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Conceptual Framework towards Unified 3D Topological Modelling and Visualization based on CityGML

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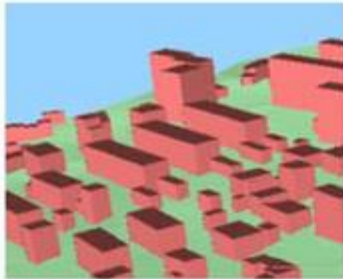
Introduction

(LoD)

T. H. Kolbe, G. Gröger, 2004



LoD 0



LoD 1



LoD 2






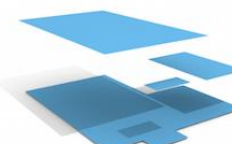
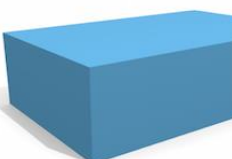











LoD 3



LoD 4

- Each LoD has its own viewer, geometry, attribute and almost no topology relationship between objects of the same LoD.
- 5 LoDs with 5 separate geometries, attributes and semantic information.

- More LoDs (e.g. 16 LoDs)?

	LOD x.0	LOD x.1	LOD x.2	LOD x.3
LOD0	 LOD0.0	 LOD0.1	 LOD0.2	 LOD0.3
LOD1	 LOD1.0	 LOD1.1	 LOD1.2	 LOD1.3
LOD2	 LOD2.0	 LOD2.1	 LOD2.2	 LOD2.3
LOD3	 LOD3.0	 LOD3.1	 LOD3.2	 LOD3.3

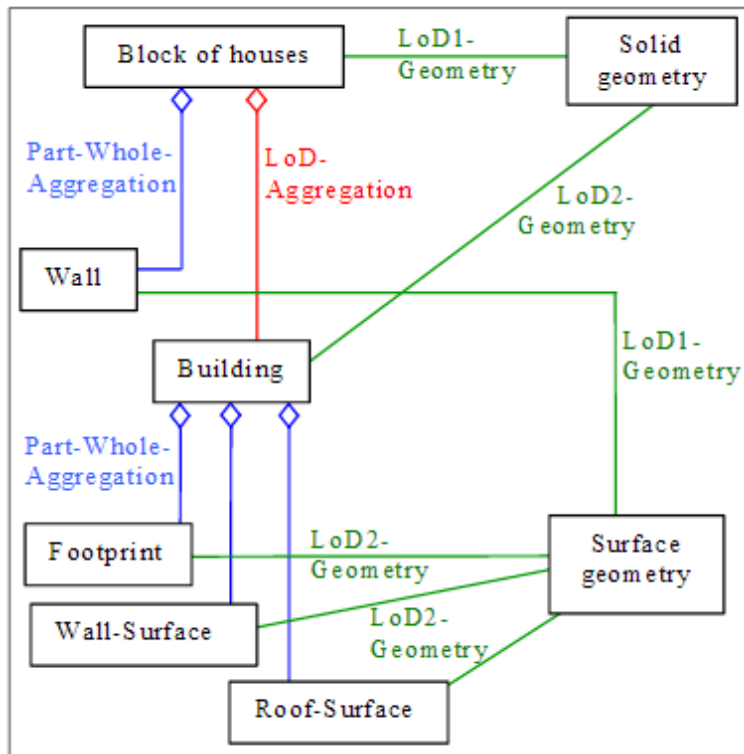
Biljecky (2017)

Why unified 2D and 3D topology?

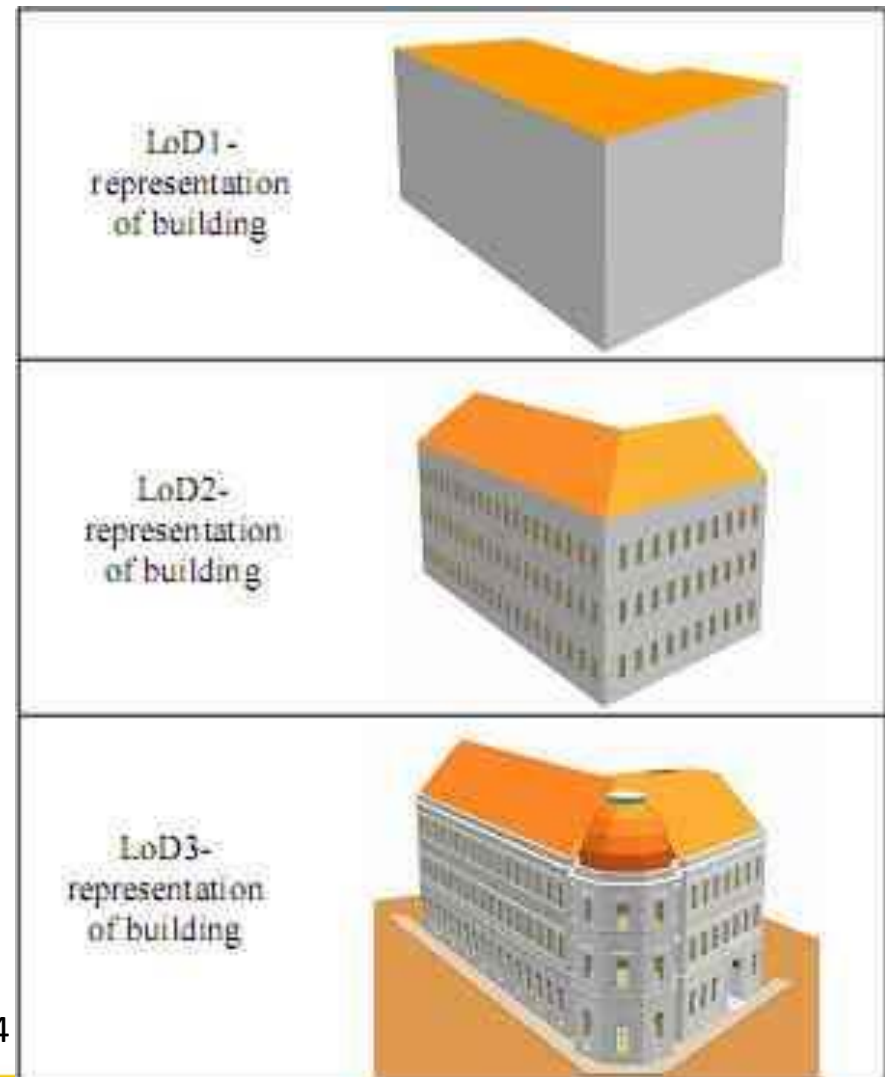
- Existing topological techniques hardly able to provide correct relationships of 3D objects e.g. 3D buildings with its surroundings.
- Current solutions hardly able to integrate/provide 2D and 3D information seamlessly.
- Different LoDs have different semantic information, thus, create redundancy in storing and updating the information.
- A framework for most use-cases e.g. utility, cadaster and environmental modelling.
- No ready commercial solutions on unified topology and semantic with different geometry (LoDs).

