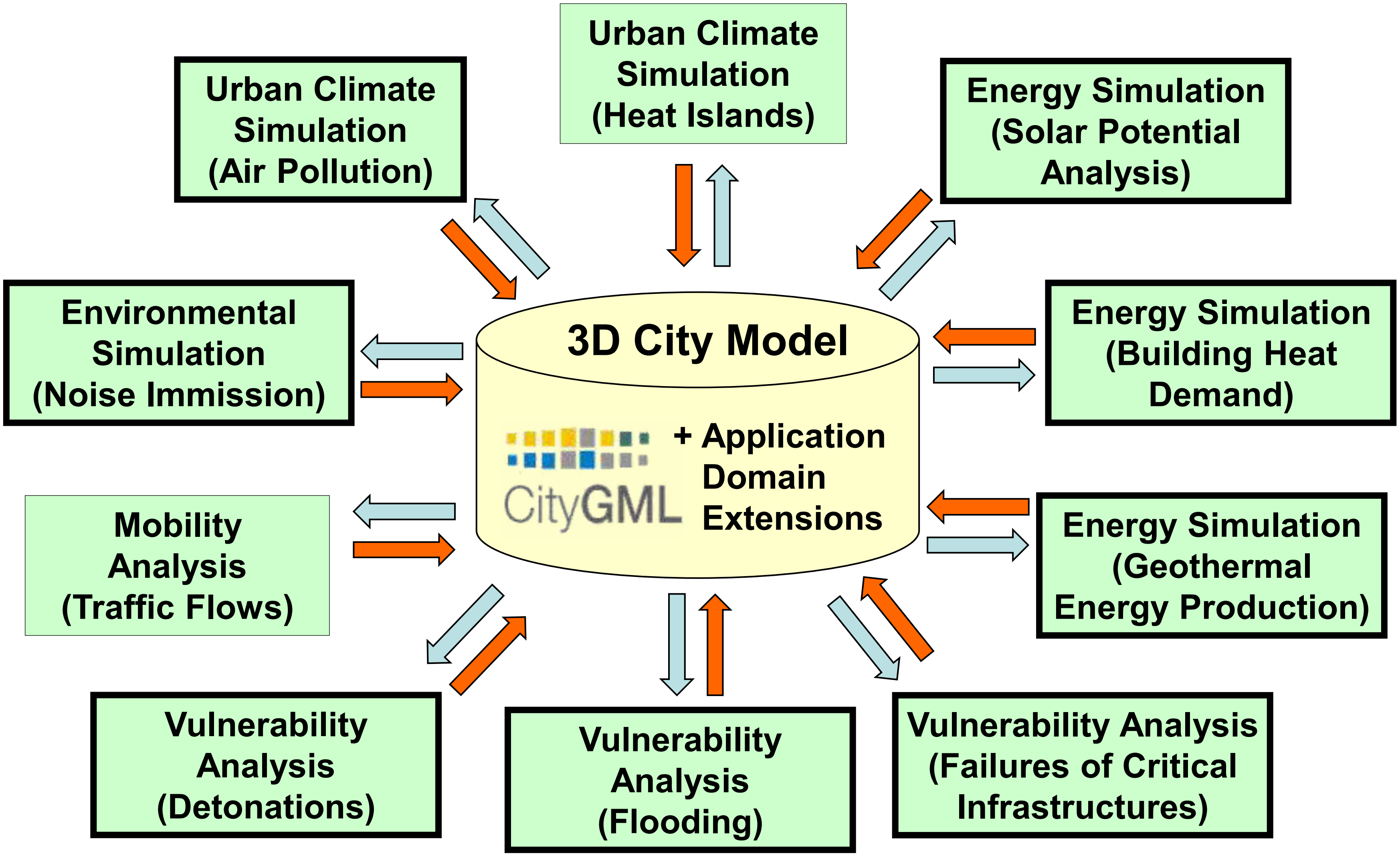


Standardized Access to Semantic City Models

Mapping the state of a city at time t_i → CityGML ← Virtually carrying out planned actions by changing the city model accordingly

- Energy Demand & Production Estimation
- Noise Immission Simulation & Mapping
- Real Estate Management & Urban FM
- Vulnerability Analysis & Disaster Management

Multi-Simulations with 3D City Models



Bold-framed boxes: projects that were carried out by or with participation of my teams so far

Motivating Example

Vulnerability Analysis (Detonation Simulation)

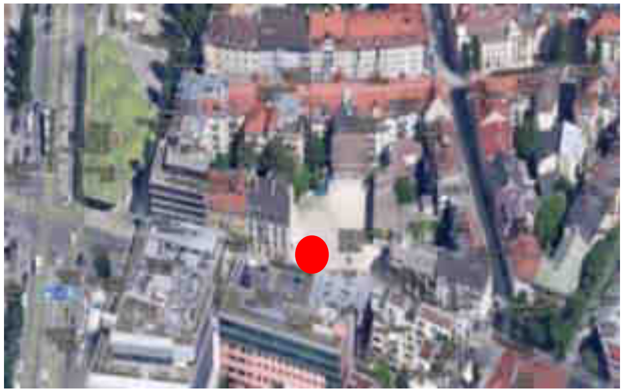
‘Controlled‘ Blast of discovered unexploded Bomb from World War II

