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

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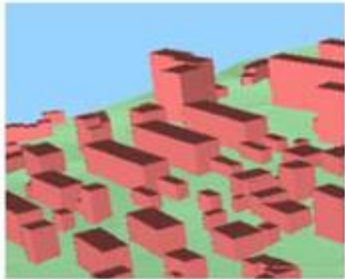- Potential applications
- Concluding remarks

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Introduction
(LoD)
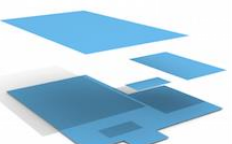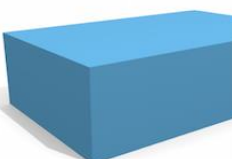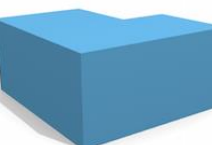
LoD 0   LoD 1   LoD 2   LoD 3   LoD 4

- Each LoD has it 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)?

Biljecky (2017)

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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

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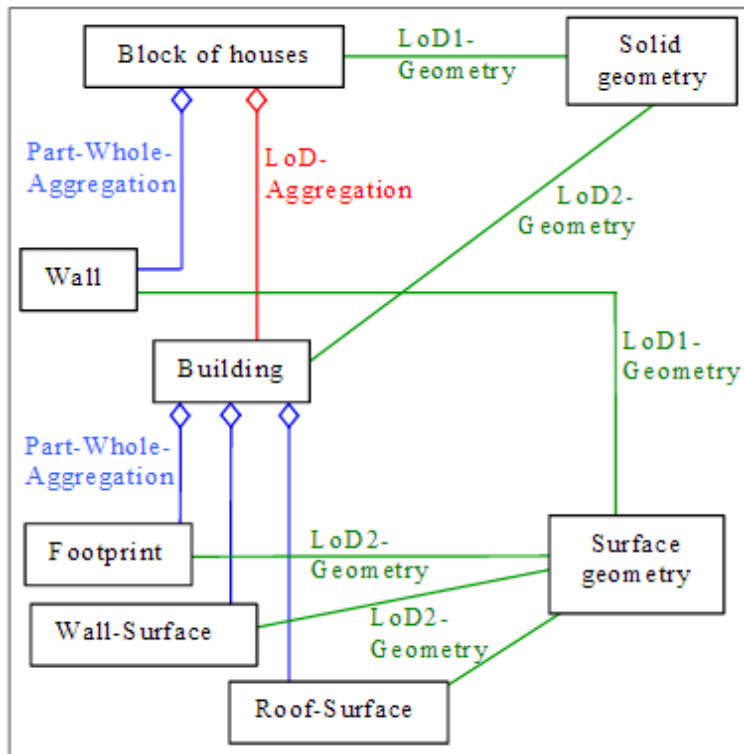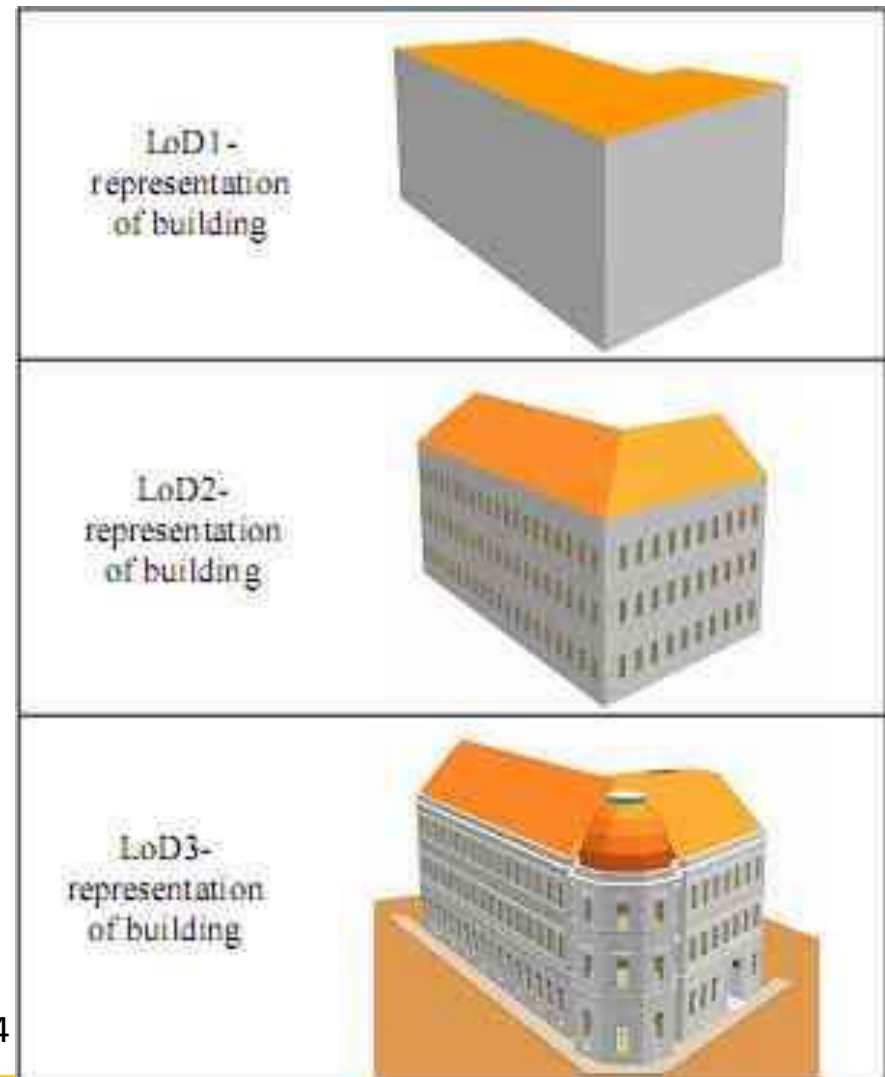
Previous research works

