



Design and Development of a 3D Cadastral System Prototype based on LADM and 3D Topology

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Overview



1. Introduction

2. 3D cadastral model in LADM and the prototype

3. Body construction based on SketchUp

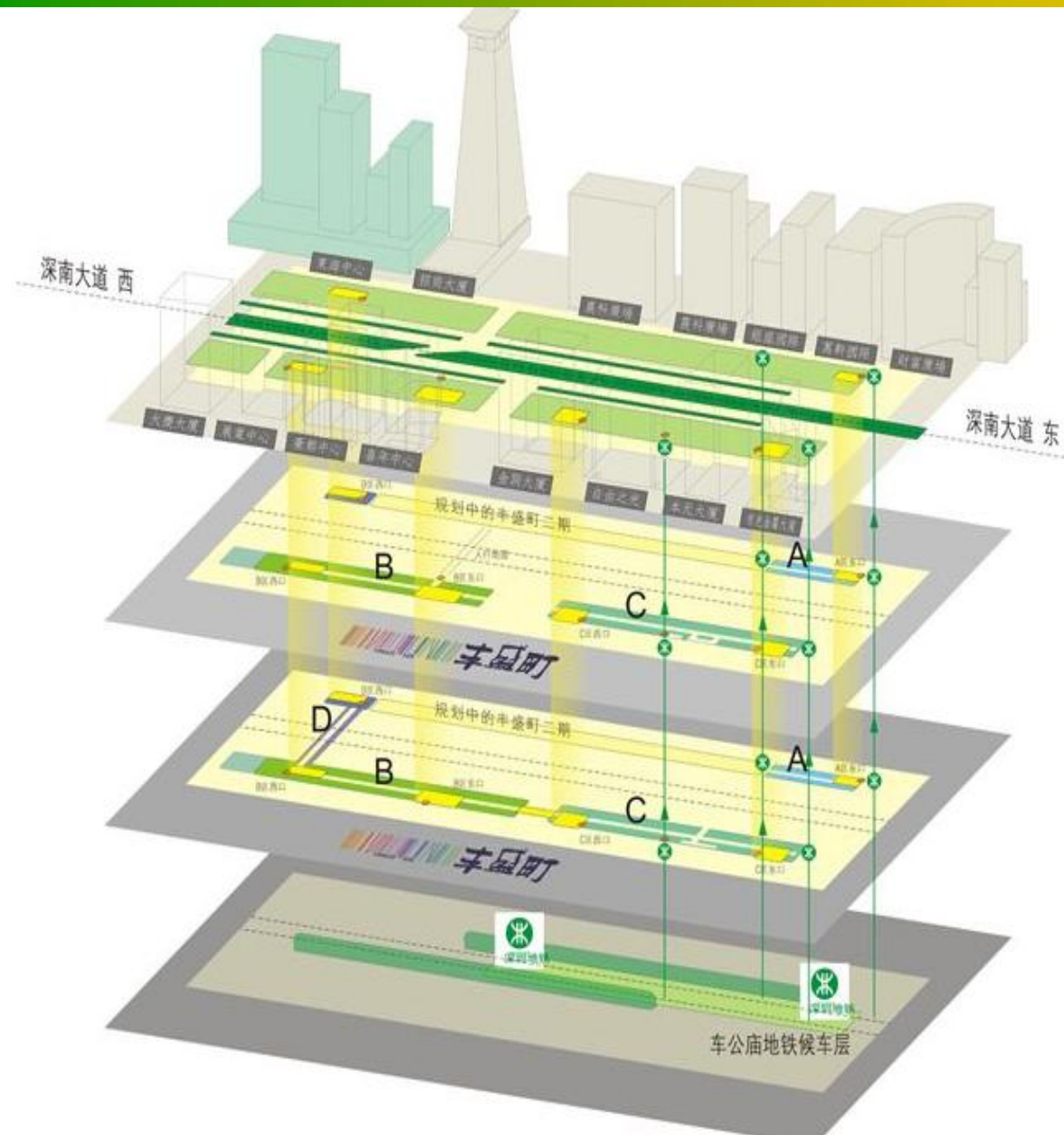
4. Prototype system

5. Conclusion and prospective outlook

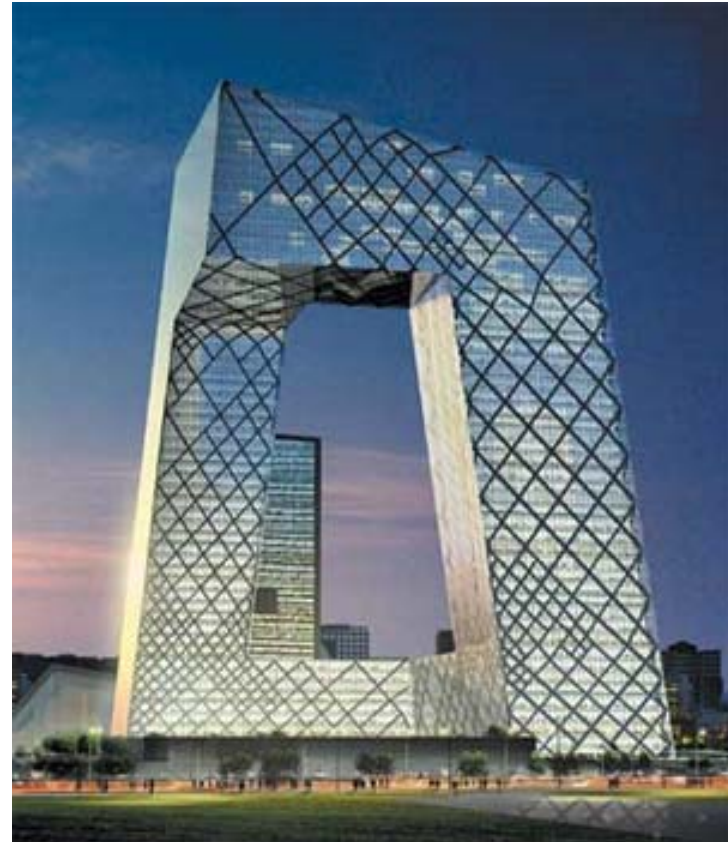




Multi-layer land use









1.Introduction

- The development of land use has promote the land parcels to be **subdivided in three dimensional (3D) space** according to certain property rights.
- To manage 3D space becomes an urgent task for the government, so we should **mode these 3D** space with geometric representation as “solids”.
- The cadastral application requires the **operations** on the solid objects to manage, operate and analyse the 3D parcels.

Three aspects should be clearly described :

- 1) the **precise geometric model** that describe the shape and geographic location of various 3D parcels, mainly based on **sets of boundary faces**.
- 2) **solid model** that indicates all its boundary faces with orientation to present the corresponding 3D parcel object.
- 3) the **topological relationship** that encode all the information among the solids/parcels to keep the consistence of the objects' geometries.