Detonation in Munich, District Schwabing, 2012

Source: Münchner Abendzeitung Bildzeitung

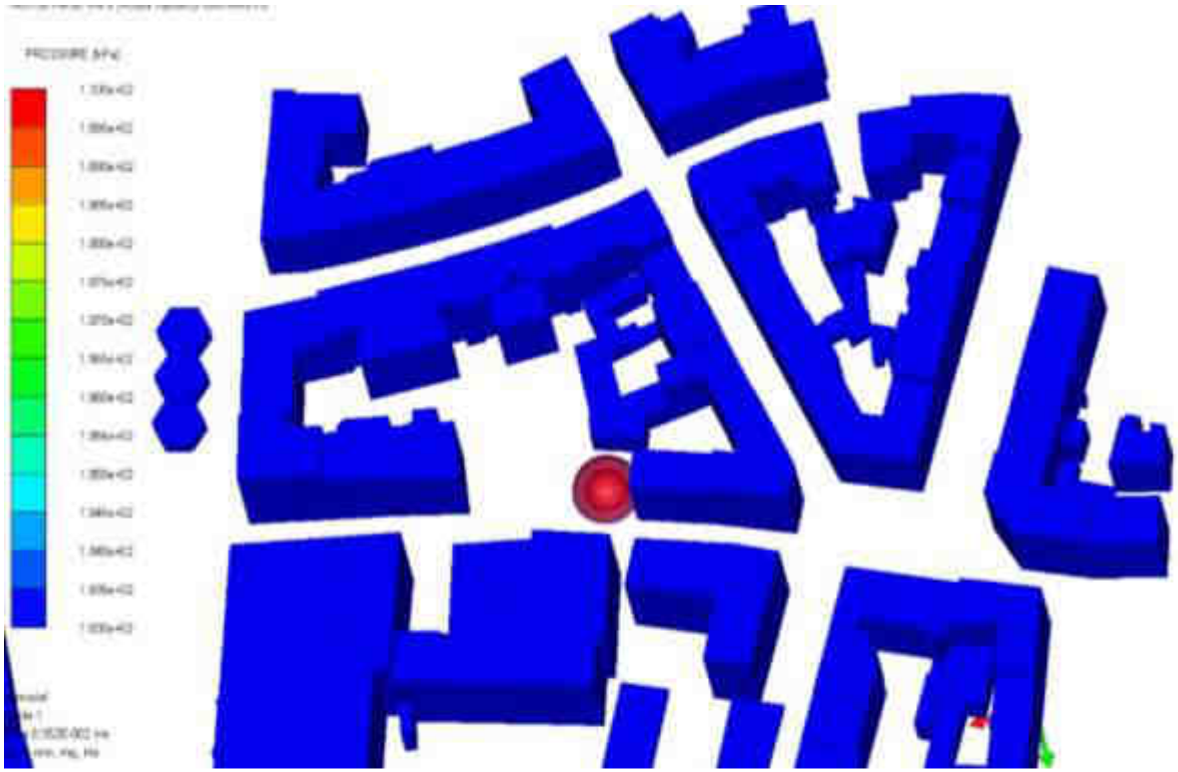
Unexploded American 500 lbs Bomb (120kg TNT)
Evacuation of 2500 citizens