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

  Jamali et al. (2017)

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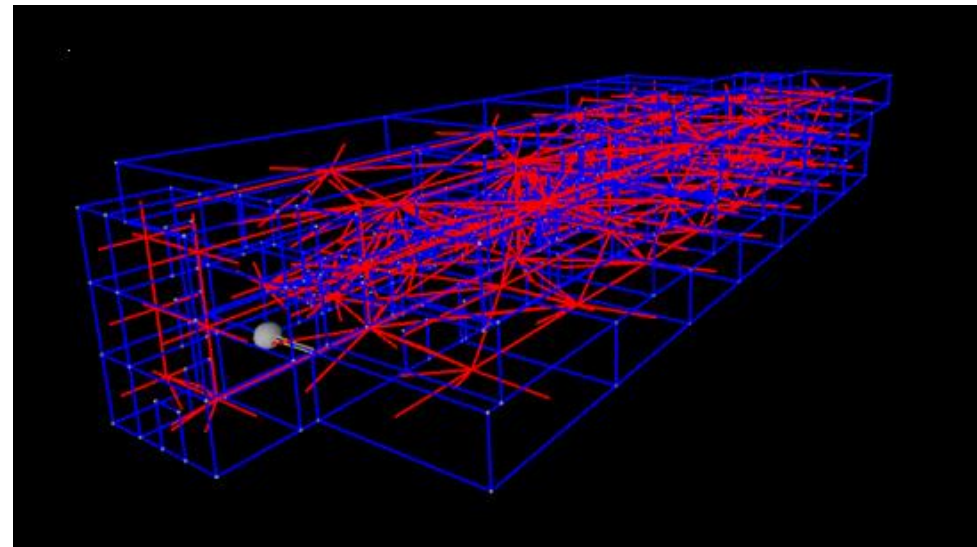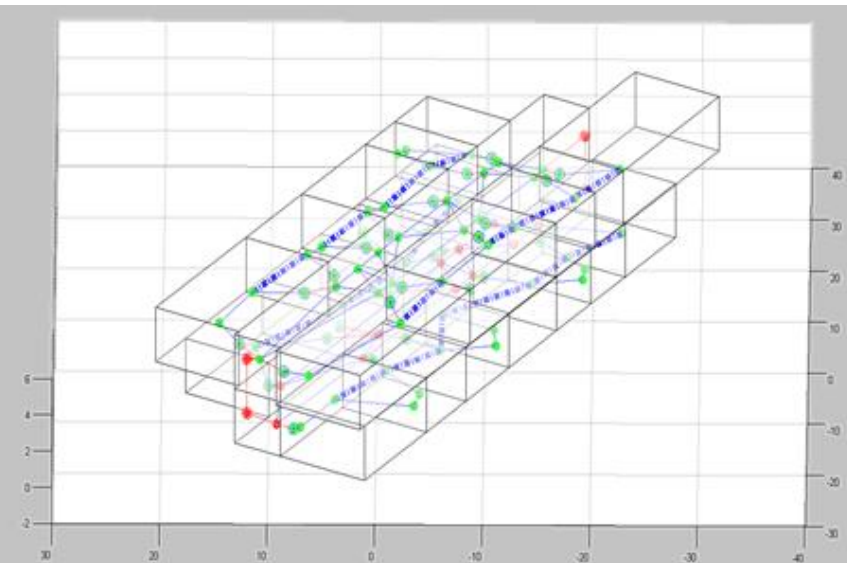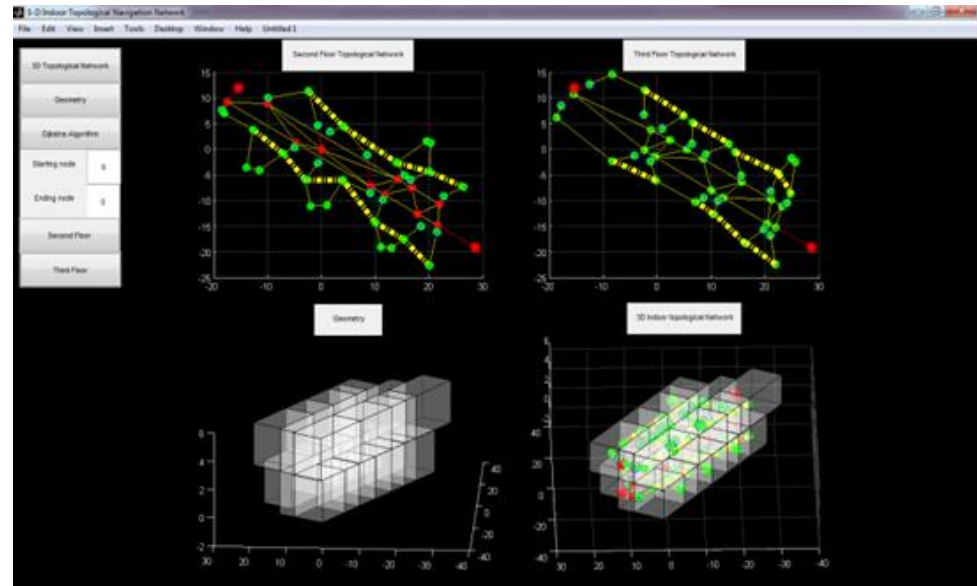
Simple & Basic Topology
(derived from the geometry)
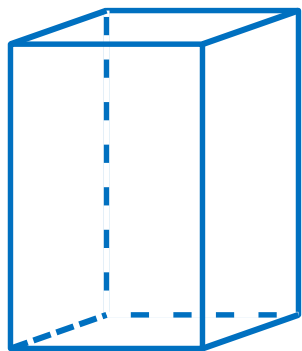
Constructed topology:

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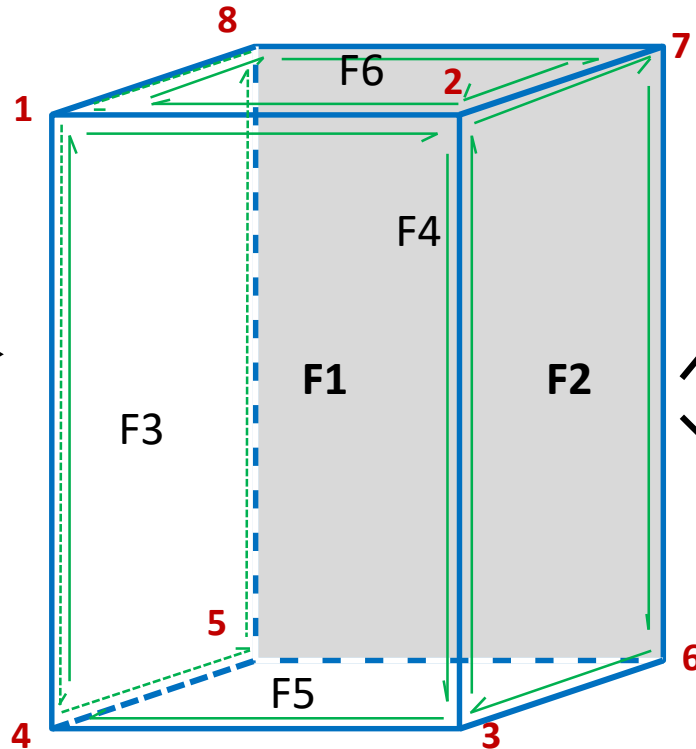
Simple object
(geometry + simple topology)
Half Edge (HE) data structure

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

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

Simple geometry (e.g. a room)
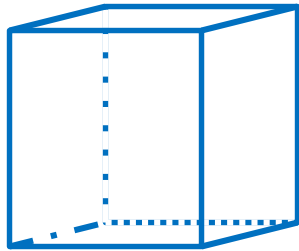
Dual vertex/node
Dual topology of a cell
Dual for external shell

Geometry and the dual
for a complex cell (e.g. a building)
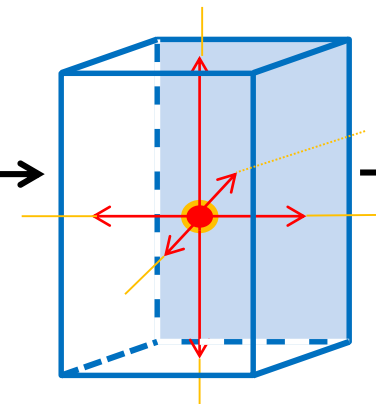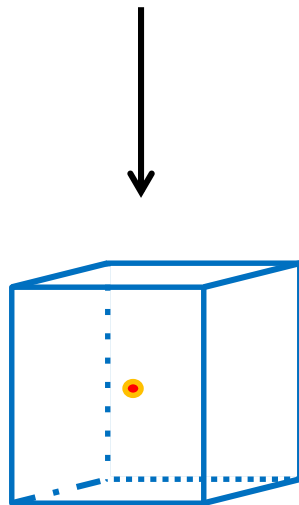
Geometry and the dual
for simple cell
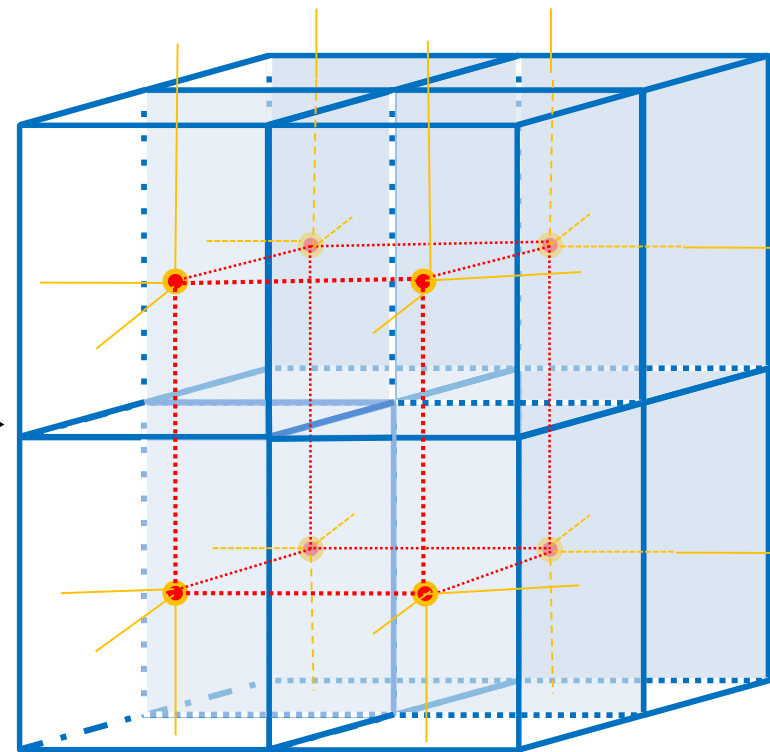
Existing Approach (cont.):
Dual Half Edge (DHE) data structure

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.

