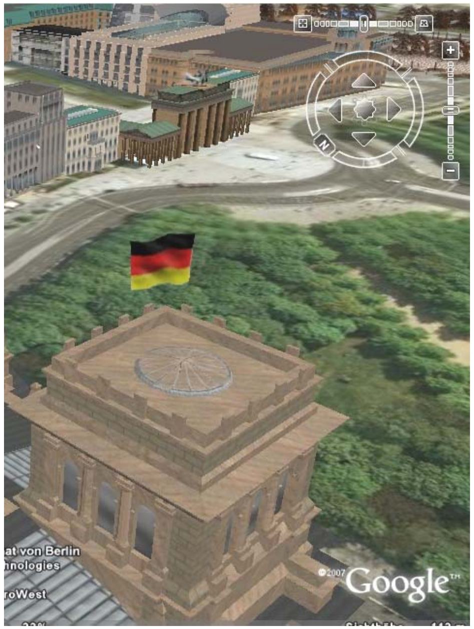
Section I

Introduction – CityGML and GML



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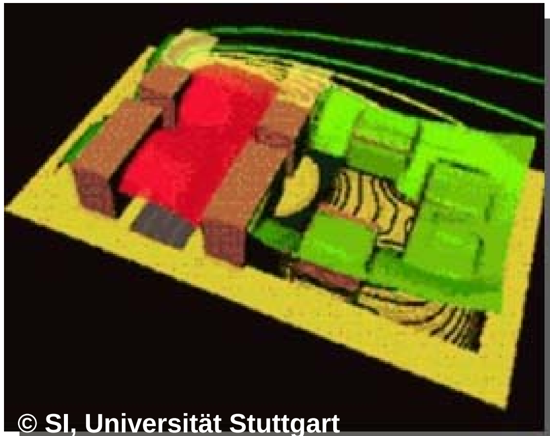
Overview

- Section I
  - Introduction: Urban Information Modelling
  - CityGML Overview and Status
  - OGC Geography Markup Language (GML)
- Section II
  - CityGML Details I
- Section III
  - CityGML Details II
- Section IV
  - Extending CityGML
  - Application Examples
- Section V
  - Relations to Other Standards

Urban Information Modelling

Applications of Virtual 3D City Models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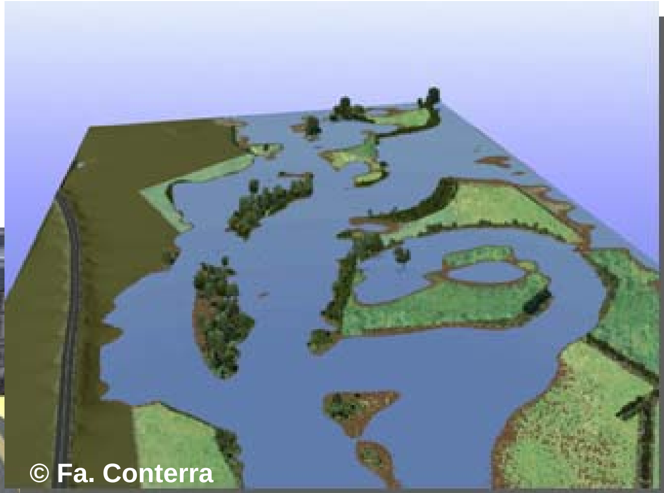
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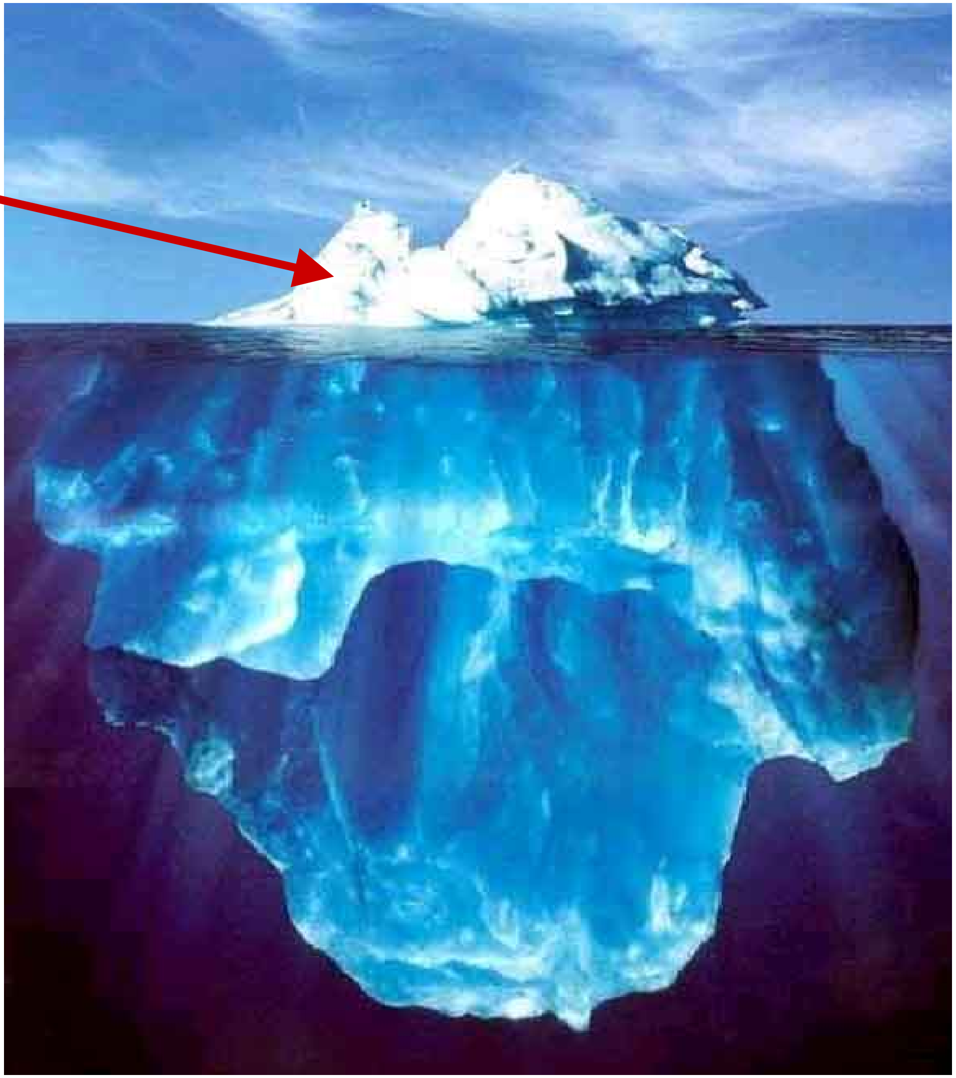
… is far more than the 3D visualization of reality



