Smart Cities: Data Representation Model

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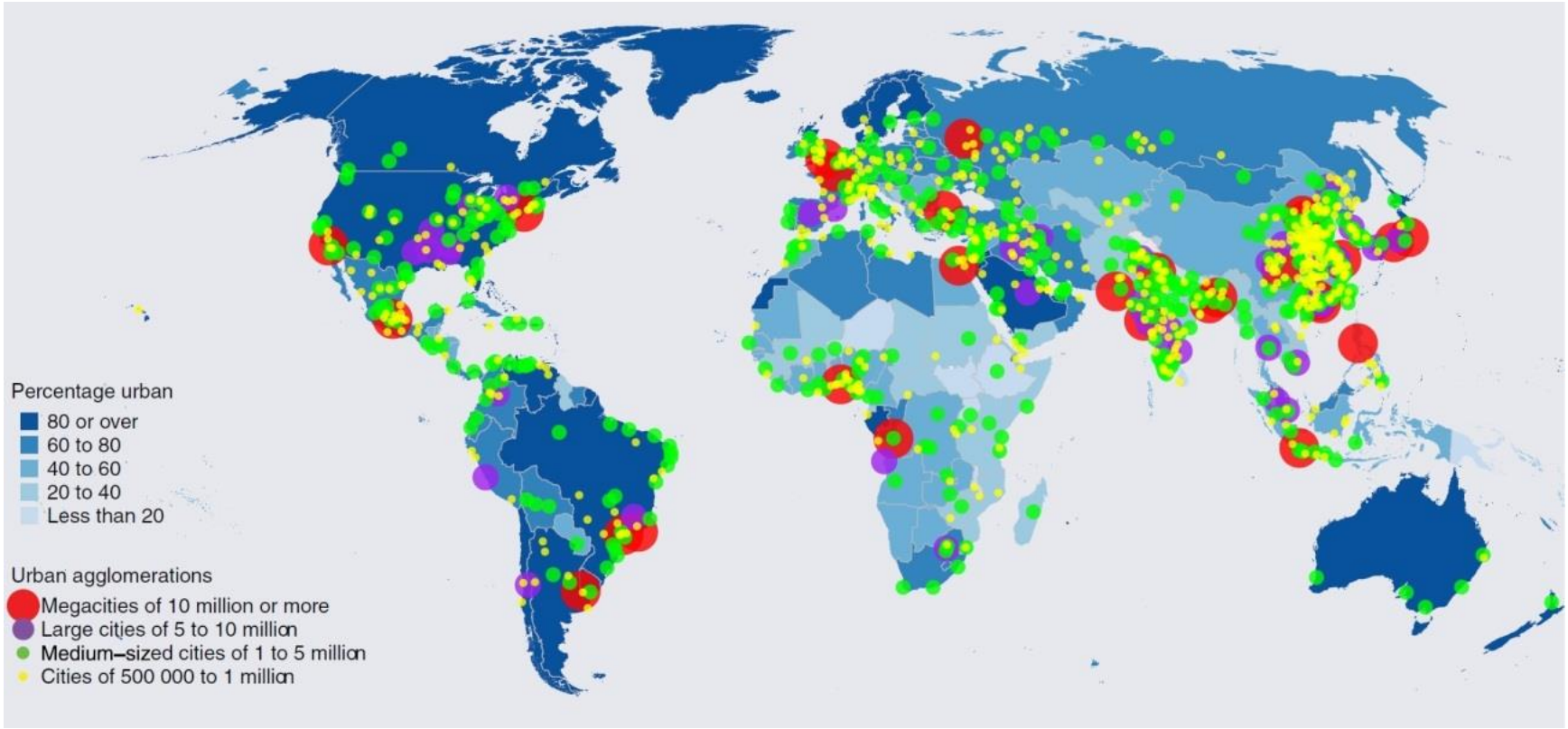
Presentation Overview

- Smart Cities
- City and Smart City Models
- Representation of data
- Visualization of Smart City
- Application of SC24 Standards
- Areas for standardization