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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

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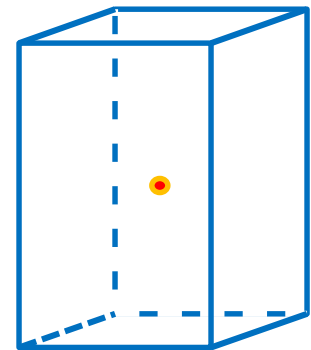
Simple geometry
(e.g. a block)
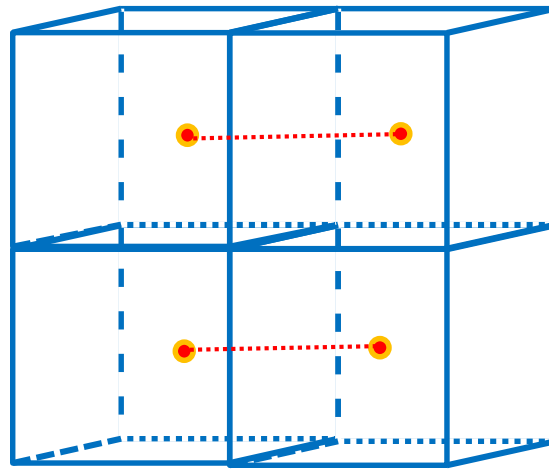
Simple Building
(e.g. with four houses)
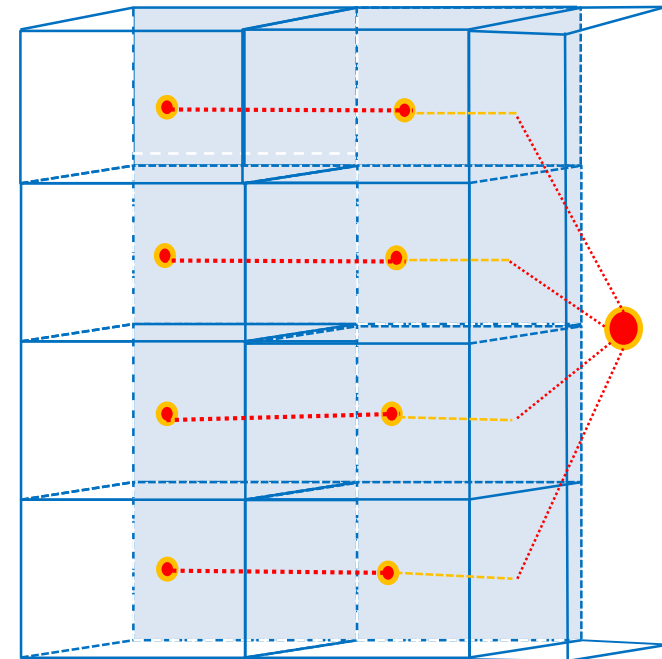
A Building
(e.g. four floors -2 houses each and a
connecting stair)

Proposed Concept (Cont.):
Unified data structure for 2D & 3D with LoDs.
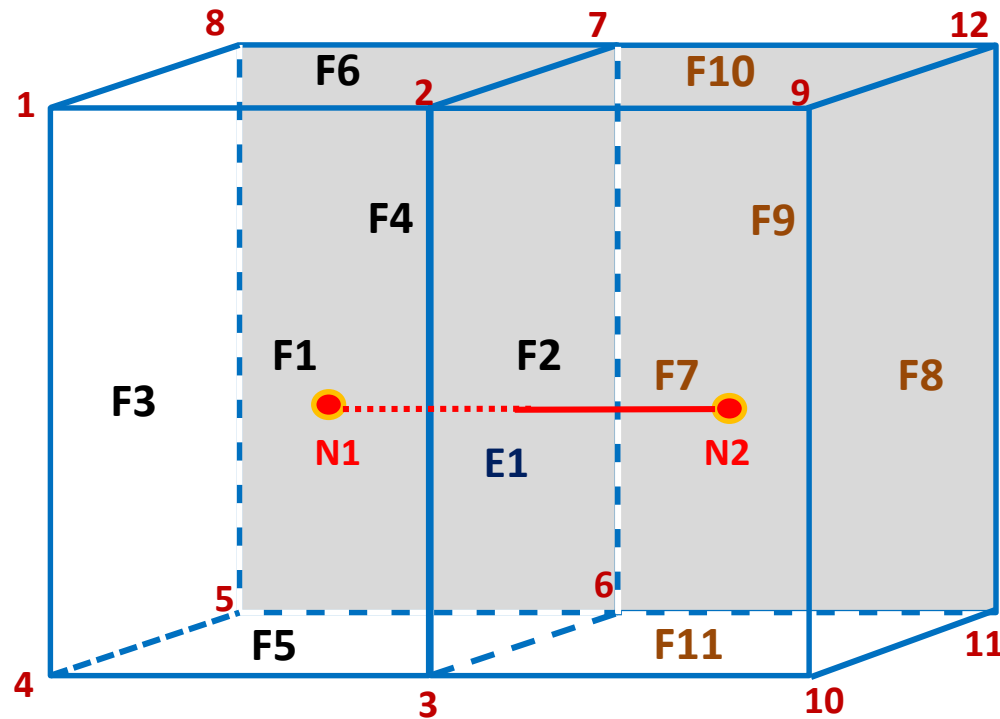
Simple 3D topological graph
(e.g. two rooms)