In fact, the **geometry** and its **appearance** are **only one aspect** of an entity!

Key issue: Semantic Modelling

- Ongoing paradigm shift in spatial modelling:
  - **from geometry / graphics** oriented models
  - **to representation of well-defined objects** with their properties (among them spatial and graphical ones), structures, and interrelationships
- Concerning 2D data: long tradition in European cadastres
  - Germany: ALKIS/ATKIS/AFIS (AAA)
  - UK: Ordnance Survey Mastermap
  - Netherlands: Top10NL
- Concerning **3D data: often seen as being identical with 3D graphics models** of the respective region
  - Google Earth [KML, COLLADA], X3D, 3D PDF, 3D Studio Max
- However: numerous **applications beyond 3D visualization**

- are **a product family on their own** (like Building Information Models, BIM, are a product family)
- with specific applications (differing from BIM)

Characteristics

- complete representation of city topography / structures **‘as observed‘** (typically **not ‘as planned‘**)
  - often full spatial coverage of a city or district
  - built-up environment (buildings, infrastructure)
  - natural features (vegetation, water bodies, terrain)
- 3D geometry, topology, semantics, and appearance
- homogeneous data quality (at least on the same scale)

Query your 3D city model! (Possibly even without 3D visualization)

- *From which windows in which rooms from which buildings do I have visible coverage of a certain place, road, or monument?*
- *To what floors have all buildings in a flooded area been affected?*
- *Where are audience halls in a specific area of the town (or on the campus) with more than 500 seats, 3D projection capabilities and less than 15min to walk from a public transport stop?*

Semantics supported navigation aid

- *Give me a tour of the XYZ plaza, have a special focus on the buildings with less than 10 storeys. And: always stay on the pedwalk!*