Previous research works

- TOWARDS UNIFIED 3D CITY MODELS: smooth integration of subsurface objects



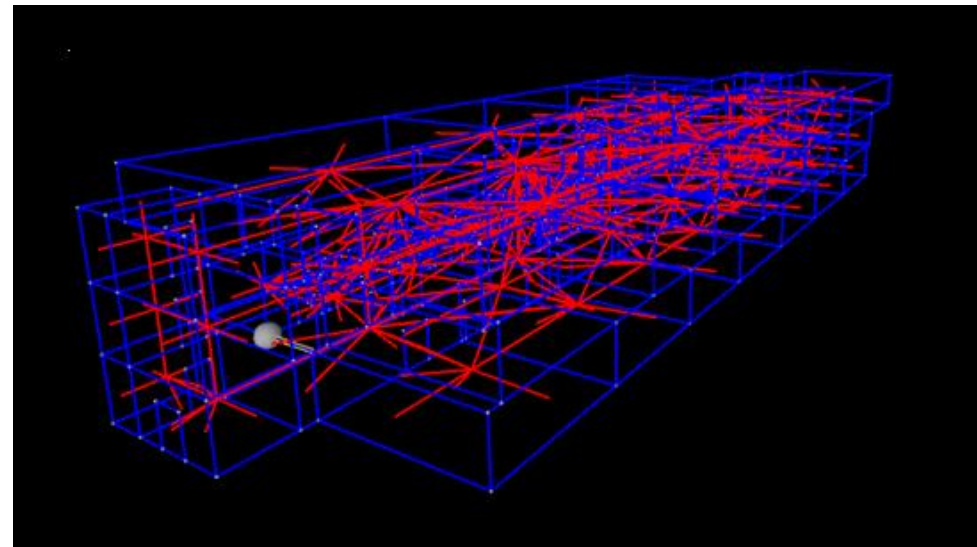
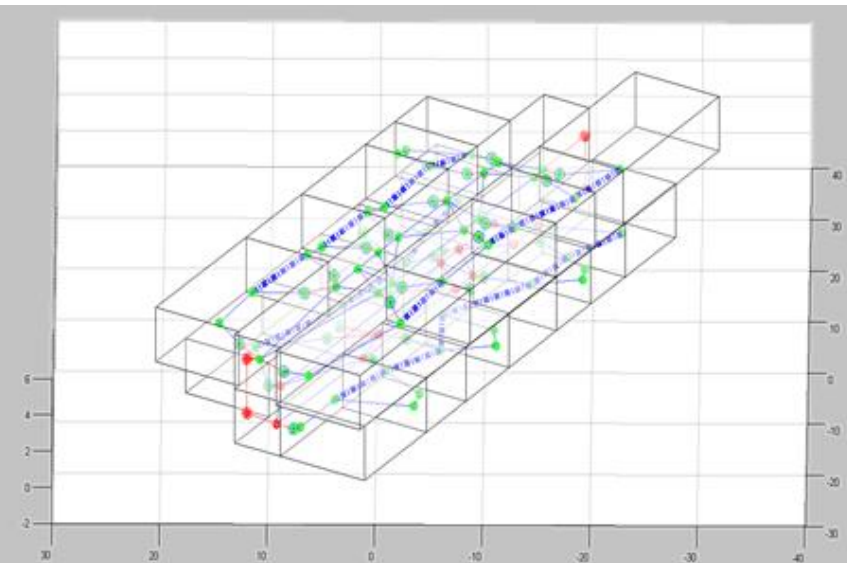
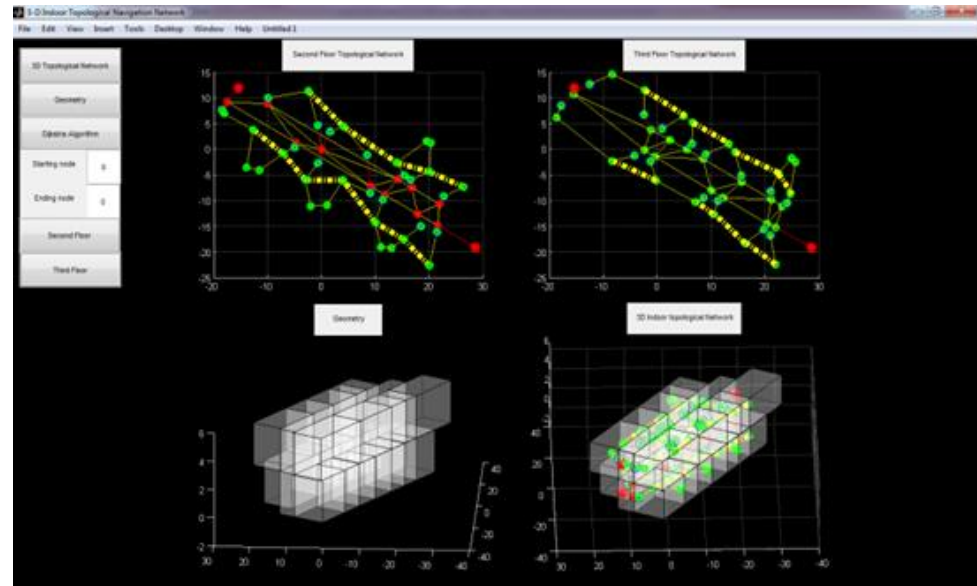
T. H. Kolbe, G. Gröger, 2004