World Urbanization Trends

- World population 10 billion by 2050
- Increasing urbanization
  - 1950: 2/3 in rural; 1/3 in urban
  - 2050: 6-7 billion in urban areas accounting for 80% of energy consumption and Greenhouse Gas emissions
  - Innovation in infrastructure and technology essential to reduce energy consumption and increase efficiency
  - UN Sustainable Development Goal:
    - Sustainable Cities and Communities

World Urbanization



World Urbanization Prospects (United Nations):
https://esa.un.org/unpd/wup/publications/files/wup2014-highlights.pdf

Smart City

- Applies advanced ICT (IoT, Cloud, Big Data etc) to manage city assets and utilities
- Provides efficient, secure urban services through smart systems (eg transport) and infrastructure (buildings, homes)
- Reduces environmental impact, enhances sustainability with emerging technologies

Smart Cities

- Barcelona – Smart City department
- Amsterdam – Smart City program
- Stockholm – broadband cover, on line gov, collects data from vehicles, sensors etc
- Songdo (송도/松都)

Smart Cities and ISO

- **ISO/TC 268 Sustainable Cities and Communities**
  - 8 standards with 14 in development
- **ISO/IEC JTC1/WG11 – Smart Cities (ICT aspects)**
  - ISO/IEC 30145-1 *Smart City ICT Reference Framework – Part 1: Smart City Business Process Framework (UK)*
  - ISO/IEC 30145-2 *Smart City ICT Reference Framework – Part 2: Smart City Knowledge Management Framework (UK)*
  - **ISO/IEC 30145-3 *Smart City ICT Reference Framework – Part 3: Smart City Engineering (China)***
  - ISO/IEC 30146 *Smart City ICT Indicators (China)*
- SC24 contribution discussed at WG11 meetings

Traditional City vs Smart City (Model)

Traditional City	Smart City
3D geometric models of buildings etc at minimal LOD, some appearance features	3D models at highest LOD with detailed appearance etc
Limited semantic representation	Full semantic representation – ownership, history, irradiation, shadowing..
Partial georeferencing	Full georeferencing for all significant city assets
No models of city services	Models of smart city services such as transport, lighting, health
Limited ability to use city model to calculate characteristics such as energy consumption	Enables determination of city characteristics on demand and in real time such as energy usage, traffic flow

Smart City Representation

- Digital Twin
  - Model of real city – eg Tokyo, Amsterdam, New York
  - Future city to be developed
- Static Components
  - Buildings, roads, parks, water bodies
- Animated Components
  - Cars, people etc included
- Semantic data
  - Legal, noise etc

Smart City Components

- **Physical, Geometric Objects**
  - Static
    - Buildings, Roads
    - Open spaces – parks, gardens, sports
    - Water bodies – rivers, lakes
  - Mobile Objects (if animation needed)
    - Cars, aircraft, ships
    - Humans, individual and crowds
    - Robots (eg drones)
- **Semantics**
  - Legal: ownership, road rules, security…
  - Feature: noise levels, pollution, network traffic, smart city indicators..
- **Sensors**

Physical / Geometric

- **CityGML**
  - Defines classes and relations for geometric, topological, semantic and appearance properties of **cities**
    - LOD 0: footprint
    - LOD 1: blocks with roofs
    - LOD 2: texture and roofs
    - LOD 3: architecture model of exterior
    - LOD 4: interior models
  - CityGML models can be visualized with X3D

- **Industry Foundation Classes ISO 16739**
  - Building Information Modelling
  - Building models – geometry, topology, semantics

- **SEDRIS**
  - Spatial reference model, data representation model
  - environmental data coding specification (register of environmental items)

Semantic Data

- **CityGML**
  - limited semantics
  - Focus on building details
  - Can / has been extended to include other features

- **Industry Foundation Classes ISO 16739+**
  - Building Information Model
  - Building models – geometry, topology, limited semantics

- **SEDRIS (ISO)**
  - Has all components needed for city modelling (DRM, SRM, EDCS)
  - military focus but can be extended
  - Needs visual presentation (X3D?)

