Indoor-Outdoor Integrated Spatial Representation Issues for Seamless Services

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1. Background

- 9/11 Attacks, London Bombing, Tokyo Subway Gas Explosion, etc.
- 80% of life time spending in indoor space.
- Need new geospatial technologies applied to from outdoor to Indoor Space
Overview

1. Background;
2. Spatial Representation Issues for Seamless Services:
   Indoor–Outdoor Integrated Spatial Data Models:
   1. Indoor–Outdoor Integrated Coordinate Systems
   2. Spatial Representation Frameworks
   3. LoD–based Indoor Space Representations
   4. Spatial Relationships
3. Introduction to IndoorGML OGC Standard
4. Summary
1. Background

Need to develop indoor-outdoor integrated spatial data model

- to provide seamless LBS between different scale representations

Macro-scale Representation

City View

Exterior View (Outdoor)

Micro-scale Representation

Interior View (Indoor)
2. Spatial Representation Issues for Seamless Services: Indoor-Outdoor Integrated Spatial Data Models

- **Outdoor Representations** (ex. CityGML)
- **Representations of Indoor space**
- **Connection of Indoor/outdoor**
- **Indoor–Outdoor Integrated Spatial Data Model**
- **Data Integration** / Seamless Movements
  Space Representations in three different views

**Supporting Seamless Spatial analysis**
2. Spatial Representation Issues for Seamless Services: Indoor-Outdoor Integrated Spatial Data Models

- Goal of Indoor-Outdoor Integrated data model
## 2.1 Indoor-Outdoor Integrated Coordinate Systems

### Indoor-Outdoor integrated Geo-Reference model development

- **Position Reference System of Indoor-Outdoor Space Data Model**

<table>
<thead>
<tr>
<th>Outdoor Space</th>
<th>Indoor Space</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Necessary equipment for providing position information</td>
<td>• Difficult to obtain absolute position information</td>
</tr>
<tr>
<td>• Absolute Coordinate System</td>
<td>• Relative Coordinate System</td>
</tr>
</tbody>
</table>

- Different location reference system between Indoor and Outdoor
- Require integration or conversion between location reference systems of indoor space and outdoor space

### Integration plan on the location reference systems of indoor and outdoor

<table>
<thead>
<tr>
<th></th>
<th>Geometric Data</th>
<th>Topological Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model 1</strong></td>
<td>Independent reference system using Anchor</td>
<td>Indoor-Outdoor integrated reference system</td>
</tr>
<tr>
<td><strong>Model 2</strong></td>
<td>Indoor-Outdoor integrated reference system</td>
<td>Topology relationship (Topological Space)</td>
</tr>
</tbody>
</table>

![Building Object](image-url)
2.2 Spatial Representation Frameworks

- Direction of an Indoor/Outdoor Object Data Model

- CityGML ADE; Indoor Spatial Data Model (ISDM)

- Indoor Spatial Model

- Indoor-Outdoor Spatial Model

- CityGML

- IndoorGML

- GML

- XML

- ISO 191XX
2.2 Spatial Representation Frameworks

- **Indoor Spatial Data Model (ISDM)**
  - **CityGML ADE**
    - It is available to use classes of indoor space object or building that is provided by CityGML
    - Increase the expression of Indoor object, by defining additionally needed classes
  - Define additional LoD for geometry of indoor objects
2.3 LoD-based Indoor Space Representations

- Development of Indoor/outdoor Integration model

- **Methods for representing indoor spaces**
  - Using Boundary Surface
  - Difference depending on how Boundary Surface is represented
  - That is, how LoD is defined

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Simple | Detail

...
2.3 LoD-based Indoor Space Representations

- **Indoor Space Object Geometric LoD Model**
  - **Simple**
    - **LOD 1**: Footprint data
    - **LOD 2**: Image Data
    - **LOD 3**: Simple Geometry + Texture Files
    - **LOD 4**: Geometry Modeling + Texture Files
  - **Detail**

Same as CityGML LOD 4
2.3 LoD-based Indoor Space Representations

Indoor/outdoor Integrated Spatial Data Model

- Application domains of Indoor Object data model

- Integrating Inter-Scales & Inter-LoDs representations

**Topoogy**
- Topology Model (Semantic)

**Geometry**
- LOD 1 (Footprint)
- LOD 2 (Image Data)
- LOD 3 (Simple Geometry + Texture Files)
- LOD 4 (Geometry Modeling + Texture Files)

**Application**
- Indoor navigation
- Store View
- Indoor simulation in buildings
### 2.3 LoD-based Indoor Space Representations