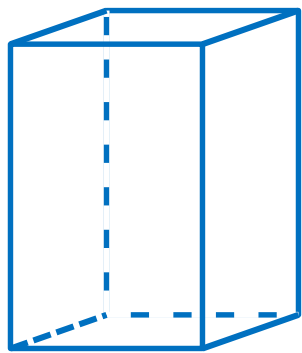
Previous research works

- Data structure (Dual Half Edge, Half Edge)
 - Navigational network (Topological graph)
 - Geometry, semantic and topology

Jamali et al. (2017)



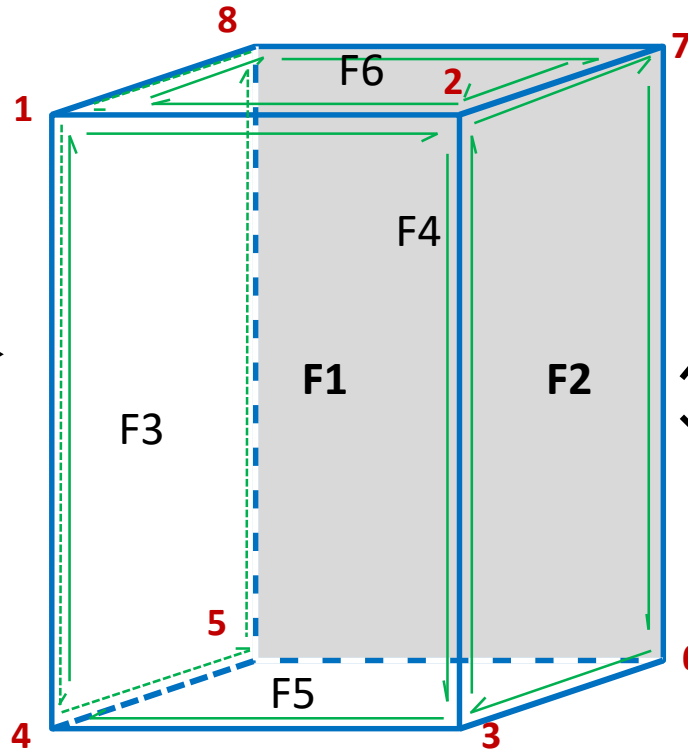
Simple & Basic Topology (derived from the geometry)



Simple object
(geometry)



Constructed topology:



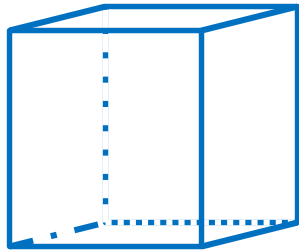
Simple object
(geometry + simple topology)
Half Edge (HE) data structure




Node	Coordinate
1	X_1, Y_1, Z_1
2	X_2, Y_2, Z_2
3	X_3, Y_3, Z_3
4	X_4, Y_4, Z_4
5	X_5, Y_5, Z_5
6	X_6, Y_6, Z_6
7	X_7, Y_7, Z_7
8	X_8, Y_8, Z_8

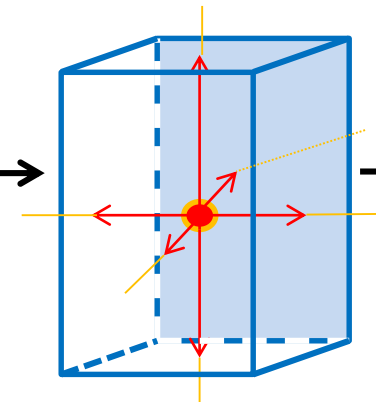
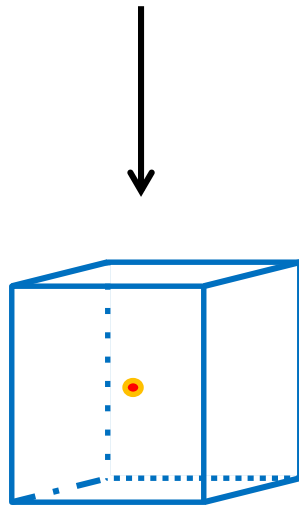
Face	Order
F1	1,2,3,4
F2	3,2,7,6
F3	1,8,5,4
F4	5,6,7,8
F5	3,6,5,4
F6	2,1,8,7

Existing Approach: (Complete topology) e.g. Dual Half Edge (DHE) data structure

Simple geometry (e.g. a room)

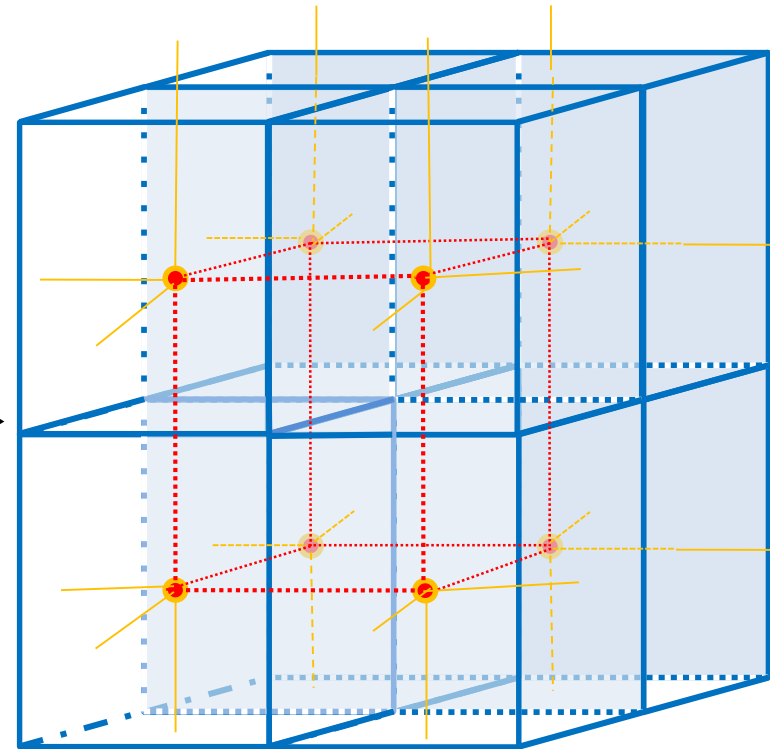


-  Dual vertex/node
-  Dual topology of a cell
-  Dual for external shell



Geometry and the dual
for simple cell

Geometry and the dual
for a complex cell (e.g. a building)