ISO/TC 184/SC 4 Industrial data

CityGML

- Open Geospatial Consortium standard
- 3D City Models
- XML-based
- Can be visualized and navigated using X3D

Rodrigues, J. I., Figueiredo, M. J. and Costa, C. P. (2013) Web3DGIS for city models with CityGML and X3D. In: *Information Visualisation (IV), 2013, 17th International Conference*, IEEE

New York in CityGML

- 26 public data sets from 5 city departments
- All NYC buildings, land, roads, parks, DTM, water bodies
  - 2 million buildings
  - 16 000 parks
  - 150 000 streets
  - 280 000 trees
  - 9500 water bodies
  - 1.6 TB CityGML dataset

Kolbe, T. H., Burger, B. and Cantzler, B. (2015) CityGML goes to Broadway. In: *Photogrammetric Week 2015,* Stuttgart, Germany: 7 - 11 September 2015

Industry Foundation Classes (IFC)

- **Industry Foundation Classes ISO 16739+**
  - Building Information Model
  - Building models – geometry, topology, semantics
  - No appearance representation
  - Simple georeferencing
  - Exchange format based on STEP
  - Similar to CityGML with different scope and scale

SEDRIS

- ISO standard
- Parts 1, 2, 3 and C Language Binding
- Spatial Reference Model (SRM)
  - Position, orientation, reference frames
- Environmental Data Coding Specification (EDCS)
  - Identification/registration of objects
- Data Representation Model (DRM)
  - Relationships between objects and data

3D City Model Formats

	X3D	COLLADA	KML	Shape	CityGML	IFC	DXF
GP: General purpose IM: Information model	GP	GP	GP	GP	IM	IM	GP
3D geometry	+	+	•	•	+	++	•
Georeferencing	+	•	•	+	++	•	
Appearance	++	++	•		+	•	
3D topology	•	•			•	•	
Semantics	•	•	•	•	++	++	
Levels of detail	+	+	•		++	•	
Links/embedding	+	++	++		++		
Extensibility	+	++	+		++	•	
Fast rendering	++	++	+	+	+	•/+	+

• basic, + sophisticated, ++ comprehensive, empty not supported

Kolbe, T. H. (2012) BIM, CityGML, and related standardization.
In: *2012 Digital Landscape Architecture Conference,* Bernburg/Dessau, Germany

Smart City Data Model

- 3D buildings, features
- Transport
- Lighting
- Roads
- Waste collection
- Health resources
- Networks
- etc