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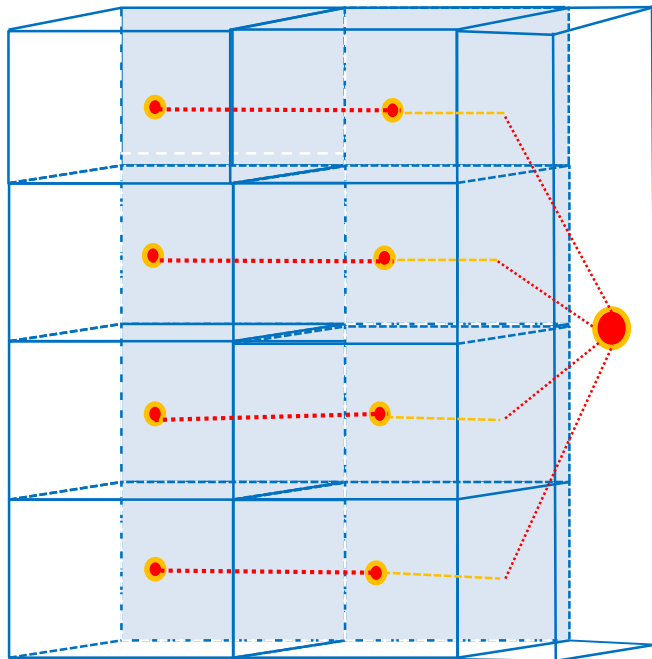
A Building
(e.g. four floors -2 houses each and a connecting stair)

Block
(single vertex represent each LoD)

Floor
(graph/edge)

Unit/house
(vertices)

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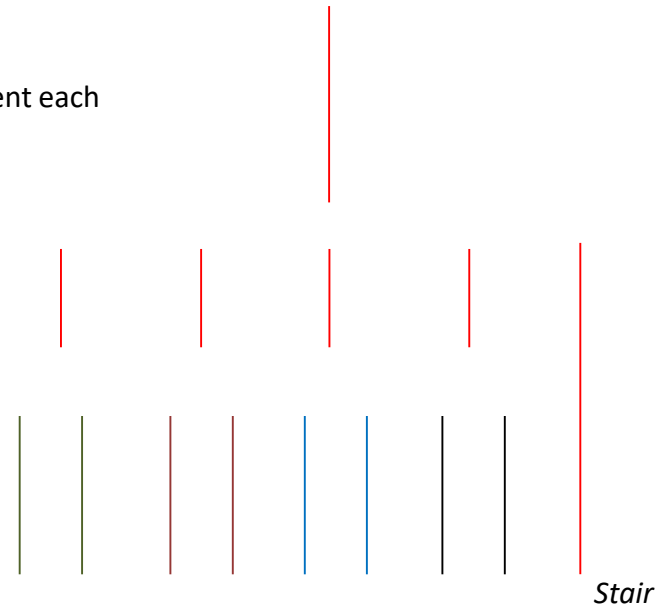
Proposed Concept :
3D Simplified data structure
(Topological & Geometrical tables)

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}

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	......

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

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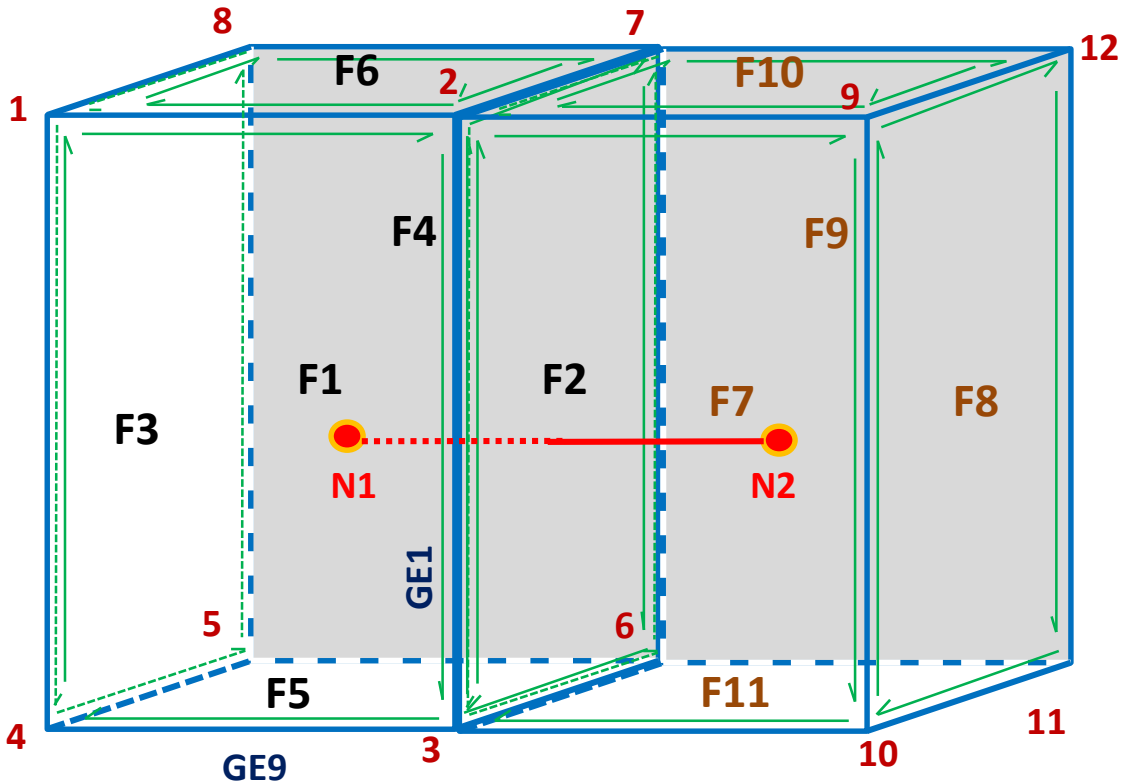
Face	FaceOrder	Structure	Accessibility
F1	1,2,3,4	Wall	Yes, door
F2	3,2,7,6	Wall	Yes, door
F3	1,8,5,4	Wall	No
F4	5,6,7,8	Wall	No
F5	3,6,5,4	Floor	No
F6	2,1,8,7	Roof	No
F7	2,9,10,3	Wall	Yes, door
F8	10		
F9	7,6		
F10	2,7		
F11	10		