Existing Approach (cont.): Dual Half Edge (DHE) data structure

Advantages

- Designed especially for indoor navigation.
- Utilize the potential of internal and external topology.
- Capable to store details information and semantic either in primal (geometry) or dual (topology).

Disadvantages

- Expensive in storage, time-graphic consuming in rendering process.
- Complex and rigid structure – difficult to integrate with 2D and other 3D data structures.

The Proposed Approach

A unified topological structure with a centralized existing geometrical data for multi-level information retrieval with following features:

1) 3D simplified topological data structure

- Unified 2D and 3D topological data structure that able to access attribute/semantic information
- Attribute and semantic information can be stored in topology.
- Less storage, graphic and time required for rendering

2) Able to integrate multiple LoDs (geometry) to extract semantic and information using topological structure

3) Able to integrate 2D and 3D model into a single topological structure

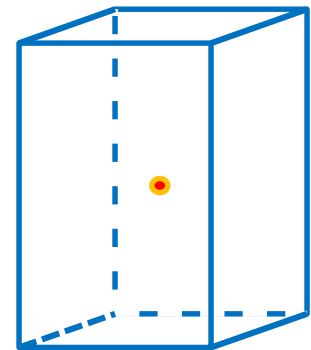
Proposed Concept :

Unified data structure for 2D & 3D with LoDs.

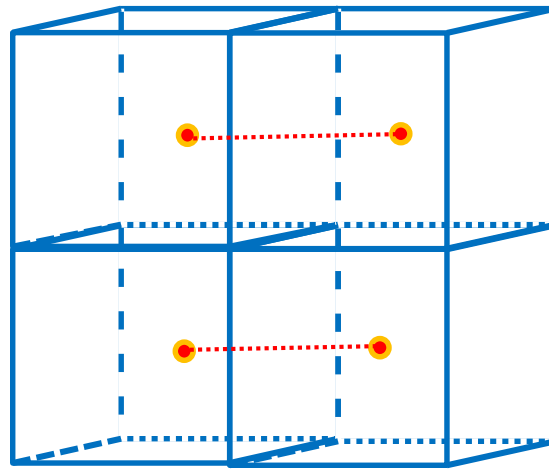
Proposed Concept :

1) 3D Simplified data structure

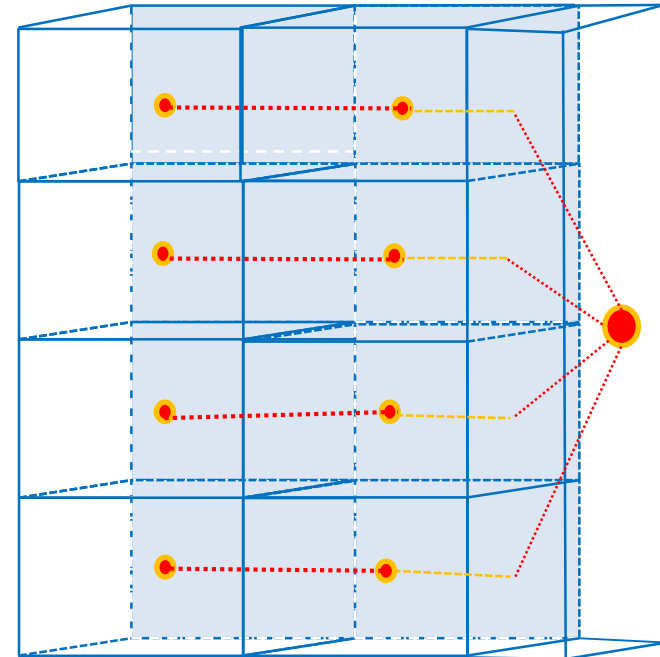
- Geometry (Primal)
- Dual vertex/node
- Dual topology of a cell
- Dual for external shell



Simple geometry
(e.g. a block)



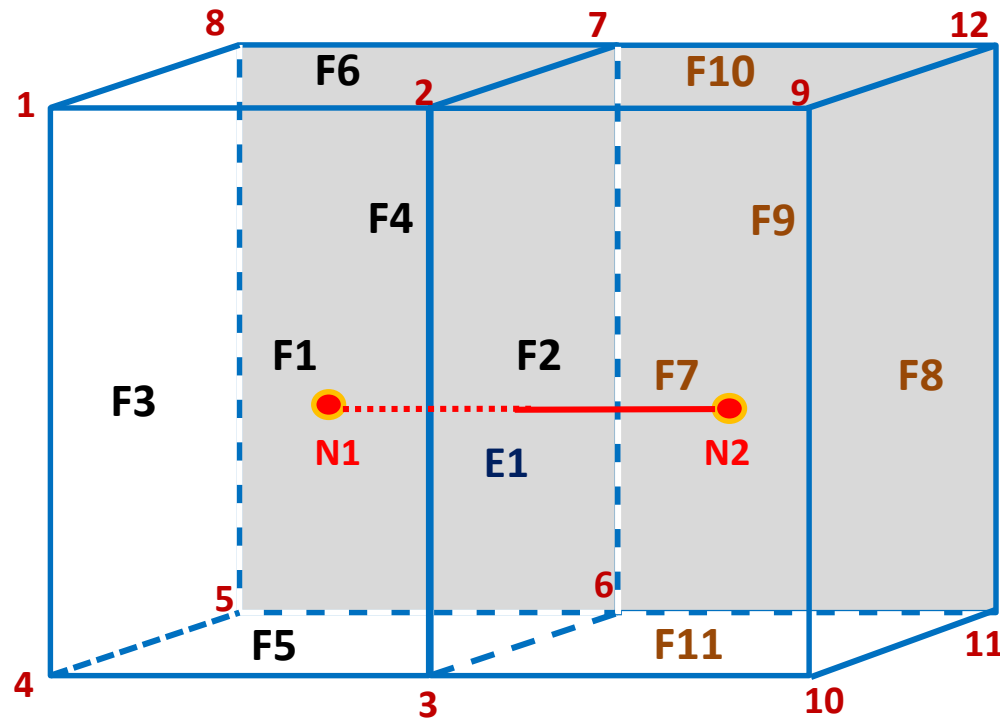
Simple Building
(e.g. with four houses)