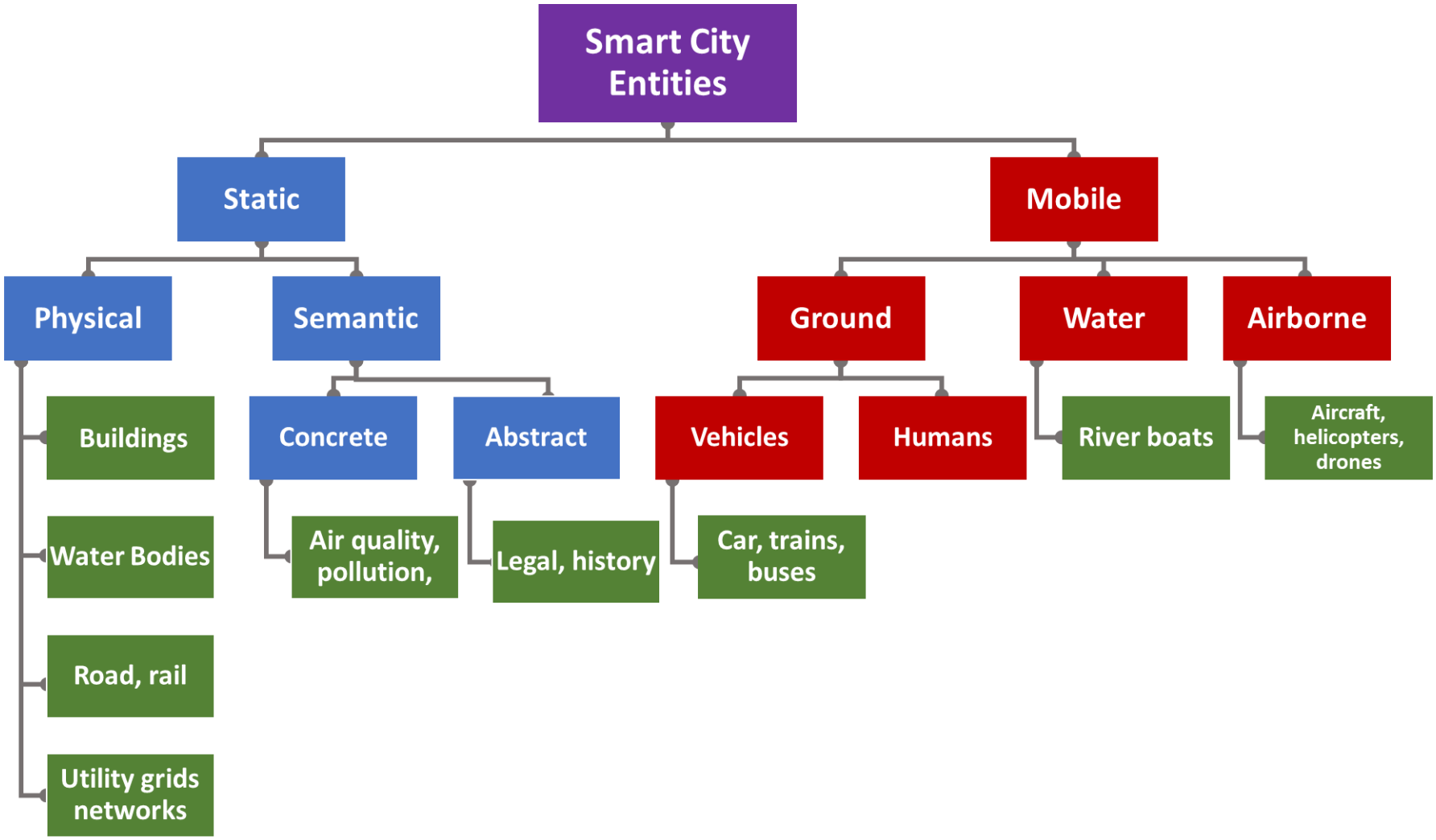
Smart City Data Model Example

Sources and formats of City Data

GeoData	GIS
Public transport system	REST web service in JSON format
City lighting system	XML
Road maintenance	MS SQL
Waste collection system	MS Excel
Urban fault reporting system	mySQL database

Consoli, S., et al. (2015) A Smart City Data Model based on Semantics Best Practice and Principles. In: Proceedings of the 24th International Conference on World Wide Web, Florence, Italy