#### Indoor Space Object Geometric LoD Model Definition:

<table>
<thead>
<tr>
<th>LOD1</th>
<th>LOD2</th>
<th>LOD3</th>
<th>LOD4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial Object Geometry Information</td>
<td>–</td>
<td>–</td>
<td>Solid (Representing vertical protrusion and sink of surface and slope)</td>
</tr>
<tr>
<td>Accuracy Classification</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>3D absolute coordinates accuracy (location/height)</td>
<td>1m (Location Accuracy of 2D)</td>
<td>GSM</td>
<td>0.4/0.4m</td>
</tr>
<tr>
<td>Generalization (Minimum size: Plane/Height)</td>
<td>–</td>
<td>–</td>
<td>2X2m/1m</td>
</tr>
<tr>
<td>Visualization data</td>
<td>–</td>
<td>Panoramic Image</td>
<td>Actual Ortho Imagery</td>
</tr>
<tr>
<td>Texture Image Resolution</td>
<td>–</td>
<td>GSM</td>
<td>7 – 9cm</td>
</tr>
<tr>
<td>Application Field</td>
<td>Route Guidance</td>
<td>Store-view, Virtual Indoor Experience, Route Guidance</td>
<td>Route Guidance, Virtual Building Build, Disaster simulation</td>
</tr>
<tr>
<td>Data Format</td>
<td>IMG</td>
<td>Panoramic Imaging Format based GML</td>
<td>CityGML</td>
</tr>
</tbody>
</table>
2.3 LoD-based Indoor Space Representations: Data Prototype of Indoor Space (LoD 2)

- Acquisition of Omni-directional Image Data of Indoor Space
  - The progress of test and videography for interactive services, using a device that has been developed.
  - Rotating 360 degree, 3D View is possible from all directions.
  - Image Acquisition of 8000 x 4000 resolution.
2.3 LoD-based Indoor Space Representations: Data Prototype of Indoor Space (LoD 2)

Acquisition of Omni-directional Image Data of Indoor Space
Data Prototype of Indoor Space (LoD 2)
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2.4 Spatial Relationships: Indoor Feature Model Viewer
2.4 Spatial Relationships
: Navigable Space from Indoor Feature Model

Navigable Space For Handicapped Persons

by Semantically Spatial Query
2.4 Spatial Relationships
: Indoor Spatial Data Model (Representation of Space)

- **Interior View** (to represent *Indoor Space*)
- **Exterior View** (to represent *Semi- or Open Space*)
  (Roof-top, balcony, etc)
- **City (or Site) View** (to represent *Open Space*)
  (open space between buildings)

Seamless Movements Represent the Relationships among SPACE:
Space-Oriented Data Model
Graph Representation of Space
IndoorGML v. 0.6 – an OGC candidate standard for indoor navigation

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Jeremy Morley, University of Nottingham, UK
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7. International Standardization of IndoorGML

7.1 IndoorGML SWG, OGC

- SWG Charter
  - Chair: Ki-Joune Li (Pusan National University, South Korea)
  - Vice Chairs: Jiyeong Lee (University of Seoul, South Korea)
    Sisi Zlatanova (TU Delft, The Netherlands)
    Jeremy Morley (University of Nottingham, UK)
  - Editors: Thomas H. Kolbe (TU Berlin, Germany)
    Ki-Joune Li, Jiyeong Lee, Sisi Zlatanova

- March 19, 2012, first IndoorGML v. 0.1 SWG meeting (Austin, USA)
- June 13, 2012, second IndoorGML v. 0.2 SWG meeting (Exeter, UK)
  - IndoorGML V. 0.2 was drawn up
1. Overview of IndoorGML

• IndoorGML
  – To represent and exchange the geo-information that is required to build and operate indoor navigation systems
  – provides well-defined interfaces to connect semantic models of topographic indoor space
    • Complementary standard to CityGML and IFC
    • Not restricted to 3D models
2. Introduction

• Motivations and requirements
  – Navigation services:
    • Seamless between indoor and outdoor spaces
    • Different navigation context
      – e.g. Wheelchair, Robots, Avatars, Door Direction, etc.
  – Tagging (or Checking) in indoor space
    • e.g. Checking in indoor space for Foursquare
  – Complementary representation of existing 3D models
    • CityGML, IFC, X3D, KML, etc.
  – Different and multiple localization methods/infrastructure

• Goal
  – Establish a common schema framework for indoor navigation applications
  – An application schema of GML
3. General Characteristics of IndoorGML:

3.2 Modularization

- IndoorGML data model is thematically decomposed into a core module and thematic extension modules.
- The core module comprises the basic concepts and components of the IndoorGML data model.
- IndoorGML introduces a thematic extension module *IndoorNavigation*

![Diagram](image-url)
3. General Characteristics of IndoorGML:

3.3 Node-Relation Structure (NRS)

- The NRS utilizes the Poincare Duality in order to simplify the complex spatial relationships between 3D objects by a combinatorial topological network model.