A Building
(e.g. four floors -2 houses each and a connecting stair)

Proposed Concept (Cont.):

Unified data structure for 2D & 3D with LoDs.



Simple 3D topological graph
(e.g. two rooms)

Geometry tables:

- 1) Node
- 2) Edge/Line
- 3) Face/polygon

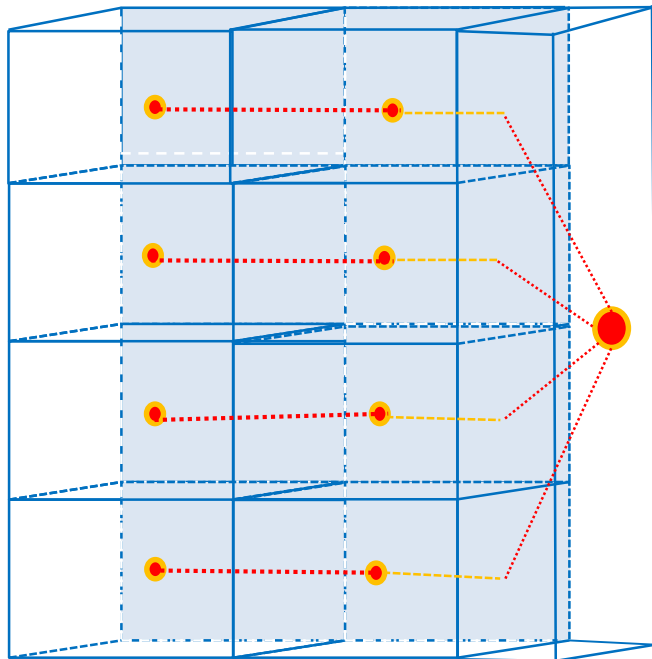
+

Topological structure (generated from the geometry):

TopGraph	Face	A	B	A-B	B-A
E1	F2	N1	N2	Y	Y
...
E2	F2	N2	N1

Topological structure

Illustration

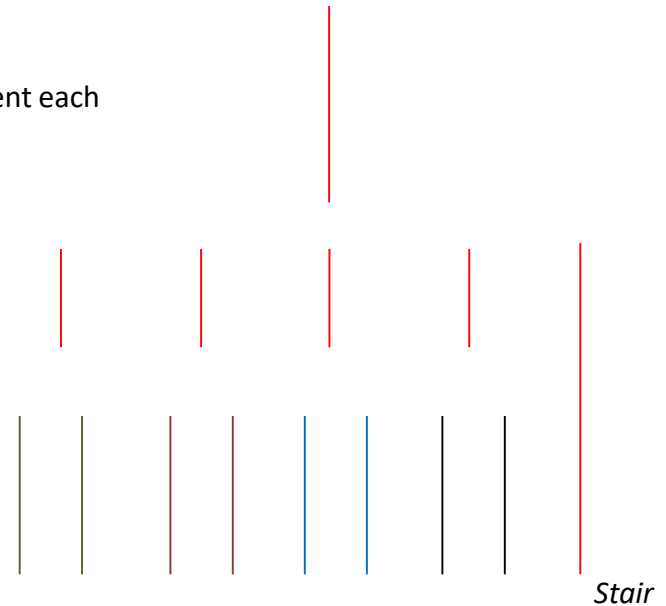


A Building
(e.g. four floors -2 houses each and a connecting stair)

Block
(single vertex represent each LoD)

Floor
(graph/edge)

Unit/house
(vertices)



Proposed Concept : 3D Simplified data structure (Topological & Geometrical tables)

Topology tables

1) Topology Graph

TopGraph	Face	A	B	A-B	B-A
E1	F2	N1	N2	Y	Y
...
E2	F2	N2	N1		

2) Topology Node

TopNode	TopGraph	Cell_Name	Owner	Volume (m3)
N1	E1	CEO Room	Company A	45.5
N2	E1	Meeting Room	Company A	60.25
....
....
N....	E...	Office	Company B