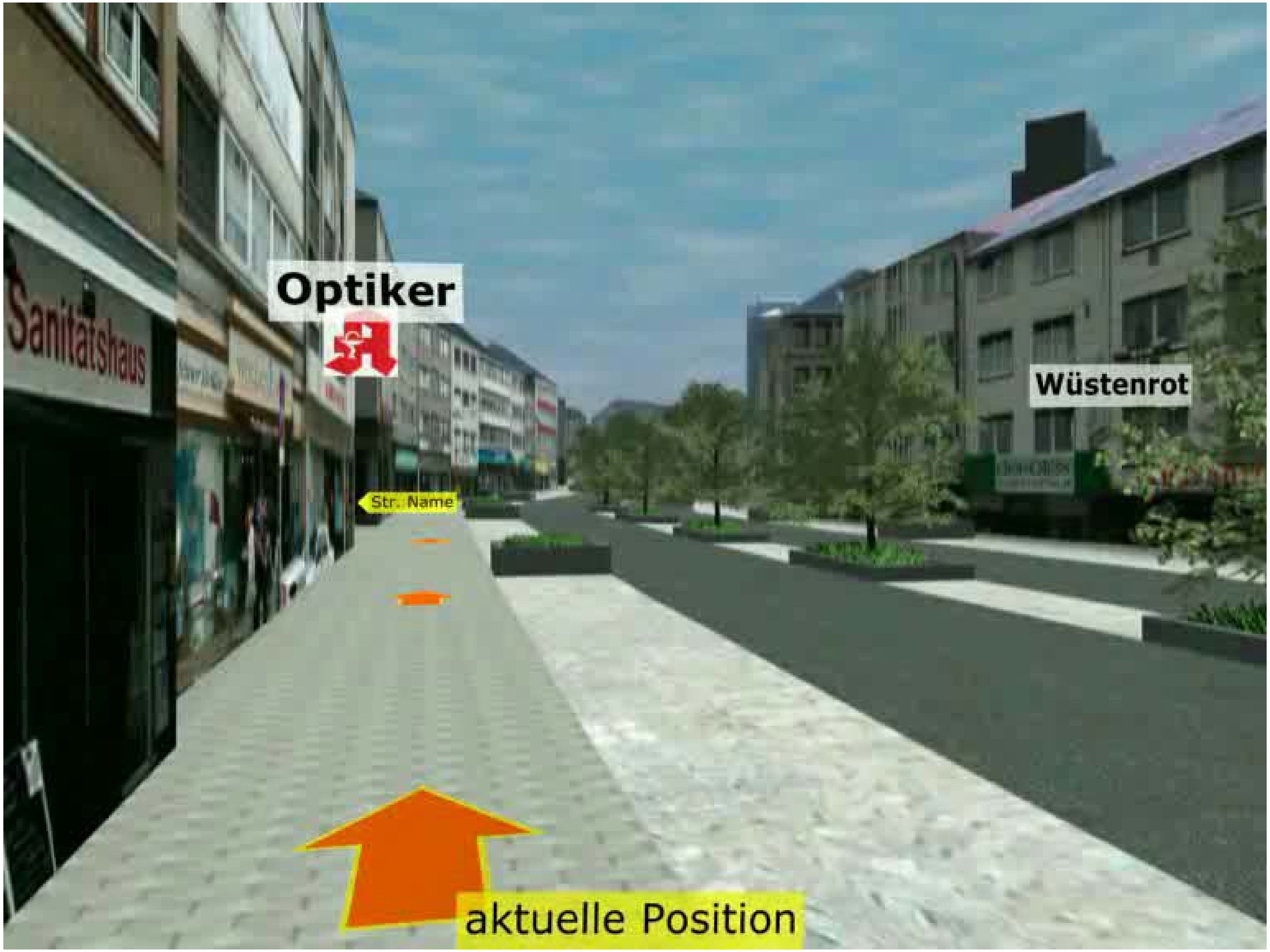
Mobile robotics

- Ensure that robots move in safe regions (classified areas like pedwalks, pedestrian crossings (outdoor) or hallways and rooms (indoor))

Urban Data Mining

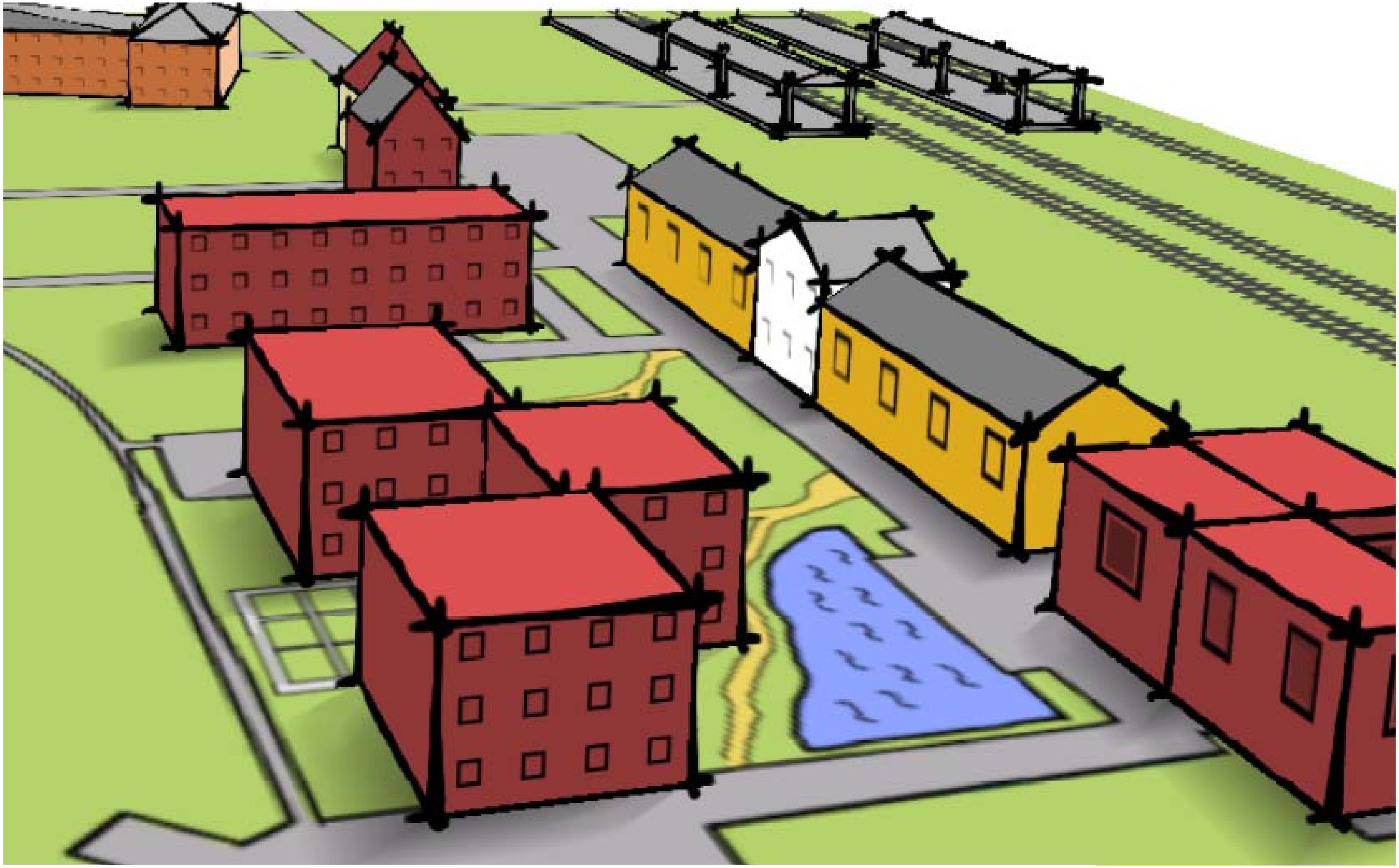
3D cartography; non-photorealistic rendering