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)
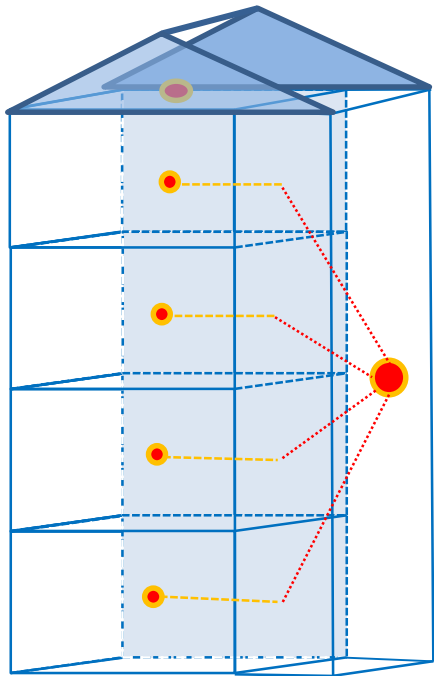
Visualization: LoD2

LoD 1

LoD 2

3D Topological LoDs Database
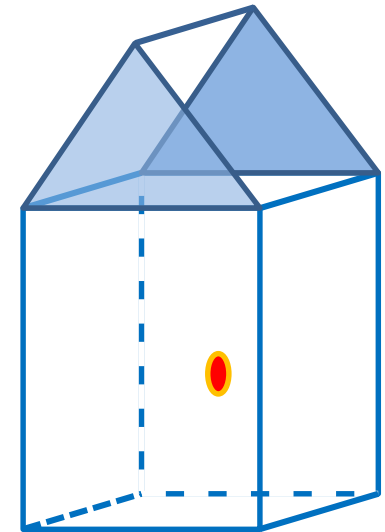
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Proposed Concept :

Capable to integrate multiple LoDs (Geometry) to extract semantic and information using topological structure
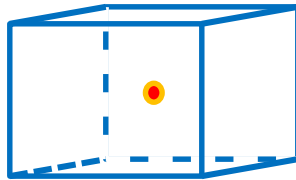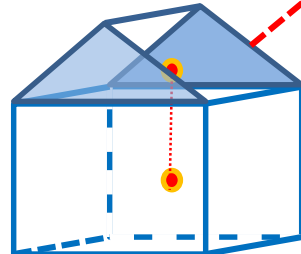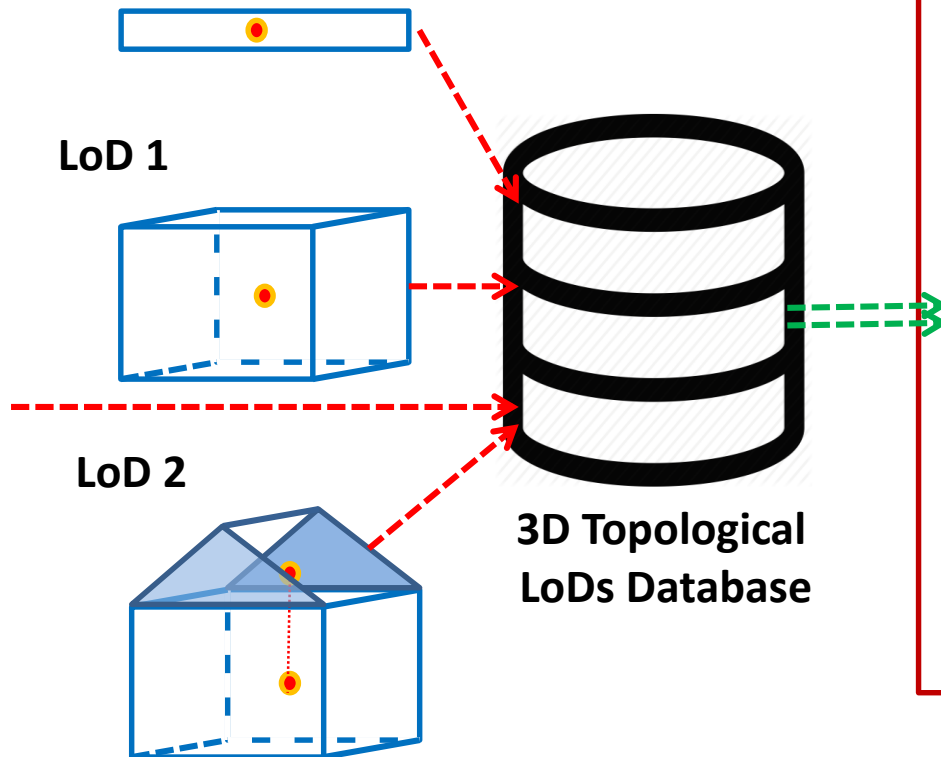
Analysis/Query for other LoD information/semantic