Geometry tables

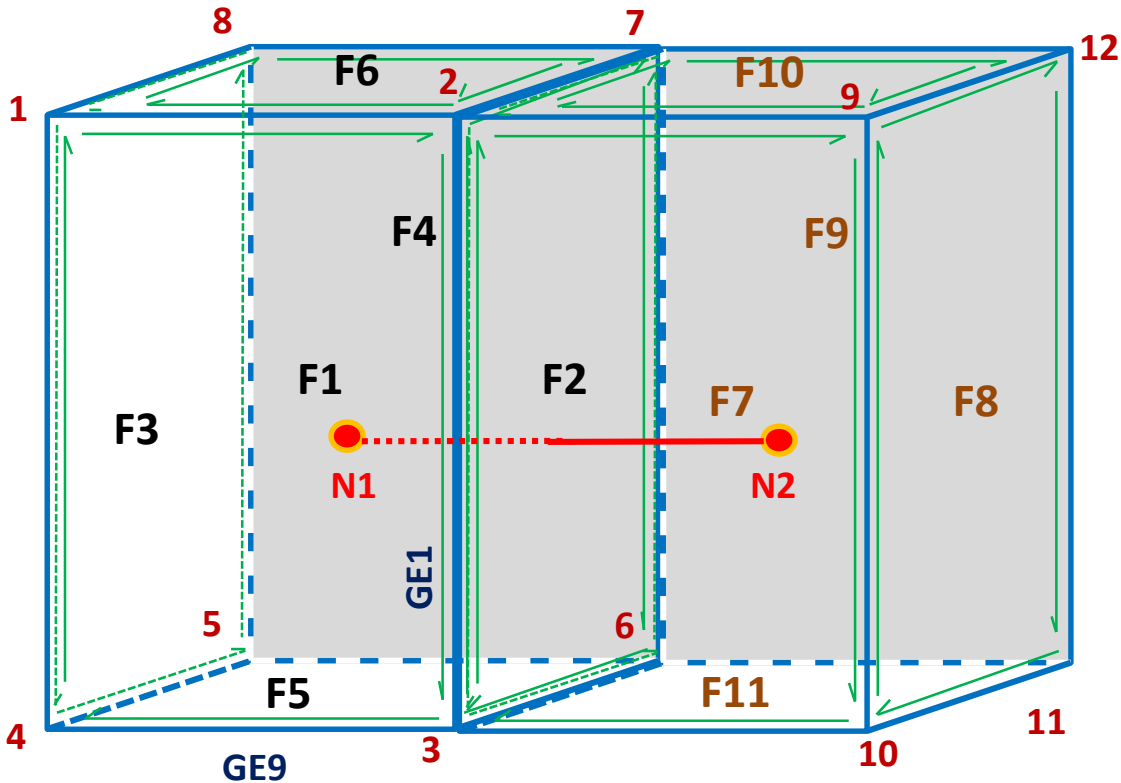
Node	Coordinate
1	X ₁ , Y ₁ , Z ₁
2	X ₂ , Y ₂ , Z ₂
3	X ₃ , Y ₃ , Z ₃
4	X ₄ , Y ₄ , Z ₄
...
...
11	X ₁₁ , Y ₁₂ , Z ₁₂
12	X ₁₂ , Y ₁₂ , Z ₁₂

Face	FaceOrder	Structure	Accessibility
F1	1,2,3,4	Wall	Yes, door
F2	3,2,7,6	Wall	Yes, door
F3	1,8,5,4	Wall	No
F4	5,6,7,8	Wall	No
F5	3,6,5,4	Floor	No
F6	2,1,8,7	Roof	No
F7	2,9,10,3	Wall	Yes, door
F8	10,9,12,11	Wall	No
F9	7,6,11,12	Wall	No
F10	2,7,9,12	Wall	No
F11	10,3,6,11	Floor	No

Proposed Approach: Unified data structure for 2D, 3D and LoDs.

Proposed Concept :

2) Flexible and Easy to integrate with other available 2D and 3D data structure



Face	FaceOrder	Structure	Accessibility
F1	1,2,3,4	Wall	Yes, door
F2	3,2,7,6	Wall	Yes, door
F3	1,8,5,4	Wall	No
F4	5,6,7,8	Wall	No
F5	3,6,5,4	Floor	No
F6	2,1,8,7	Roof	No
F7	2,9,10,3	Wall	Yes, door
F8	10		
F9	7,6		
F10	2,7		
F11	10		

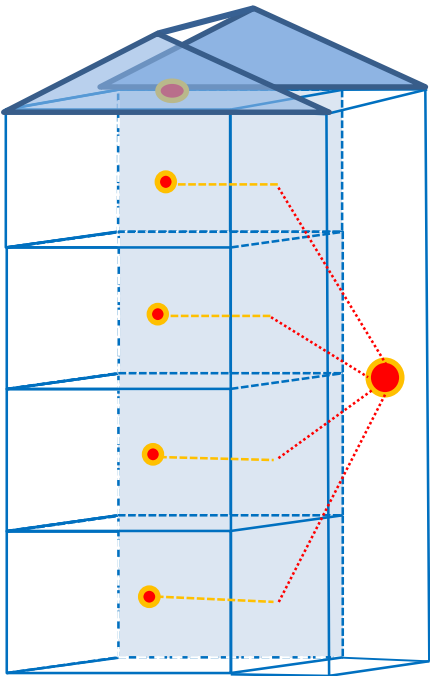
Edge	NodeA	NodeB	Face
GE1	2	3	F1
GE1	3	2	F1
GE3	2	3	F2
GE4	3	3	F2
...	1...	...	
GE...			

Proposed Approach: Unified data structure for 2D, 3D and LoDs.

Proposed Concept :

3) Capable to integrate multiple LoDs (Geometry) to extract semantic and information using topological structure

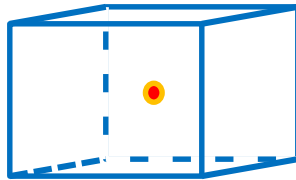
LoD 3 (example)



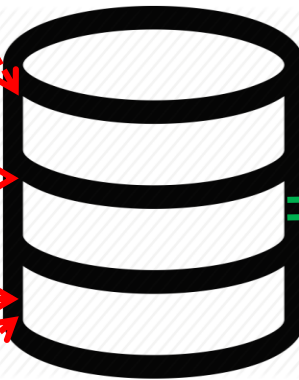
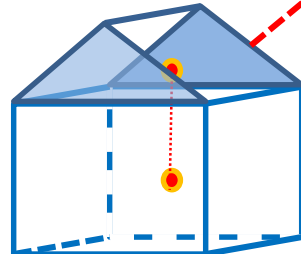
LoD 0 (2D drawing)



LoD 1

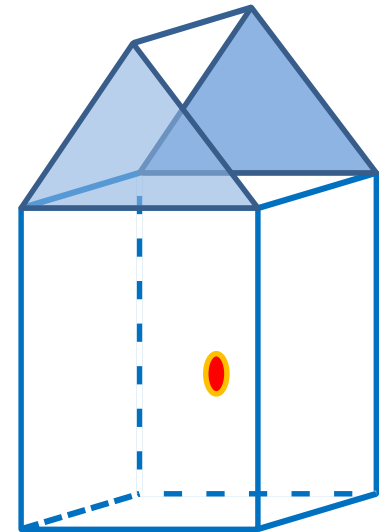


LoD 2



3D Topological
LoDs Database

Visualization: LoD2



Proposed Concept :