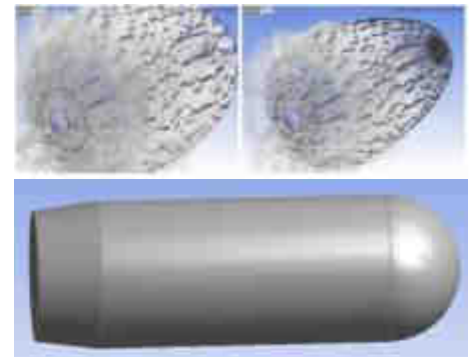
Source: Google Maps

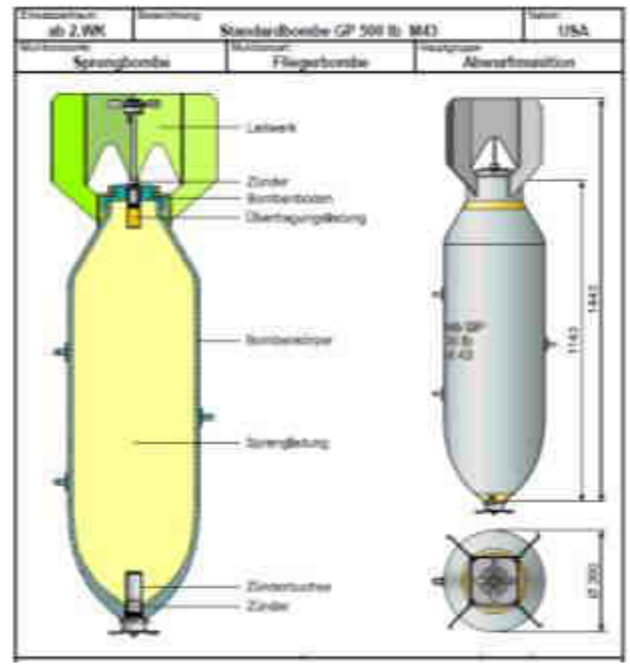


‘Controlled‘ Blast of discovered unexploded Bomb from World War II

Detonation in Munich, District Schwabing, 2012







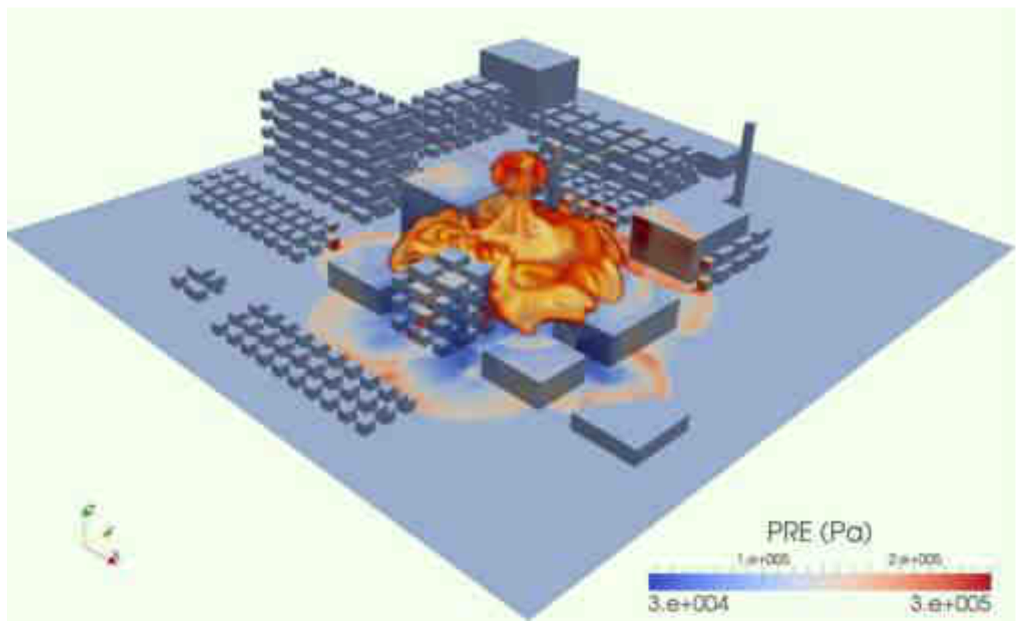
2013 Dresdner Sprengschule GmbH

Apollo Blast Simulator

APOLLO BLASTSIMULATOR

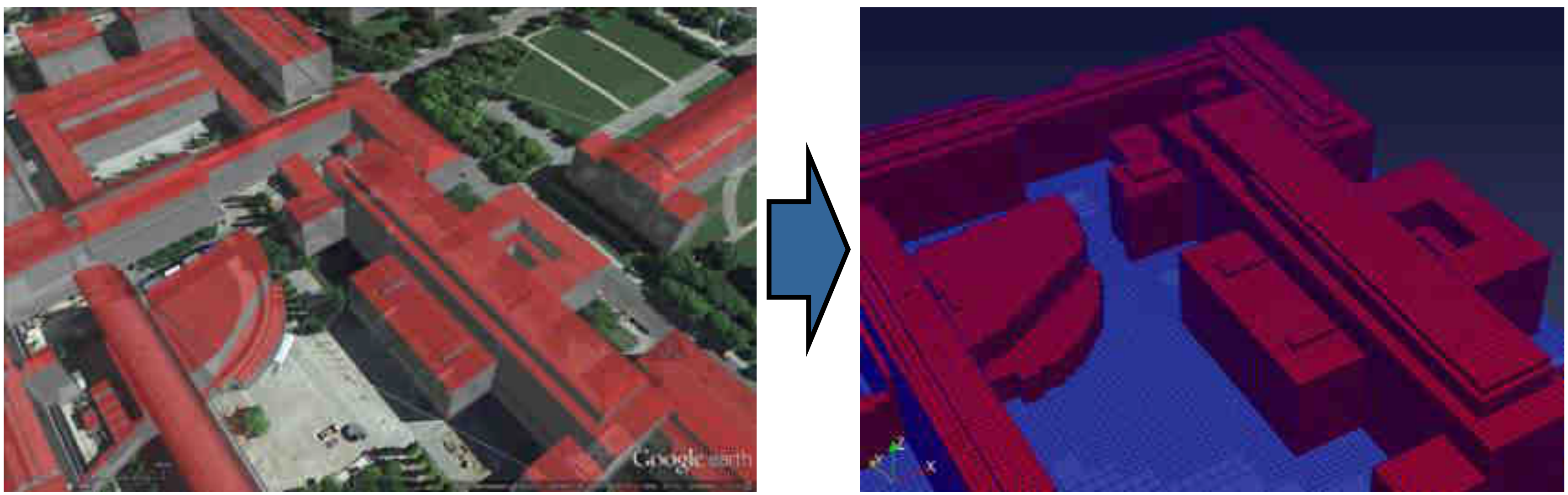
Fraunhofer EMI

- Developed by Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut (EMI) in Freiburg
- Computational Fluid Dynamics (CFD) simulation for
  - Detonations
  - Shock waves
  - Gas dynamics
- Physical values
  - Pressure, impulse
- Application areas
  - Risk assessment
  - Vulnerability analysis



Derivation of a Voxel Model from CityGML

- Selection of the simulation area
- Generation of a complete regular voxel grid for the simulation area
- Intersection of the voxel grid with the vector representation of the CityGML objects → occupancy grid



[Bruno Willenborg 2015]