- Adopted network structure concept to represent topological relationships, e.g., adjacency and connectivity, among 3D objects.
3. General Characteristics of IndoorGML:

3.4 Structured Space Model

- The Structure Space Model defines the general layout of each space layer independent from the specific space model which it represents.
  - Each layer is systematically subdivided into four segments
3. General Characteristics of IndoorGML:

3.5 Multi-Layered Space Model

3.5.1 Multi-Layers

• Different space models with different partitioning schema
• Each partitioning corresponds with a single layer
• Example
  – Topographic subsspacing layer,
  – Sensor coverage
  – layerSecurity zone layer

3.5.2 Inter-Space Relation

• The joint state of navigation is exactly a clique of all active states of all space layers and is represented by an edge within the graph structure.
• Edge denotes possible simultaneous space occupancies.
3. General Characteristics of IndoorGML:

3.5 Multi-Layered Space Model
4. IndoorGML Data Model

4.1 IndoorGML Core Module Data Model

Structured Space Model: Geometry

- `<Geometry>` GM_Curve
- `<Geometry>` GM_Surface
- `<Geometry>` GM_Solid

Dual Space

- `<Geometry>` GM_Point
- `<Geometry>` GM_Curve

Multilayered Space Model: Semantic + Topology

- `<Feature>` AbstractSpace
- `<Feature>` AbstractSpaceBoundary
- `<Feature>` SpaceLayer
  - `+layerName : string`
  - `+Class : SpaceLayerClassType`
- `<Feature>` Transition
- `<Feature>` State
- `<Feature>` InterSpaceConnection
  - `+comment : string`
  - `-typeOfTopoExpression : TopoExpression`

Multilayered Space Model: Semantic + Topology

- `<Feature>` MultiLayeredGraph
  - `0..1`

Primal Space

- `0..1`

1..*
5. Details on each module

5.2 Indoor Navigation Module

5.2.1 Conceptual Indoor Navigation Module

❖ Cardinality ‘0’ case:

❖ Cardinality ‘1’ case:
3. General Characteristics of IndoorGML:

3.6 External reference

- Indoor Navigation data model on reference to ISO 19107 and OGC CityGML
-Designed as a GML application schema representing spatial objects and relationships between them

![Diagram showing the relationship between CityGML, IFC Standard, IndoorGML, GML, XML, and ISO 191XX]
4.1 External reference

- `<AbstractSpace>` and `<AbstractSpaceBoundary>` are interface class to existing 3D data models (e.g. CityGML, KML, IFC, etc)
4. IndoorGML Data Model

4.2 External reference

- Example

Indoor::AbstractSpace has an external reference to Bldg::Room
Indoor::AbstractSpace has an external reference to Bldg::Door
Indoor::AbstractSpaceBoundary has an external reference to Bldg::BoundarySurface
Indoor Spatial Data Model

Indoor Navigation Data Model
5. Details on each module

5.2 Indoor Navigation Module

5.2.1 Conceptual Indoor Navigation Module

- Example
5. Details on each module

5.2 Indoor Navigation Module
Navigation Analysis in Site Space:

- **3D ISDM** and
- **Optimal Route** b/t Room A and Room B defined by a Modified Dijkstra’s Algorithm
6. Application of IndoorGML

IndoorGML

Derivation

Import

IFC

KML

CityGML

2D Indoor Floor Plan

Services for handicapped persons

Application

Emergency Control

Indoor LBS

Indoor mCommerce

Indoor Robot
7. International Standardization of IndoorGML

7.2 Milestone for International standardization of IndoorGML

- Submission for OGC OAB, NA, public comments
- TC/PC and Public comments
- Reflecting TC/PC and public comments
- Submission to TC

Discussion on Draft v.0.6
- March 2013 Abu Dhabi Meeting

SWG voting for public comments
- April 2013 E-vote

Discussion on comments and replies
- April 2013
- May 2013

30-days public comments

Revisions

SWG voting for Submitting to TC
- Sept. 2013 Frascati meeting

TC voting
감사합니다

Thank you very much.