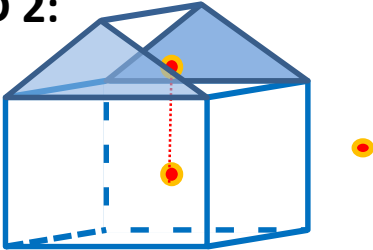
Capable to integrate multiple LoDs (Geometry) to extract semantic and information using topological structure

Analysis/Query for other LoD information/semantic

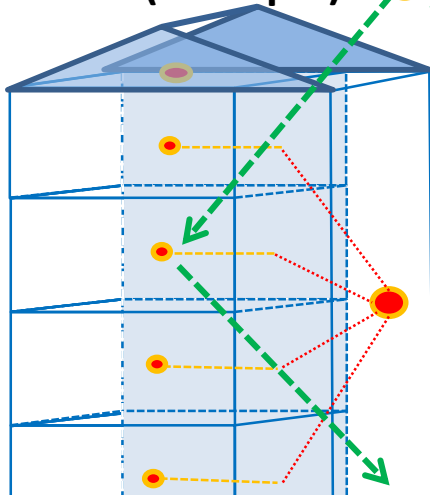
LoD0 ●

LoD1 ●

LoD 2:



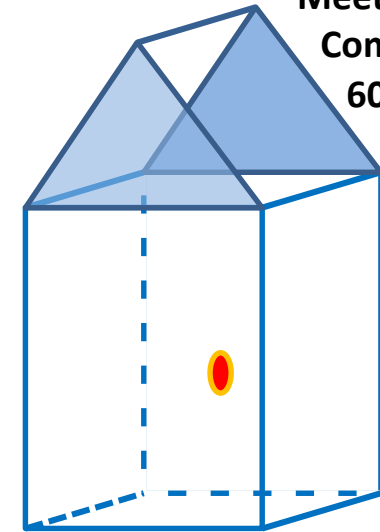
LoD 3 (example)



3D Geometrical & Topological
LoDs Database

Visualization: LoD2

Information LoD3..
L2, Room name?



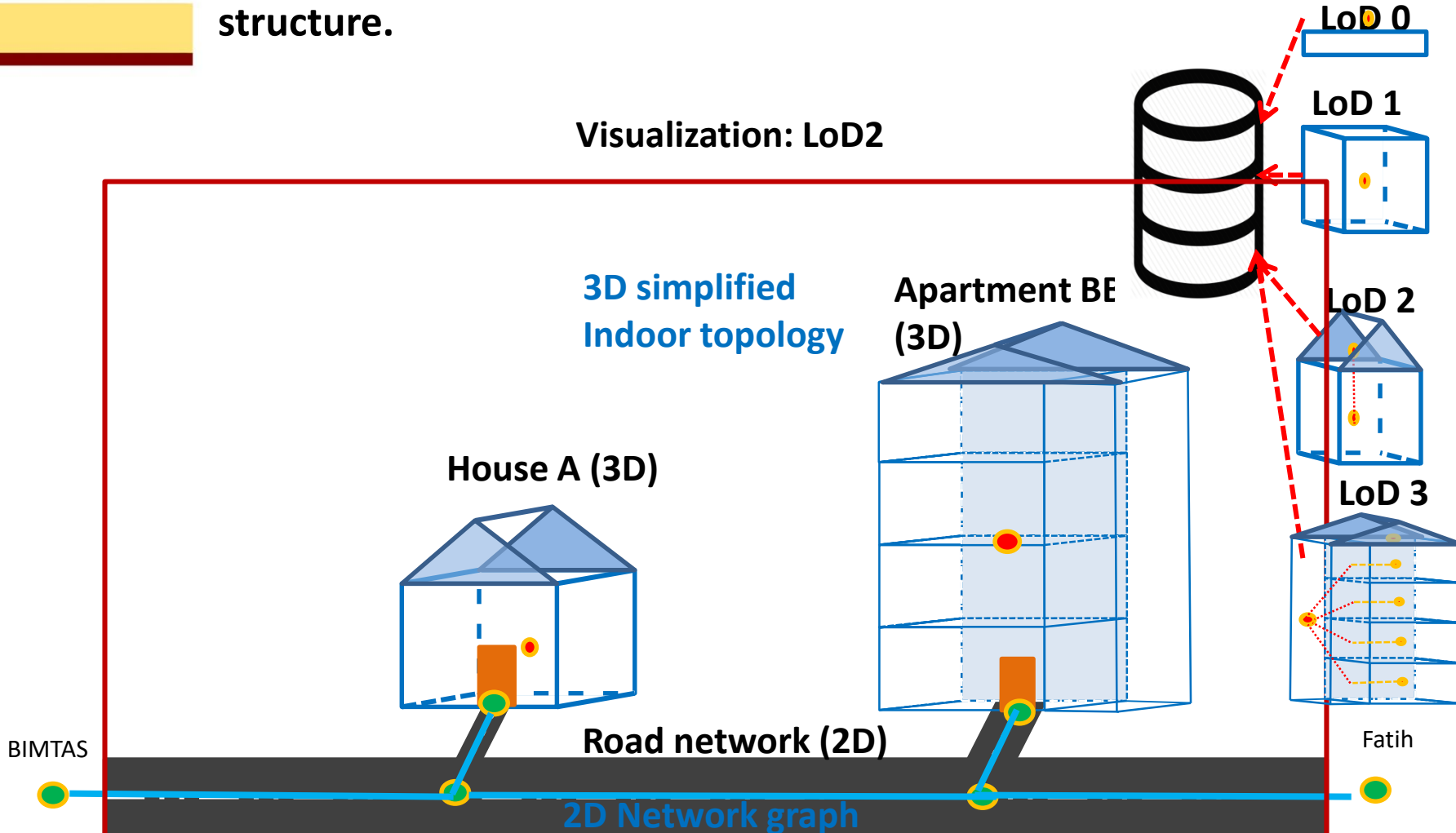
Meeting room,
Company A,
60.25 m³

TopNode	TopGraph	Cell_Name	Owner	Volume (m3)	e.t.c
N1	E1	CEO Room	Company A	45.5
N2	E2	Meeting Room	Company A	60.25

Proposed Concept :

Capable to integrate 2D and 3D model into a single topological structure.