Detonation Simulation of a WW II Aircraft Bomb

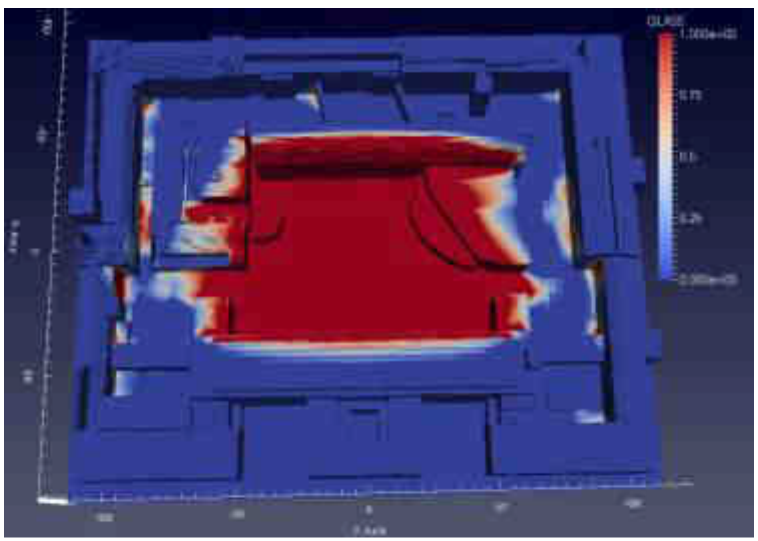
- **Fictive scenario**: during groundworks an unexploded bomb from World War II is found in the courtyard of TUM; it cannot be defused and, hence, must be detonated on place
- **Real problem**: WW II ammunition is still found every day
- maximum danger zone is estimated based on the TNT equivalent using an empirical formula

Mapping the Simulation Result back to CityGML

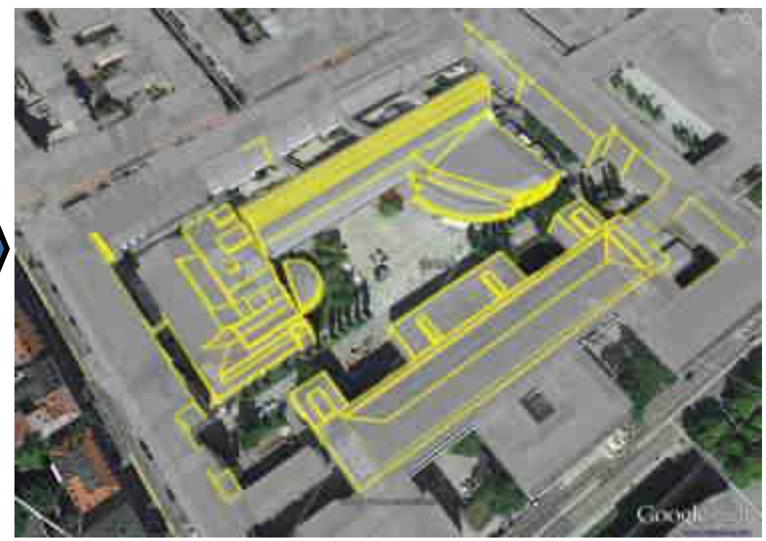
- A vector of parameters is being computed by the simulator for each voxel
  - peak overpressure, probabilities for glass & façade breakage, death, eardrum damage etc.
- These parameters are aggregated and mapped back to the objects of the CityGML model (RoofSurfaces, WallSurfaces)