Taxonomy of (Smart) City Entities



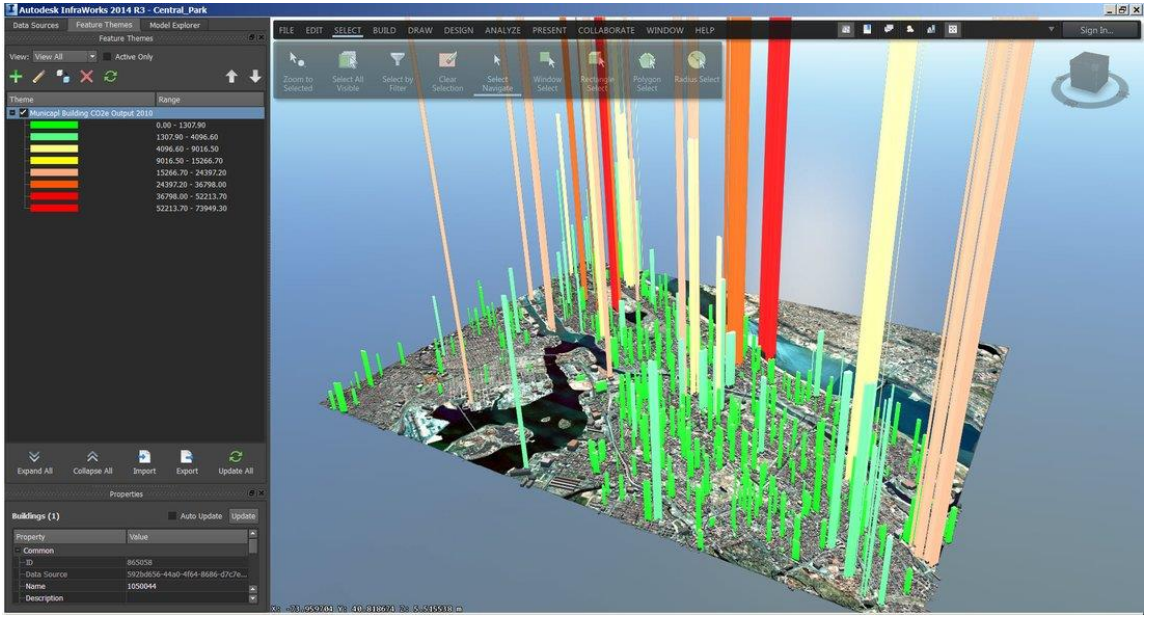
Use Cases for Smart Cities

- 29 use cases identified in 2015 review
  - More than 400 references!
- 25 visualization use cases
  - 3D visualization model required
  - Visibility analysis, shadowing, routing
- 4 non-visualization use cases
  - 3D model visualization not required
  - Solar irradiation, energy demand, building types

Biljecki, F., Stoter, J., Ledoux, H., Zlatanova, S. and Çöltekin, A. (2015) Applications of 3D city models: State of the art review. *ISPRS International Journal of Geo-Information* **4** (4) 2842-2889

Visualization for Semantic Data

- Example from:
  - http://fortune.com/2014/06/13/the-new-metropolis-the-new-urban-pioneers/
  - Autodesk modelling
  - Energy use and Greenhouse Gas emissions from New York municipal buildings
  - Emissions represented as towers with color / height describing emission type and magnitude



European Research in 3D City Modelling

European Cost action TU0801 – Semantic enrichment of 3D city models for sustainable urban development

1. Billen, R., et al. (2014) *3D City Models and urban information: Current issues and perspectives*, edp Sciences Les Ulis, France
2. Métral, C., et al. (2014) A repository of information visualization techniques to support the design of 3D virtual city models. In: *Innovations in 3D Geo-Information Sciences*. Springer 175-194
3. Métral, C. and Falquet, G. (2014) Prototyping Information Visualization in 3D City Models: a Model-based Approach. In: *3DGeoInfo 2014 Conference,* Dubai: Nov 2014
4. Metral, C., Ghoula, N. and Falquet, G. (2012) An ontology of 3D visualization techniques for enriched 3D city models. Usage, usability, and utility of 3D city models–European COST action TU0801 02005
5. Bazargan Harandi, K. (2011) *Abstract information visualization in interactive 3D virtual environments: conceptualization and usability evaluation*. [PhD] University of Geneva, Geneva, Switzerland
6. Consoli, S., Mongiovic, M., Nuzzolese, A. G., Peroni, S., Presutti, V., Recupero, D. R. and Spampinato, D. (2015) A Smart City Data Model based on Semantics Best Practice and Principles. In: *Proceedings of the 24th International Conference on World Wide Web,* Florence, Italy, ACM

Where / How to apply SC 24 Standards?