Example for 3D Label Placement & Symbols



3D Label Placement for Augmented Reality

3D visualization from the CityGML perspective



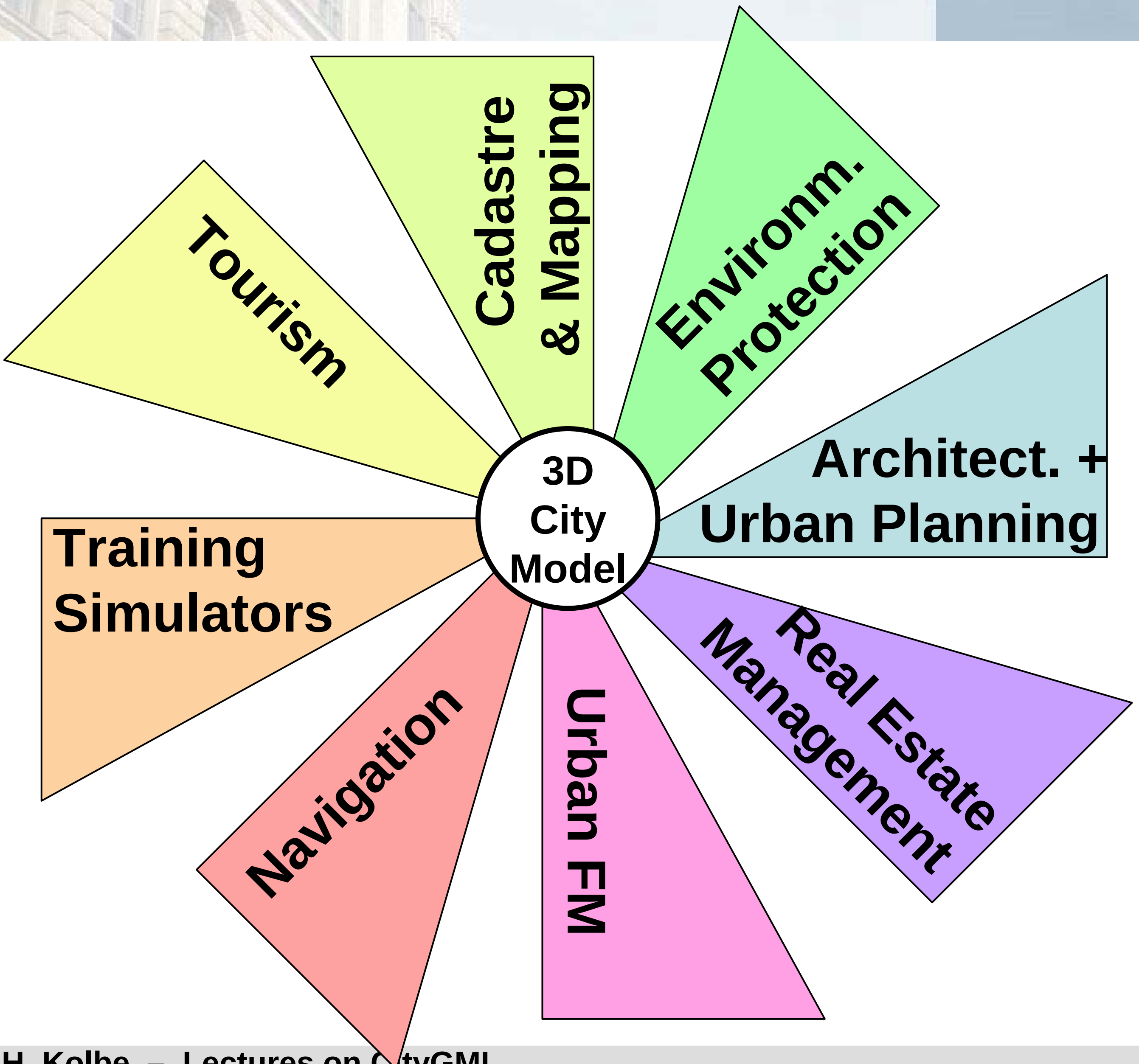
Non-photo realistic rendering. © J. Döllner & M. Walter, 2003

Prospects of a Common Ontology

- Applications can **rely on a specific data quality**
  - thematic and spatial **structure and** (a minimal set of thematic) **properties** of the geo-objects
- Data providers (e.g. municipalities) create 3D models with a **defined information level**, which they can be sure will be **required or useful for a wide range of applications**
  - this in turn **makes it feasible / profitable** for companies to create **more advanced applications** that exploit semantic information

3D City Model as Information Carrier (I)