Visualization: LoD2



e.g. Analysis:

- 1) **Query a address: Unit no 15, Floor 2, Apartment BB, road BIMTAS-Fatih? = YES.**
- 2) **Navigation route, 2D road → 3D indoor? = YES**
- 3) **House owner/information/tenant number/type of house/geometry?= YES**

Potential applications

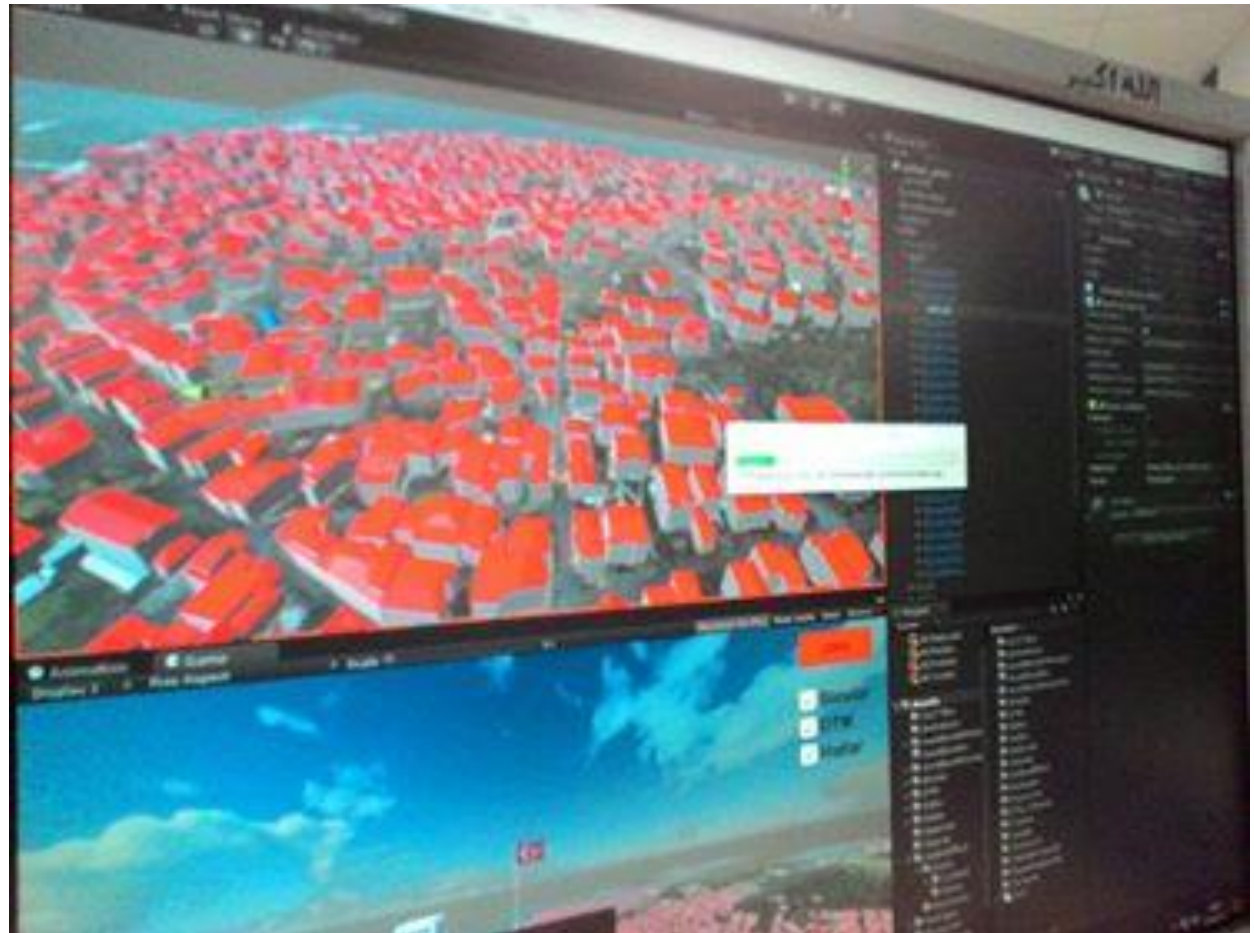
- Utility (cables, pipes, etc)
- 3D navigational distance between two buildings.
- 3D Cadaster
- Indoor network navigation
- 3D VR Gaming

Potential applications (cont.)

**3D Underground utility:
Gas pipeline / Cable.**

**BIMTAS Unity:
DSM +
Building LoD2 +
underground utility**

**Case Study:
Princess Island**



Proposed Approach/Solution: Unified data structure for 2D, 3D and LoDs.

3D Underground utility mapping: Gas/Cable

Visualization: LoD2

Benefits for utility:

1. Unified model (digital & updated road-building)
2. 3D and 2D intersection analysis
3. Effected owner and many more details information

3D simplified
Indoor topology

Apartment BB
(3D)

House A (3D)

Road network (2D)

2D Network graph

DTM
(Surface)

3D underground topology

Concluding remarks

- Some limitations of the current multi-representation model especially on visualization and attribute retrieval from other LoDs.
- A conceptual framework towards unified 2D and 3D LoDs topological modelling.
- The model has the following features:
 - Less storage
 - Access semantic, attribute and geometry information
 - Integrate multiple LoDs (Geometry) for semantic and information extraction
- The model has yet undergo validation process.

Acknowledgment

- BIMTAS of Istanbul Buyuksehir Belediyesi (IBB)
 - Datasets
 - Assistance

Thank you!

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