1. Create digital **model** of Smart City for urban management, concept evaluation, demonstrate Smart City features, prototype further technology evolution

2. Apply SC24 standards to assist residents and visitors in **real** Smart City

Relevant SC24 Standards

- **X3D** – buildings, terrain (**XML** based)
  - http://x3dgraphics.com/examples/X3dForAdvancedModeling/Buildings/index.html
- **H-Anim** – humans (**XML** based)
  - http://www.web3d.org/x3d/content/examples/Basic/HumanoidAnimation/
- **MAR** – human interaction, augmentation (**XML**-based) – sensor representation
- **SEDRIS** – SRM, DRM, EDCS components

ISO & OGC Standards for Smart Cities

CityGML	CityGML information model that has: • Digital Terrain Models • sites (buildings, bridges, tunnels etc) • vegetation and water bodies • transportation facilities • generic city objects and attributes
X3D	• Render and display 3D city model using basic X3D standards and language bindings • X3DOM to view / interact with Smart City model in browser without plugin
SEDRIS	• SRM to define spatial reference model • DRM to integrate Smart City model content and the variety of environmental data • EDCS to provide the semantics of Smart City concepts, objects, features, and attributes
Humanoid Animation	• Part 1 Architecture: Add life forms for high fidelity • Part 2 Capture motion from video and create humanoid figures for visualization
Mixed and Augmented Reality	• Reference model to relate Smart City content for MAR viewer • Information model for MAR Smart City content • Live actor and entity for human interaction • Sensor representation to model Smart City sensors • Future MAR standards that make use of IoT
Basic Image Interchange Format	Container for digital imagery of various types • BIIF format for satellite and aerial imagery of urban areas for Smart Cities • Image interchange parts of BIIF
Other SC24 standards	• PNG – 2D imagery • VRML – 3D interactive visualisation

SC24 Standards for Real Smart Cities

- MAR standards
  - Reference Model
  - Live Actor and Entity in MAR
  - Benchmarking MAR
  - Information model for MAR contents

- Human interaction with real Smart City
  - Traffic, parking, shopping, touring, wifi availability, medical etc (already available in some cities)
  - IoT devices as sensors

Application of SC24 Standards

MAR Live Actor Entity

MAR to augment 3D

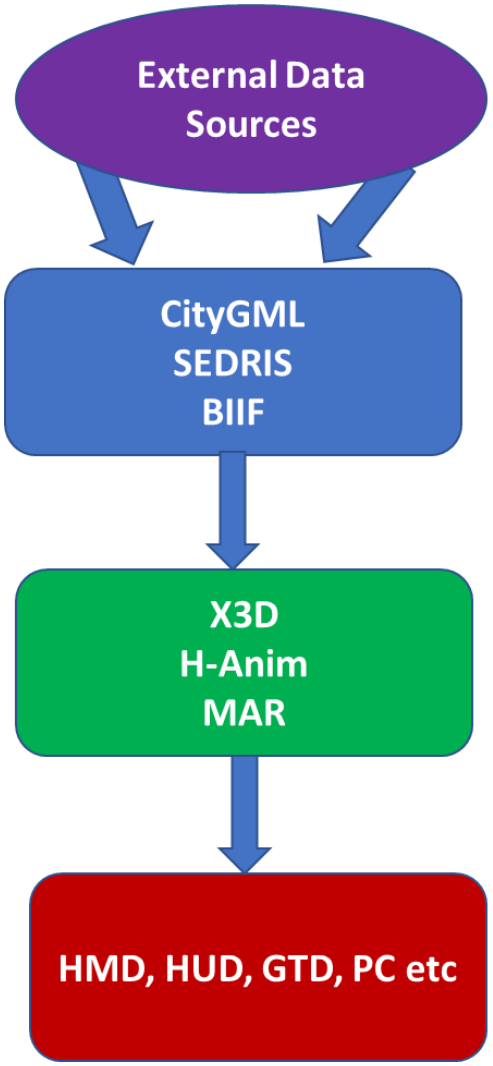
X3D City Model

H-Anim Humanoid Models

SEDRIS: geometric and semantic data

https://www.cgtrader.com/3d-models/exterior/cityscape/20-city-building-collection

Data flow for Smart Cities



Maps, DEM, building plans, lots, zoning, streets, trees, water bodies etc

Content

Presentation

Display

Where are the Sensors?