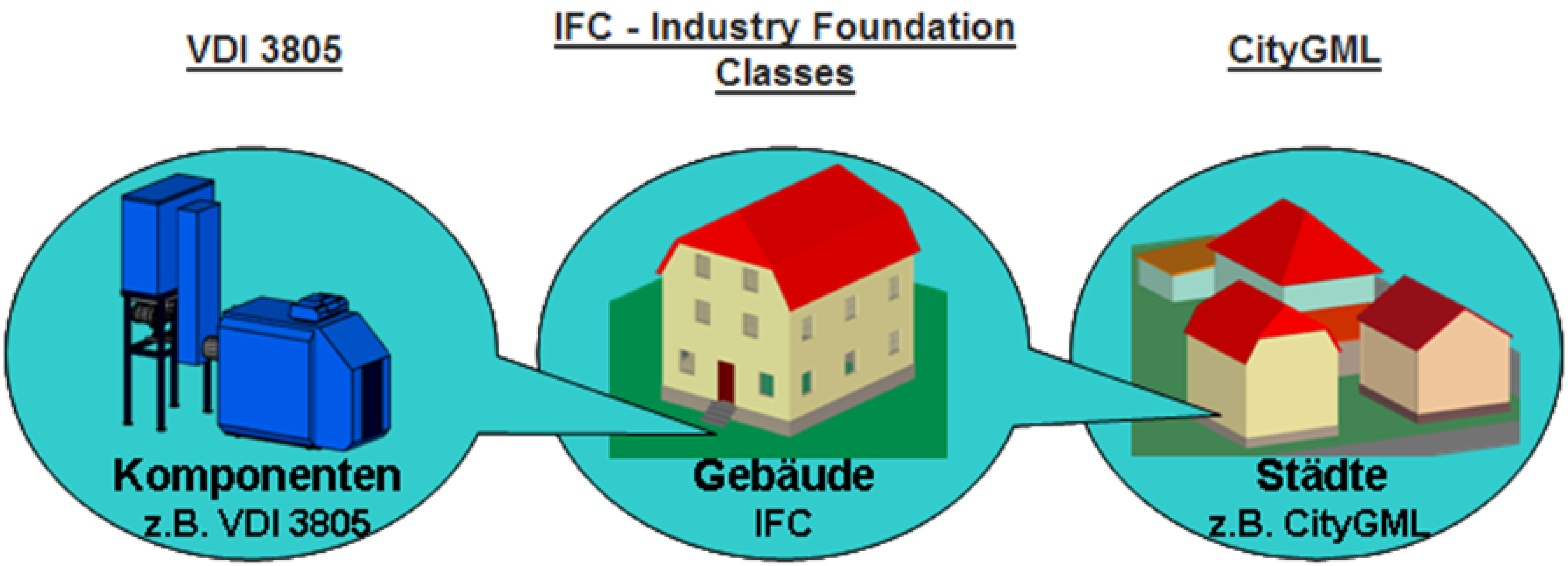
- Semantic model is a **consensus over different application domains**
- Information exchange between these domains can be aligned with the objects of the city model
  - → usage of the **3D model as an information carrier**
  - → the **city ontology** can also be taken as a schema for the organization of **domain information** that is **similarly structured**
- **domain specific information** can be **attached to** or related with the **city model objects**
  - domain specific information „rides on the back of the city model“
  - the spatial properties will not be of interest in many cases
  - however, spatial properties are basis for the attestation of the objects and their spatial extent in reality


3D
City
Model
Tourism
Cadastre
& Mapping
Environm.
Protection
Architect. +
Urban Planning
Training
Simulators
Navigation
Urban FM
Real Estate
Management

Example:

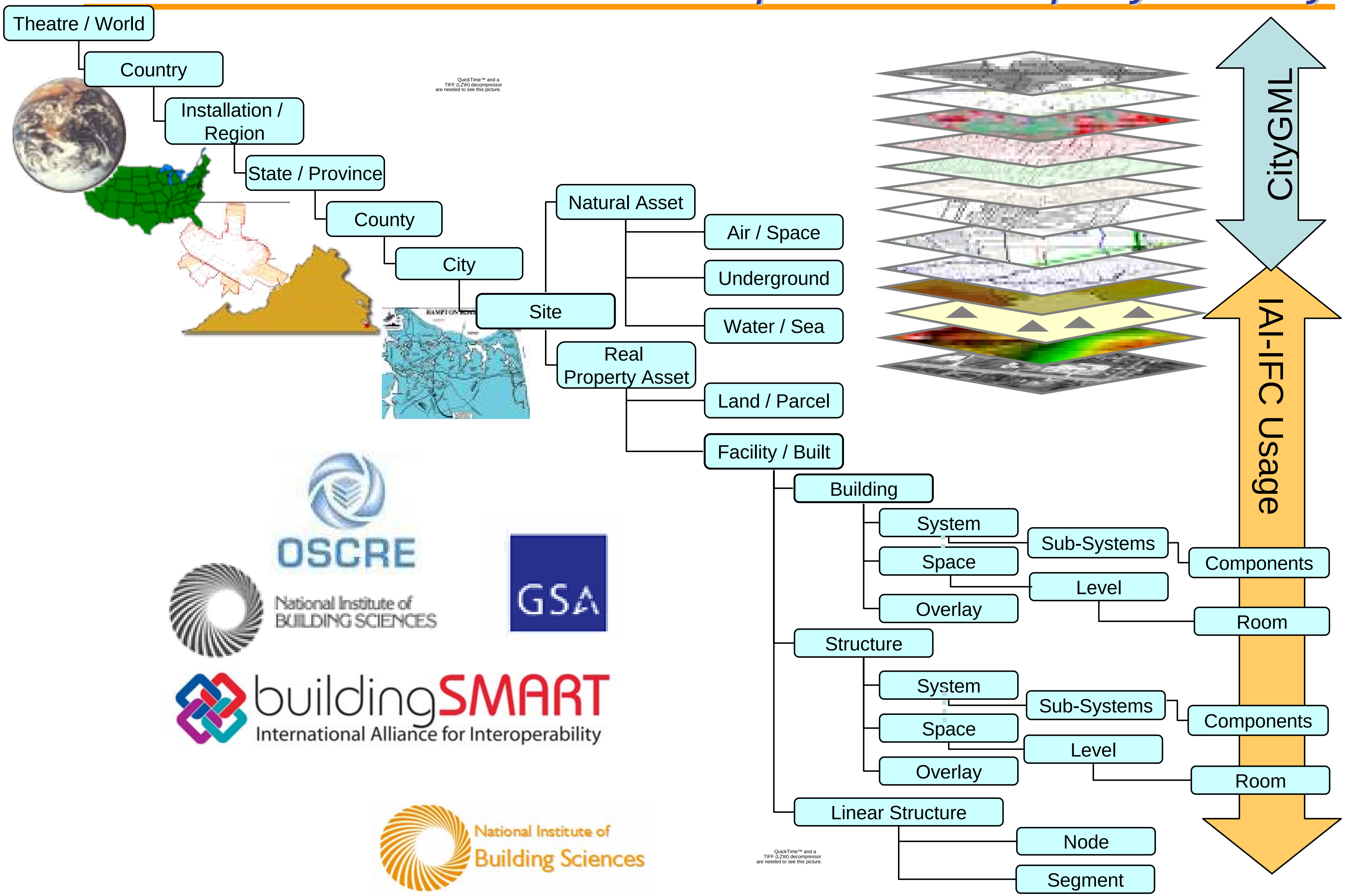
- a **bank** and an **insurance company** communicate about **financial parameters** and risks of specific **urban assets**
- both refer these parameters to the respective objects of the city model (or even to specified parts of them) to avoid ambiguity
- 3D geometry (and the appearance) will only be looked at if, for example a risk provisioning has to be done
  - inspection of the object
  - visual inspection of the surrounding environment

- Model content, structure, and employed modelling principles depend on
  - Scale
  - Scope (application contexts)