LoD0

LoD1

LoD 2:

LoD 3 (example)

Visualization: LoD2

Information LoD3..
L2, Room name?
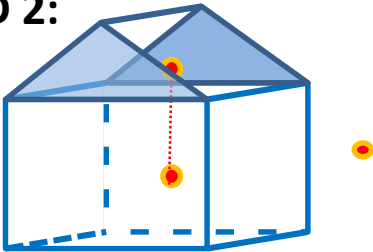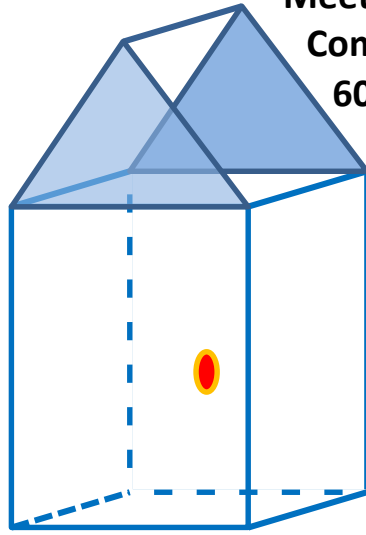
Meeting room, Company A, 60.25 m³
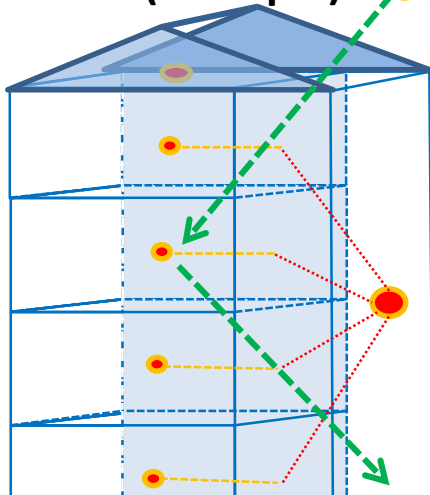
3D Geometrical & Topological LoDs Database

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	.....

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

Visualization: LoD2

3D simplified Indoor topology

Apartment BB (3D)

House A (3D)

Road network (2D)

BIMTAS

2D Network graph

Fatih

LoD 0
LoD 1
LoD 2
LoD 3
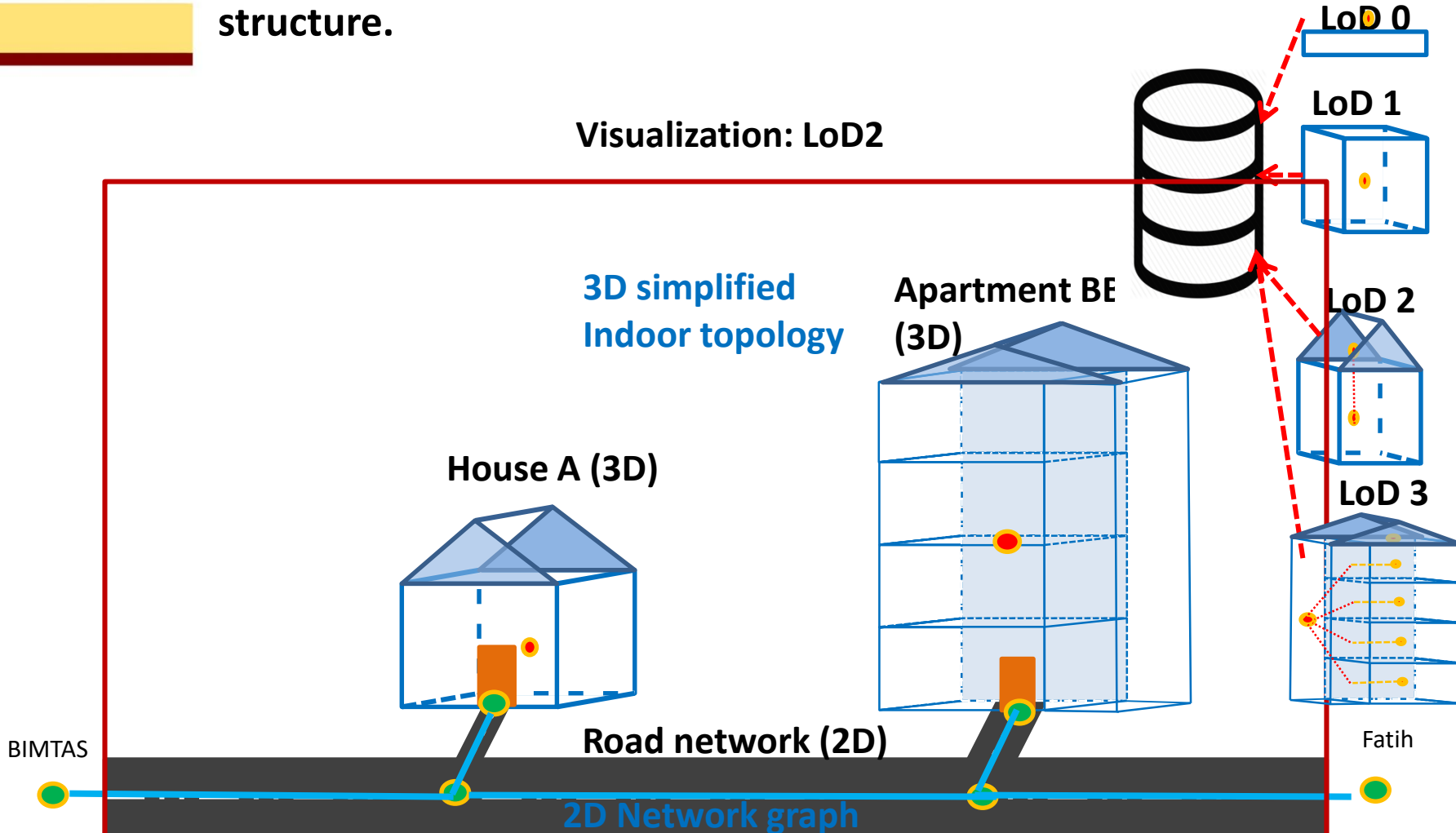
e.g. Analysis:
1) **Query a address**: Unit no 15, Floor 2, Apartment BB, road BIMTAS-Fatih? **= YES.**
2) **Navigation route, 2D road → 3D indoor? = YES**
3) **House owner/information/tenant number/type of house/geometry?= YES**