Probability for breakage of glass

$l_{voxel} = 0.40\,m$



70% max probability for breakage of glass



Comparison: Simple Estimation ↔ CFD-Simulation

Conservative method, peak overpressure



$>20\,000\ Pa$ | $>10\,000\ Pa$ | $>5\,000\ Pa$



CFD simulation, peak overpressure

Comparison: Simple Estimation ↔ CFD-Simulation

Conservative method, peak overpressure

$>20\,000\ Pa$

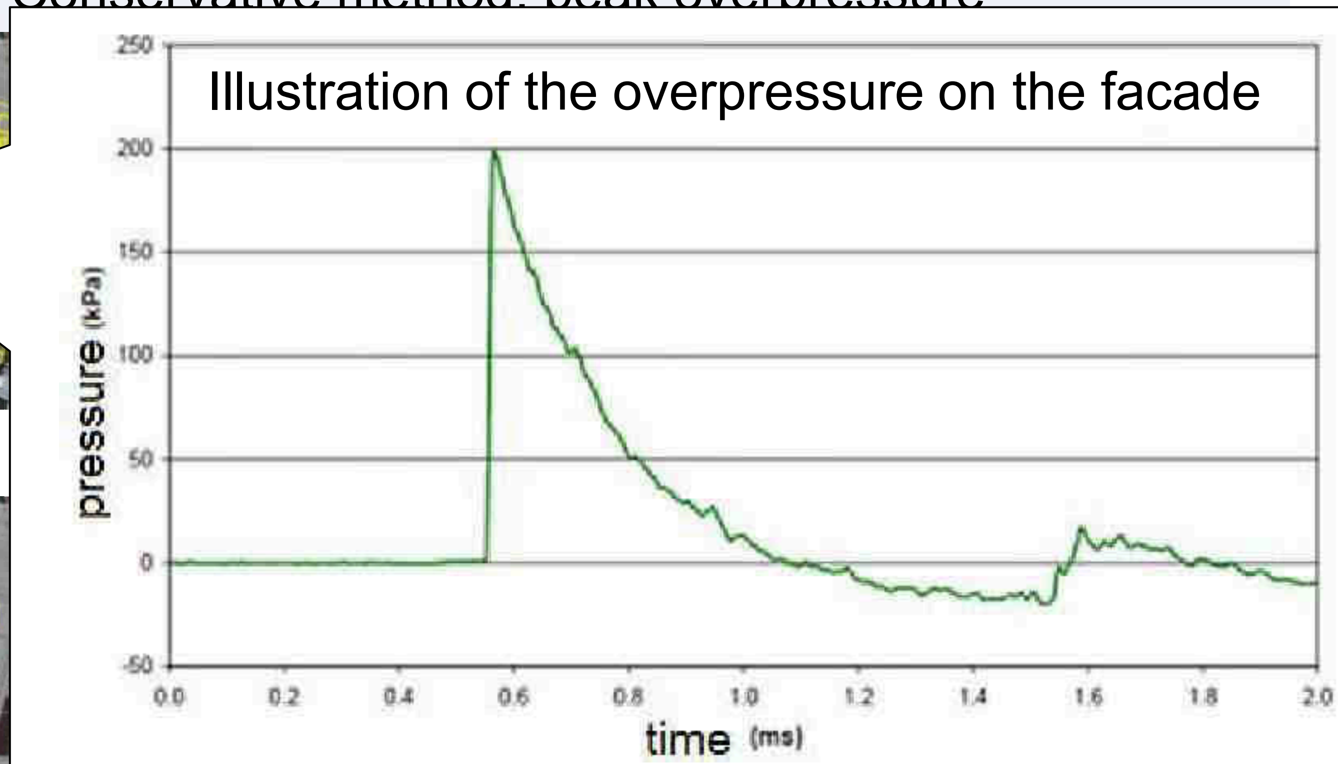


Image: [Łukasz Ślaga 2013]

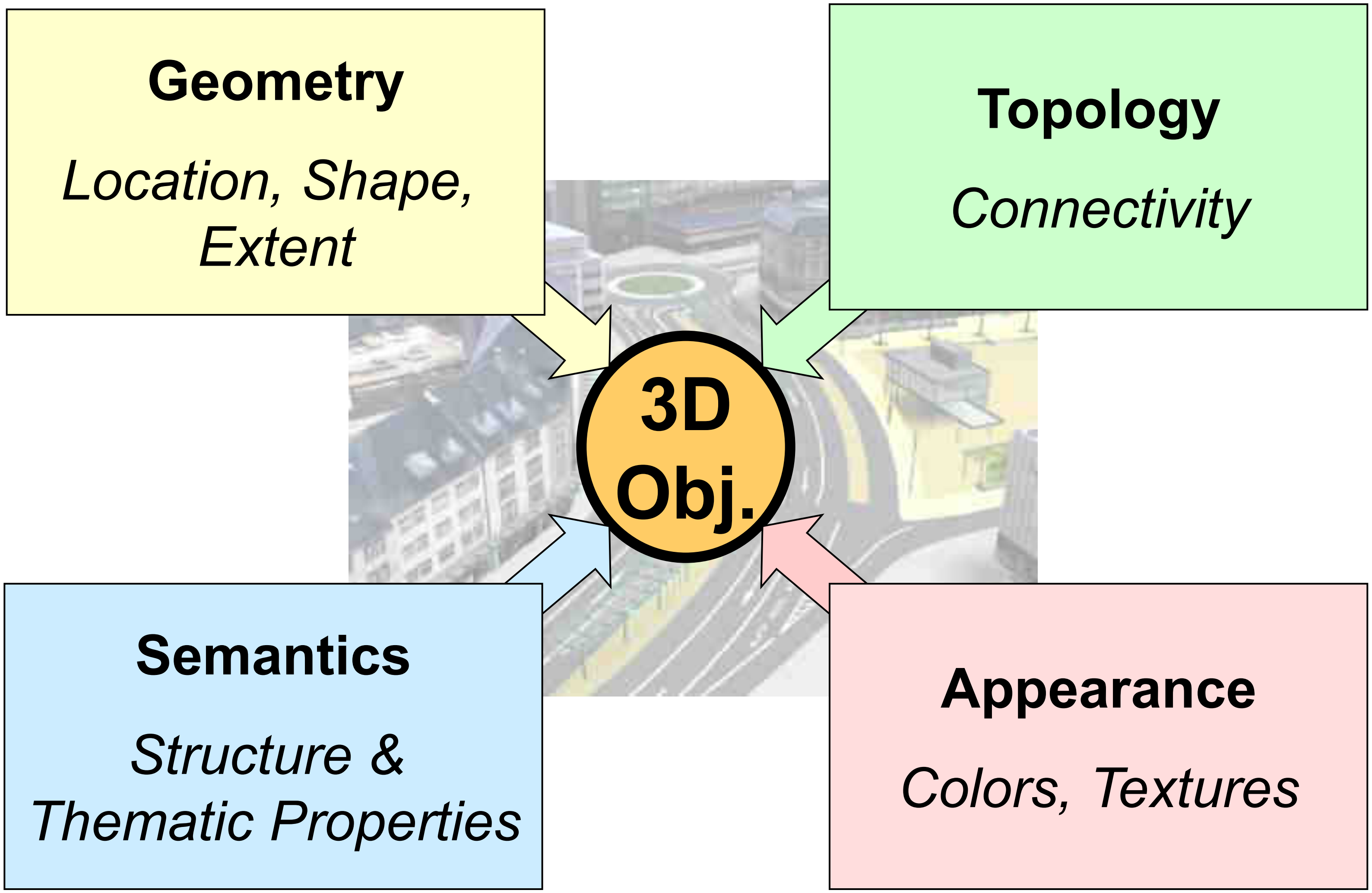
CFD simulation, peak overpressure

Linking Urban Simulations across Domains

- Output of one simulation can be the input for another one
  - **cascading simulations** need lossless information handling
- **Semantic 3D city models** are well suitable data integration platforms
  - **source for simulation input data**
  - **container for simulation output data**
- Simulations often require and produce **time-dependent data**
- Smart City projects integrate **sensors & observations**
  - **observations are also time-dependent**
- **Time-variant object properties are not supported in City Models so far**

Dynamic Data in Semantic 3D City Models

Properties of the Objects of a 3D City Model



Dynamic Data in City Models (1)

Which ***properties of a city object*** can be dynamic?