Sensor XYZ
UV radiation

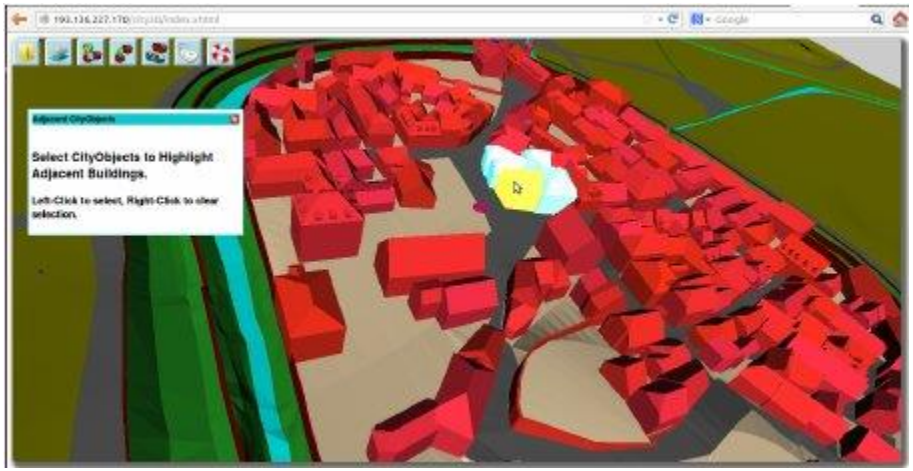
SEDRIS Smart City

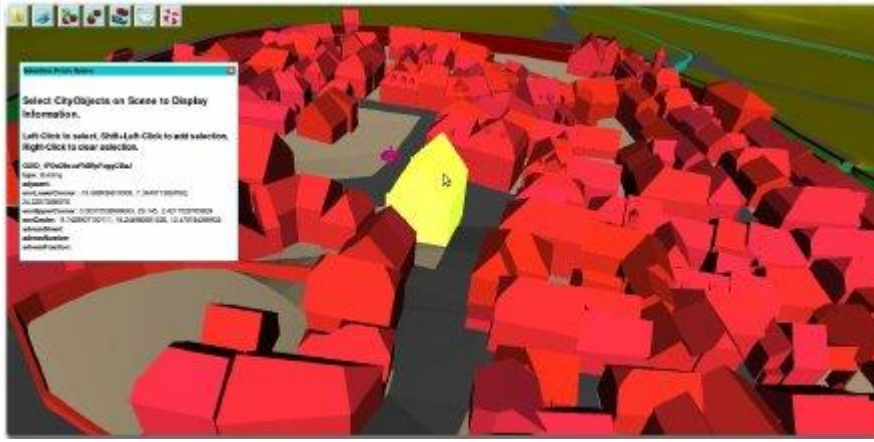
- **Parts 1, 2, 3** and **C Language Binding**
- **Spatial Reference Model (SRM)**
  - Position, orientation, reference frames
- **Environmental Data Coding Specification (EDCS)**
  - Identification/registration of objects
- **Data Representation Model (DRM)**
  - Relationships between objects and data

X3D Smart City

- X3D can be used to render CityGML models
- http://www.web3d.org/sites/default/files/attachment/node/1853/edit/X3D%20An%20Open%203D%20Digital%20World%20-%20March%202015.pdf

X3D City Model





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Discussion

- SC24 standards (X3D, SEDRIS, H-Anim) most suited to physical/geometric *sensor-based* (eg visual) representation
- SC24 MAR standards for visualization/interaction
- X3D visualization of CityGML models achieved
- OGC has expertise in city modelling via CityGML
- Potential SC24 standard:
  - *Data Model Concepts for Smart Cities*