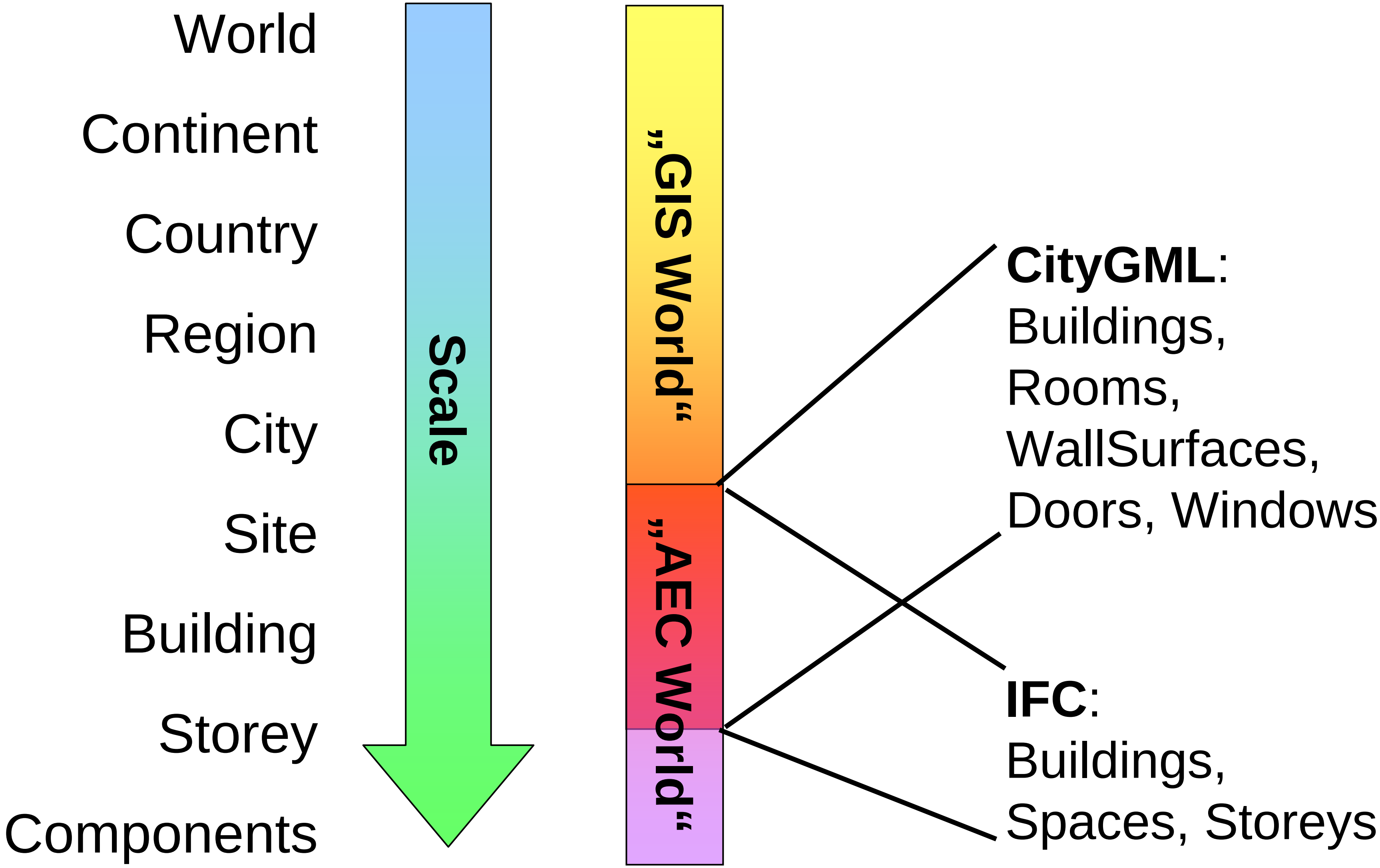


Taken from the Homepage of the Helmholtz Research Center Karlsruhe, © Karl-Heinz-Häfele buildingSMARTalliance™

Scope of Real Property Industry



Relation of Semantic GIS and CAD Models



CityGML

Overview & Status

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

- comprises **different thematic areas** (buildings, vegetation, water, terrain, traffic etc.)
- **data model (UML)** acording to **ISO 191xx** standard family
- exchange format results from rule-based mapping of the UML diagrams to a GML3 application schema
- ongoing standardisation process in OGC

CityGML represents

- 3D geometry, 3D topology, semantics and appearance
- in 5 discrete scales (Levels of Detail, LOD)

CityGML Development

Originator: SIG 3D of the Initiative Geodata Infrastructure North-Rhine Westphalia in Germany (**GDI NRW**)

- **Open group** of more than 70 parties / institutions working on technical and organizational issues about virtual 3D city models
- T-Mobile, Bayer AG, Rheinmetall Defence, Environmental Agencies, Municipalities, State Mapping Agencies, UK Ordnance Survey, 11 Univ.

CityGML was brought into **Open Geospatial Consortium** for international standardisation by the end of 2004

- Handled by the **3D Information Modelling Working Group (3DIM WG)** and the **CityGML Standards Working Group (CityGML SWG)**
- Current status:
  - Version 0.4.0 is an OGC Best Practice Paper [since July 2007]
  - Public comment phase (RFC) for Version 1.0.0 ongoing until 20/3/2008

Application backgrounds of the participants

- Cadastre and Topographic Mapping
  - Mapping agencies of Germany, UK on country, state, and municipality levels
- Urban Planning
- Building Information Modelling, AEC/FM
- Mobile Telecommunication
- Environmental Simulation
- Training Simulation and Car Navigation
- Tourism and City Business Development
- Geoinformation and Computer Science
- (at its beginning) Real Estate Management

Broad spectrum of different modeling requirements

↓

Good base for a multi-functional standard

Goals of CityGML (I)

Establish **high degree of semantic** (and syntactic) **interoperability**

- enabling multifunctional usage of 3D city models
- definition of a **common information model (ontology)**
- „3D geo base data" (in the tradition of most European 2D digital landscape models, cadastre models)

Representation of **3D topography** as observed

- explicit 3D shapes; mainly surfaces & volumes
- identification of **most relevant feature types** usable in a **wide variety of applications**
- limited inclusion of functional aspects **in base model**

Goals of CityGML (II)

Suitability for **Spatial Data Infrastructures**

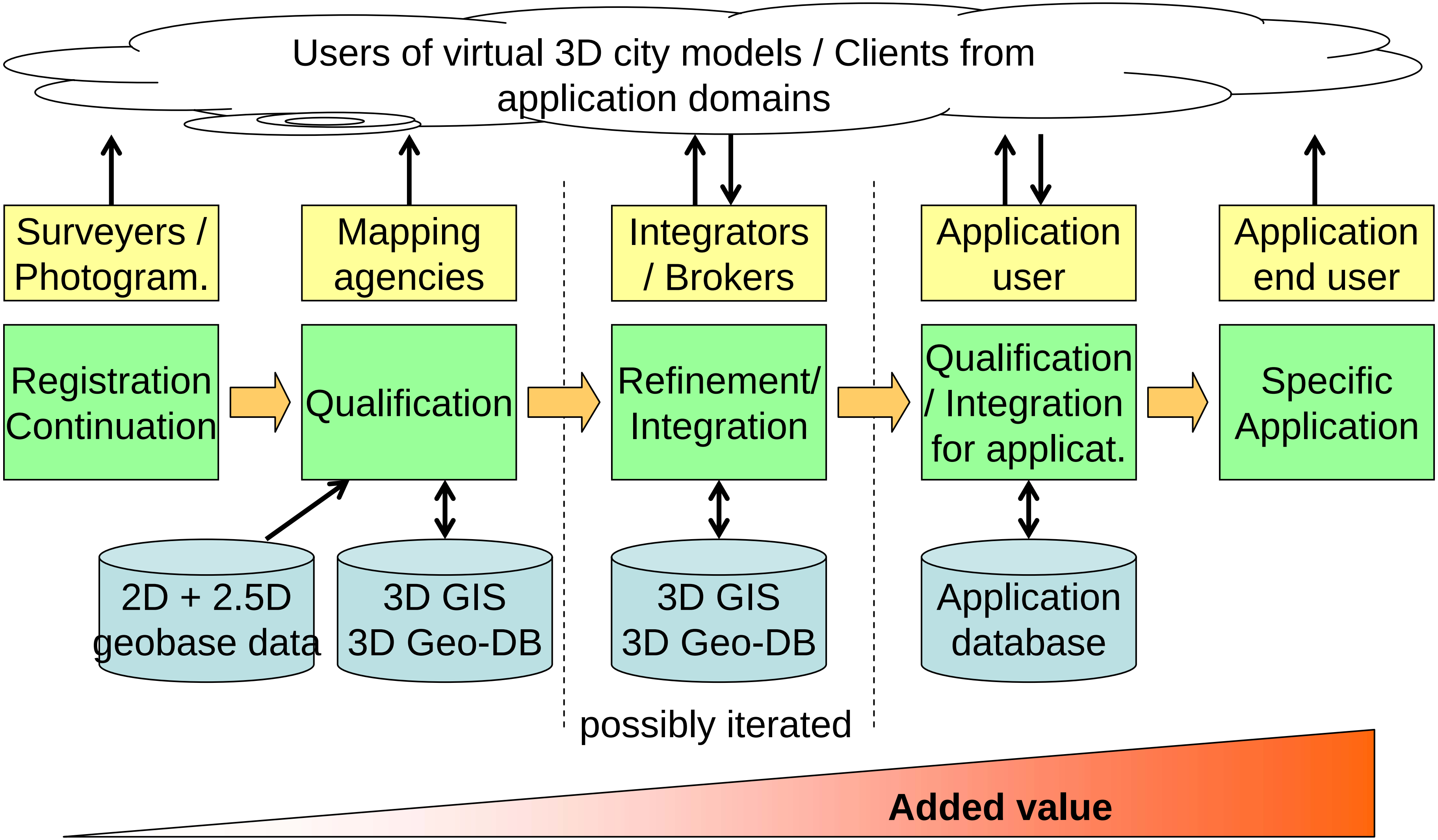
- mapping to appropriate exchange format -> **GML3**
  - needs high degree of expressivity wrt. OO models
  - must be usable in the context of OGC Web Services
- possibility to **link any CityGML feature** to more specialised, functional models / external data sources