- **Spatial Information** (Geometry & Topology)
  - **Extent and form**: e.g. retrofitting, extension, (partial) demolition of sites; plant growth; watercourse during flooding
  - **Location**: e.g. for movable objects like vehicles or persons the position and orientation
- **Appearance Information**
  - Color, texture – e.g. change of the appearance of building facades within an RGB or Thermal IR image over the day
- **Semantic Information**
  - Thematic data like e.g. electrical power consumption of a building; room temperature; traffic density in a road; evaporation of a group of trees

Dynamic Data in City Models (2)

Which ***types of dynamic behaviour*** can be distinguished?

▶ Slow Changes

- Creation and termination of objects (construction / demolition of sites, planting of trees; construction of new roads)
- Structural changes of objects (e.g. raising of buildings)
- Change of object status (e.g. change of building owner; change of the traffic direction of a road to a oneway street)
- **Few changes over a longer time period → *Evolution***

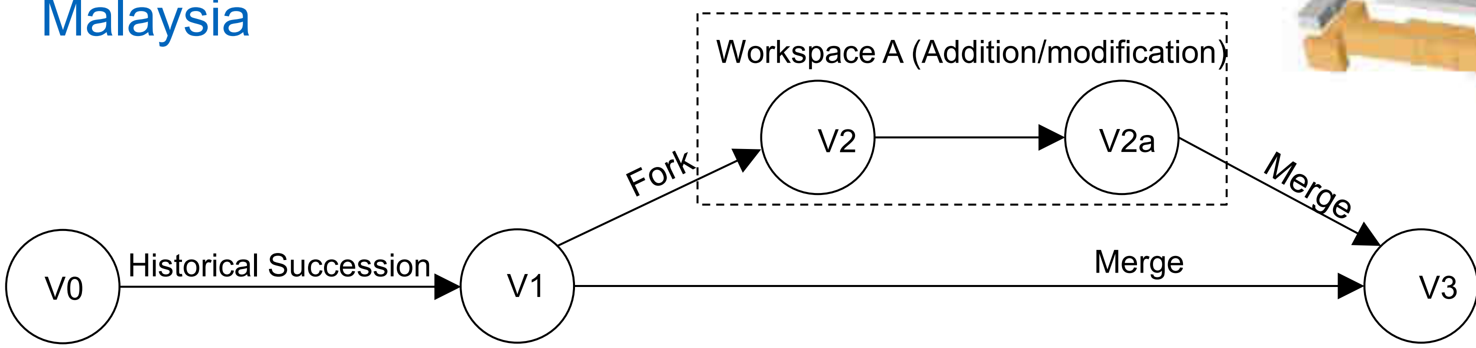
▶ Fast Changes

- Time dependent / variant object properties (e.g. energy consumption, traffic density, pollution concentration, overpressure on building walls)
- are the result of simulations or of measurements (sensor data streams)
- **Many changes over a short (but also longer) time period**

Time-varying properties (1)

▶ Slow changes

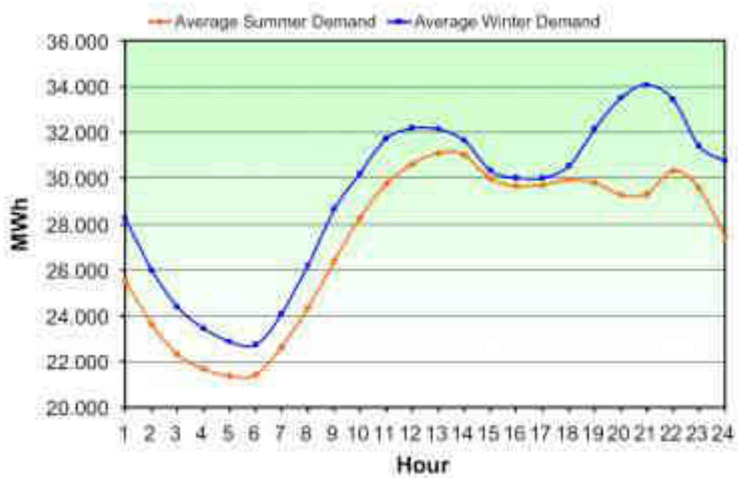
- History or evolution of cities/city models
- Change of feature‘s geometry over time
- Managing parallel or alternative versions over time
- Already published in 3DGeoInfo 2015, Kuala Lumpur, Malaysia



Source:Chaturvedi et al. , “Managing versions and history within semantic 3D city models for the next generation of CityGML”. In 3DGeoInfo (2015)

Time-varying properties (2)

- **Highly dynamic changes**
  - **Variations of spatial properties**: change of a feature's geometry, both in respect to shape and to location (moving objects)
  - **Variations of thematic attributes**: changes of physical quantities like energy demands, temperatures, solar irradiation
  - **Variations with respect to sensor or real-time data**