Potential applications

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

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Potential applications (cont.)

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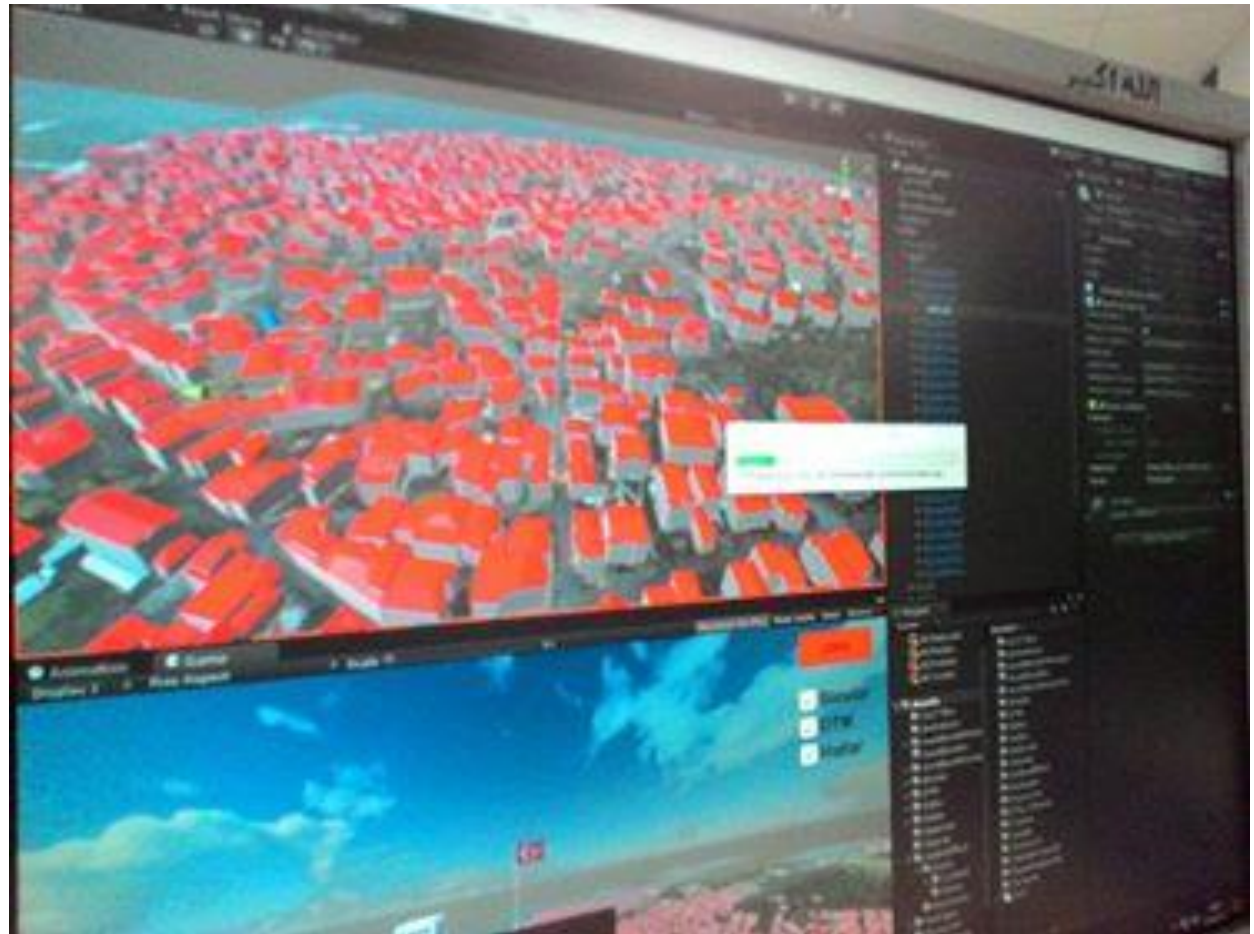**Gas pipeline / Cable.**

BIMTAS Unity:
DSM +
Building LoD2 +
underground utility

Case Study:
Princess Island

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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)

BIMTAS

Fatih

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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