Must be **simple to use** for applications

- **well-defined semantics** for feature types; however semantic structure not too fine-grained
- subset of GML3 geometries (no curved lines, surfaces)
  - **Boundary representation** with absolute coordinates
  - advantage: **directly manageable** within **3D GIS / geo DB**

- **Information preserving and adding data exchange along the processing / value adding chain**
- **Modelling requirements**
  - modelling of **geo-objects** („features"), not only 3D geometry and graphical appearance
  - Application independent base classes and attributes
  - **flexibility** wrt. geometrical, topological and structural qualities of **concrete realizations** of 3D city models
  - **System independent** and **standards based** modelling
  - **Application specific extendibility**, e.g. for Real estate management, noise immission mapping
- Business models, legal frameworks

CityGML along the Processing Chain



Difficulties along the Processing Chain

- **Diverse qualities** of **3D models** in the different steps
  - different degree of fidelity of geometry, topology, appearance
  - from simple structured objects to complex application models
- Until now: often **change of data models** and **exchange formats** inbetween the processing steps
  - loss of data because of limited modeling powers / expressivity of models and formats
  - difficult preservation of object identities
- **Missing back links / references** to original data of preceding processes
  - causes problems with updates / continuations
- **CityGML can be used along the full processing chain**

Geography Markup Language

Geography Markup Language (GML)

- GML is an **International Standard** for the **exchange and storage of geodata**
- Issued by the **Open Geospatial Consortium (OGC)**
- Version 3 was released in 2003
  - CityGML is based on (current stable) version 3.1.1
  - Specification freely downloadable from www.opengeospatial.org
- Further development jointly by OGC & ISO: GML 3.2.1 will be published as **ISO Standard 19136**
- Several national topography and cadastre models are already based on ISO 191xx and GML
  - e.g. in Germany, United Kingdom, Netherlands

Design Goals of GML3

- **Open, vendor independent** framework for the definition of **spatial data models**
- **Transport and storage** of schemas and datasets
- Support for the specification of **application schemas**
  - **GML is a meta format;** i.e. concrete exchange formats are specified by GML application schemas (like CityGML)
- Support of **distributed** spatial application schemas and datasets (over the Intra-/Internet)
- Possibility to create **profiles** (subsets of GML3)
- **Facilitate Interoperability** in the handling of geodata

GML3 Overview

- **Object oriented modelling** capabilities
  - Generalisation / specialisation & aggregations
- **Simple and complex geometries**
  - 0D: points
  - 1D: straight lines, splines, arcs
  - 2D: planar surfaces, nonplanar surfaces (spline, NURBS, TINs)
  - 3D: volumes by using Boundary Representation (B-Rep)
  - Composed geometries
- **Topology** (with or without associated geometry)
- **Coordinate** and **time reference systems**
- **Coverages** (regular and irregular rasters, TINs, maps)

Difference to other GIS exchange formats

- Object oriented; facilitates **semantic modelling**
  - In contrast to pure geometry models (like CAD formats or VRML) or geometry oriented GIS models (like Shapefiles):
  - **Identifiable objects** (with ID)
  - Spatial and nonspatial properties
  - **Specialization hierarchies** (taxonomies)
  - **Aggregation hierarchies**
  - **Associations** / relations between objects
- **Mixed usage** of **different spatial reference systems** within the same dataset possible
- **XML based**