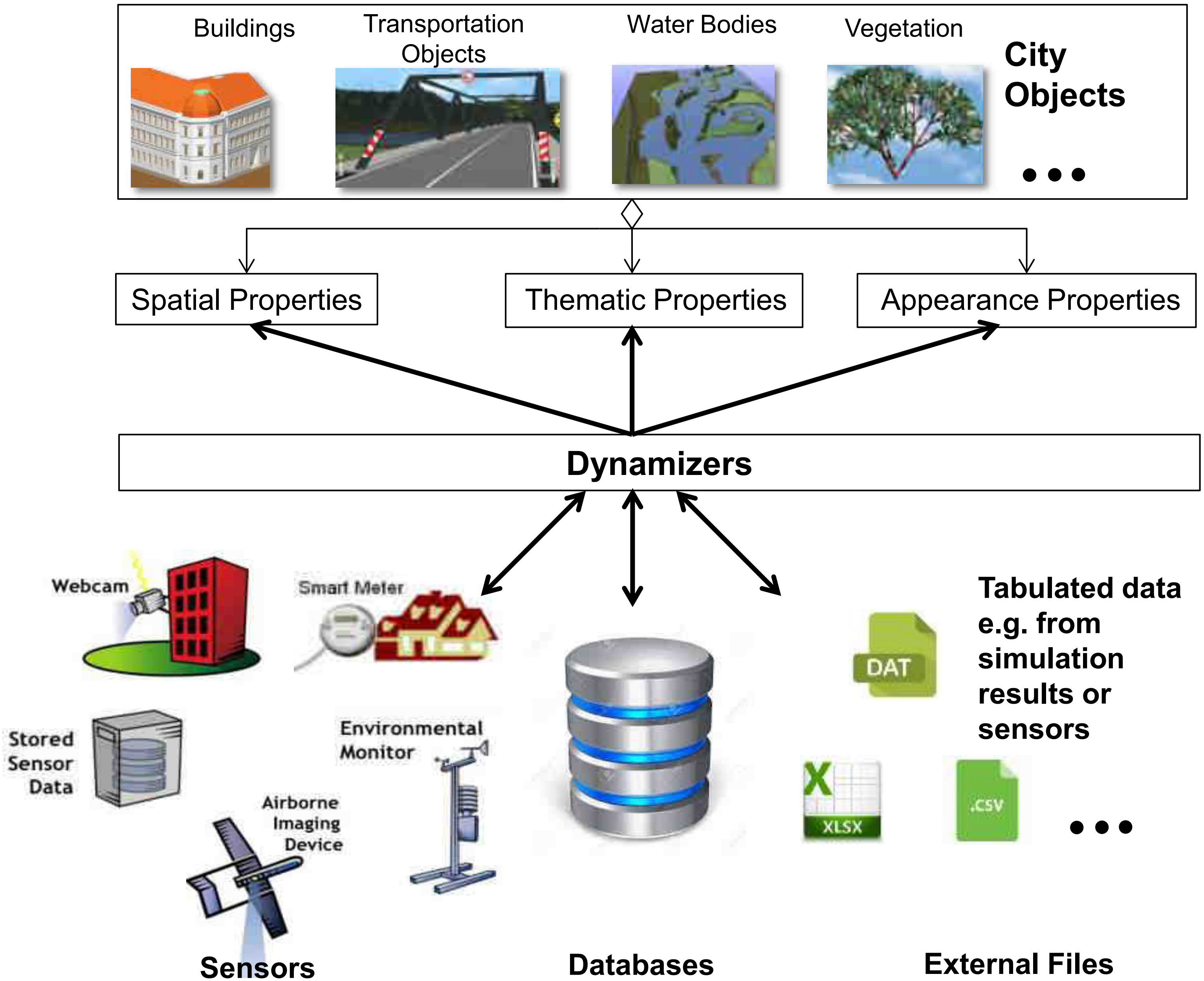
Source:C. García-Ascanio and C. Maté, "Electric power demand forecasting using interval time series: A comparison between VAR and iMLP,"*Energy Policy*

Source: MOREL M., GESQUIÈRE G., "Managing Temporal Change of Cities with CityGML". In UDMV (2014)

Modeling and Representing Dynamic Data

- **New data types for time-variant attributes** are required
  - Time series
  - Tabulation of timestamps + property values
- **Property values**
  - Simple numeric values, measures, physical quantities
  - Appearances (Textures, Colors)
  - Geometries
- Time variant properties of city objects can be represented by time series
  - Observation: only specific properties are dynamic → no general replacement of all simple data types by time series
- Specific „dynamization“ using **CityGML 3.0 Dynamizers**

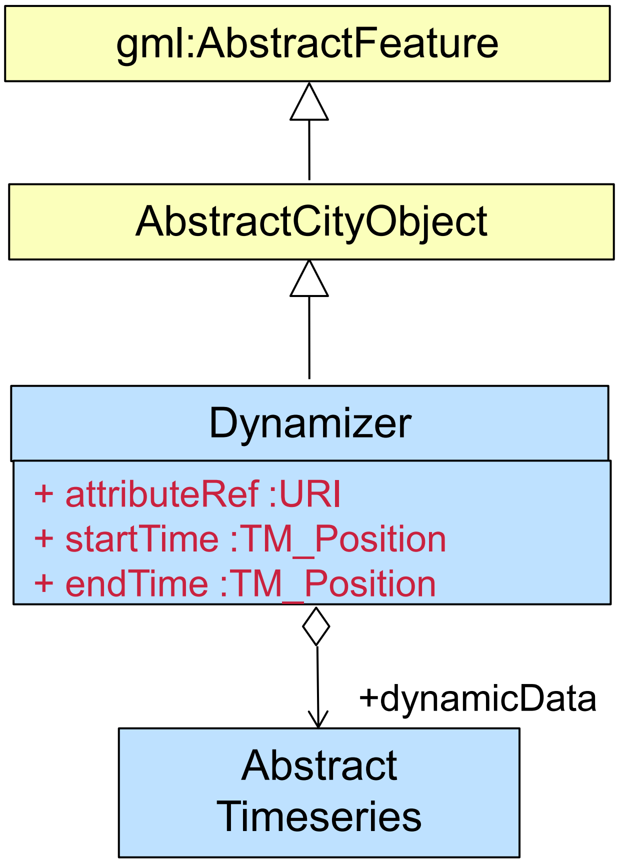
CityGML Dynamizers



From the PhD Work of Kanishk Chaturvedi

Dynamizer – New CityGML Feature Type

- attributeRef refers to a specific property of a static CityGML feature which value will then be overridden or replaced by the (dynamic) values specified in the ‘Dynamizer’ feature.
- startTime and endTime denote time span for which the Dynamizer provides dynamic values
- Dynamizer composes of AbstractTimeseries:
  - Allows representing time-variant values in different and generic ways
  - E.g. Timeseries, Sensor observations etc.



Example Scenario

CityGML object

```
<cityObjectMember>
  <Building gml:id = "building1">
      <gen:doubleAttribute name = "HeatDemand">
          <gen:value = xxx />
      </gen:doubleAttribute>
  </Building>
</cityObjectMember>
```

Source of dynamic data

Estimated (in kwh)	Heat Demand
JAN-15	61578
FEB-15	52148
MAR-15	41011
. . .	. . .
DEC-15	64984

Referencing of the object attribute using XPath

Dynamizer

```
<cityObjectMember>
  <dyn:Dynamizer>
    <dyn:attributeRef> //Building [@gml:id = 'building1']/doubleAttribute[@name = 'HeatDemand']/gen:value</dyn:attributeRef>
    <dyn:startTime> 2015-01-01T00:00:00Z </dyn:startTime>
    <dyn:endTime> 2015-12-31T00:00:00Z </dyn:endTime>
    <dyn:dynamicData>.. </dyn:dynamicData>
  </dyn:Dynamizer>
</cityObjectMember>
```

Integration of Sensors and their Observations

► By linking Dynamizers with Sensors

- Such links basically mean that a specific dynamic value for a city object property is measured by a specific sensor (service)
- Dynamizers represent these direct links to sensors and observations utilizing different requests.
  - in case of OGC SOS: DescribeSensor and GetObservation
- In order to get the dynamic data, requests to the sensor services must be performed

► By including sensor observations within Dynamizers

- Sensor observations are typically encoded in OGC O&M format.
- Dynamizers provide explicit support of O&M, which allows representing sensor observation values
  - Hence, the result of an SOS GetObservation request can directly be embedded (i.e. stored inline) within the Dynamizer

Example for a Sensor Connection

Sensor (PV Panel)

building1_roofSurface1

building1

```
<cityObjectMember>
   <dyn:Dynamizer gml:id = "PV_Power_Timeseries" >
     <dyn:attributeRef>//RoofSurface[@gml:id ='building1_roofSurface1']
                      /doubleAttribute[@name =  'PVPower']
                      /gen:value </dyn:attributeRef>
     <dyn:startTime>2016-01-01T00:00:00Z</startTime>
     <dyn:endTime>2016-12-01T00:00:00Z</endTime>
     <dyn:linkToSensor>
      <dyn:SensorConnection>
       <dyn:sensorID>. . . </dyn:sensorID>
       <dyn:serviceType>. . . </dyn:serviceType>
       <dyn:linkToObservation>. . . </dyn:linkToObservation>
       <dyn:linkToSensor>. . . </dyn:linkToSensor>
       <dyn:sensorLocation xlink:href="#building1_roofSurface1"/>
      </dyn:SensorConnection>
     </dyn:linkToSensor>
    </dyn:Dynamizer>
  <cityObjectMember>
```

- //RoofSurface[@gml:id ='building1_roofSurface1'] ← Feature of Interest
- /doubleAttribute[@name = 'PVPower'] ← Property of Interest
- <dyn:sensorID> ← Unique Sensor ID
- <dyn:serviceType> ← SOS or SensorThings API
- <dyn:linkToObservation> ← GetObservation Oper.
- <dyn:linkToSensor> ← DescribeSensor Operation
- xlink:href="#building1_roofSurface1" ← Link to CityGML Object

Image source : http://www.royalgreengas.com/index.php/photovoltaic/residential-buildings

Demonstration City Models + Sensors

Integrating Dynamic Data and Sensor with Semantic 3D City Models

Queen Elizabeth Olympic Park London

Thomas H. Kolbe, Kanishk Chaturvedi

Chair of Geoinformatics
Technische Universität München

Conclusions

- Semantic 3D City Models are a very suitable **integration platform for multi-simulations**
  - Systems for managing semantic 3D city models could become the central data management component for simulators in the future
- Many **properties** of city objects are **measured by sensors** (important in **Smart City scenarios**)
- **Handling of dynamics is mandatory** for these purposes
  - Slow changes / evolution
  - Highly dynamic changes & sensor integration
- **CityGML 3.0** will support both aspects
  - **Versioning / Historization**
  - **Dynamizers**