Overview



1. Introduction

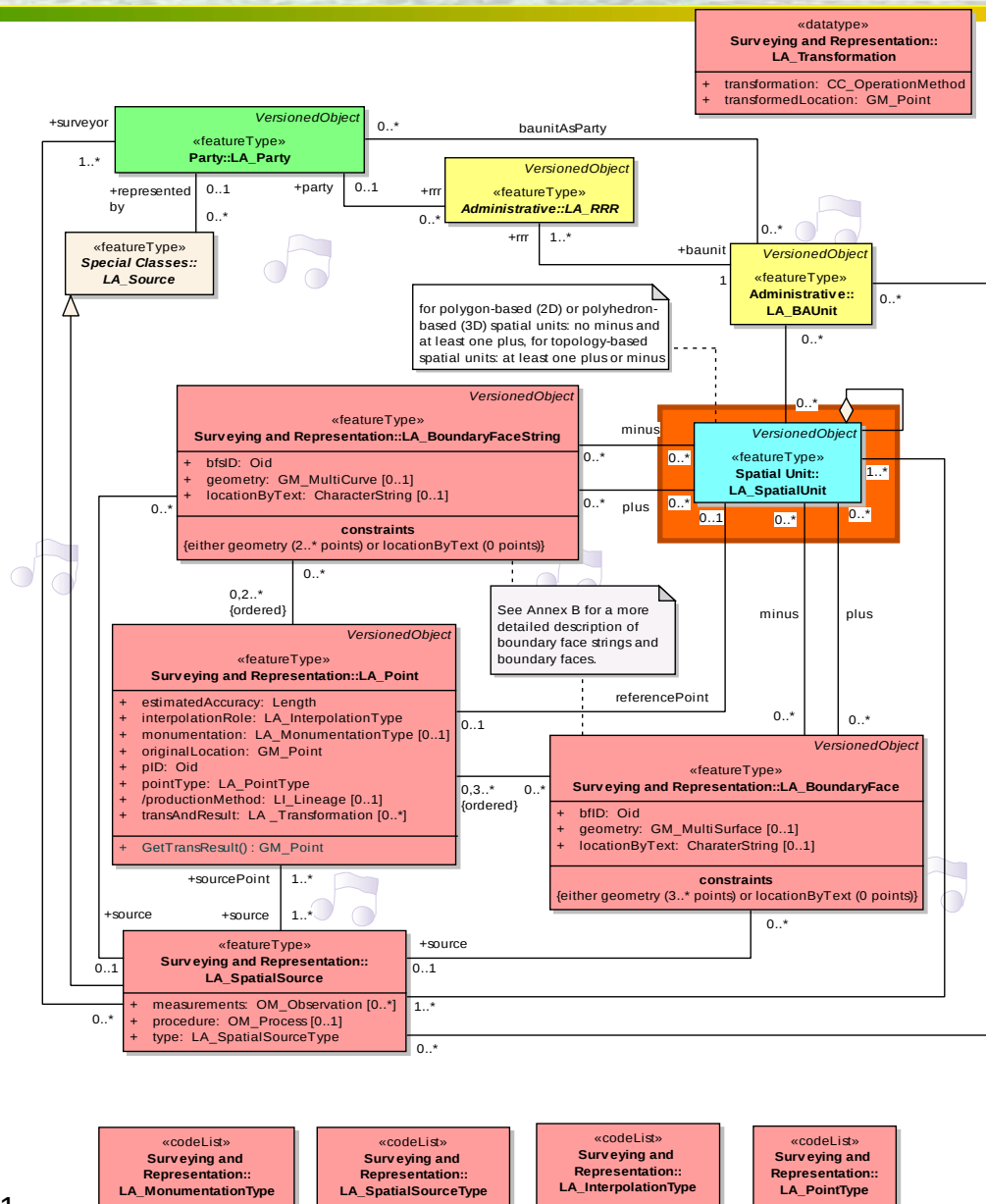
2. 3D cadastral model in LADM and the prototype

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2. 3D cadastral model in LADM



2. 3D cadastral model in LADM

This is the spatial profile of a pure 3D topology structure (so no 2D or liminal representations in this level). There are no overlapping volumes (3D_SpatialUnits). However, volumes may be open at the bottom or at the top, corresponding to non-bounded 3D_SpatialUnits (in this case the size of the volume cannot be computed).

The following class should be omitted from any implementations of the 3D_ProfileDefinition: LA_BoundaryFaceString.

This is the topological spatial profile for the 3D case. Note that in 3D_Level the attribute structure is fixed to 'topological'. In the 3D_SpatialUnit the attribute dimension is fixed to '3D', there still is an optional referencePoint, which should be provided via a 3D GM_Point. Finally, there are a set of constraints defining a valid topological structure for a 3D volume partition.

«invariant»

{All topological boundary faces are used once in plus and also exactly once in minus direction. Unless the boundary face is on the edge of the domain then either the plus or the minus direction is used once (and the other zero times).}

«invariant»

{non_intersection: boundary faces do not (self-)intersect and do meet other boundary faces at their boundaries}

3D_Profile::3D_BoundaryFace

+ bflD: Oid
+ /geometry: GM_Surface
+ quality: DQ_Element [0..*]

minus /derived LADM

0..*

0..1

plus /derived LADM

0..*

0..1

«Invariant»

{All 3D_BoundaryFaces have outward orientation (normal vector points to the outside). All 3D_BoundaryFaces together form at least one outer shell and 0 or more inner shells. In principle the shells are closed, with the exception that they may be open (unbound) to the top (sky) and bottom (earth) direction.}

LA_Level

3D_Profile::3D_Level

+ IID: Oid
+ name: CharacterString [0..1]
+ registerType: LA_RegisterType
+ structure: LA_StructureType = topological
+ type: LA_LevelContentType [0..1]

+level

0..1

/derived LADM

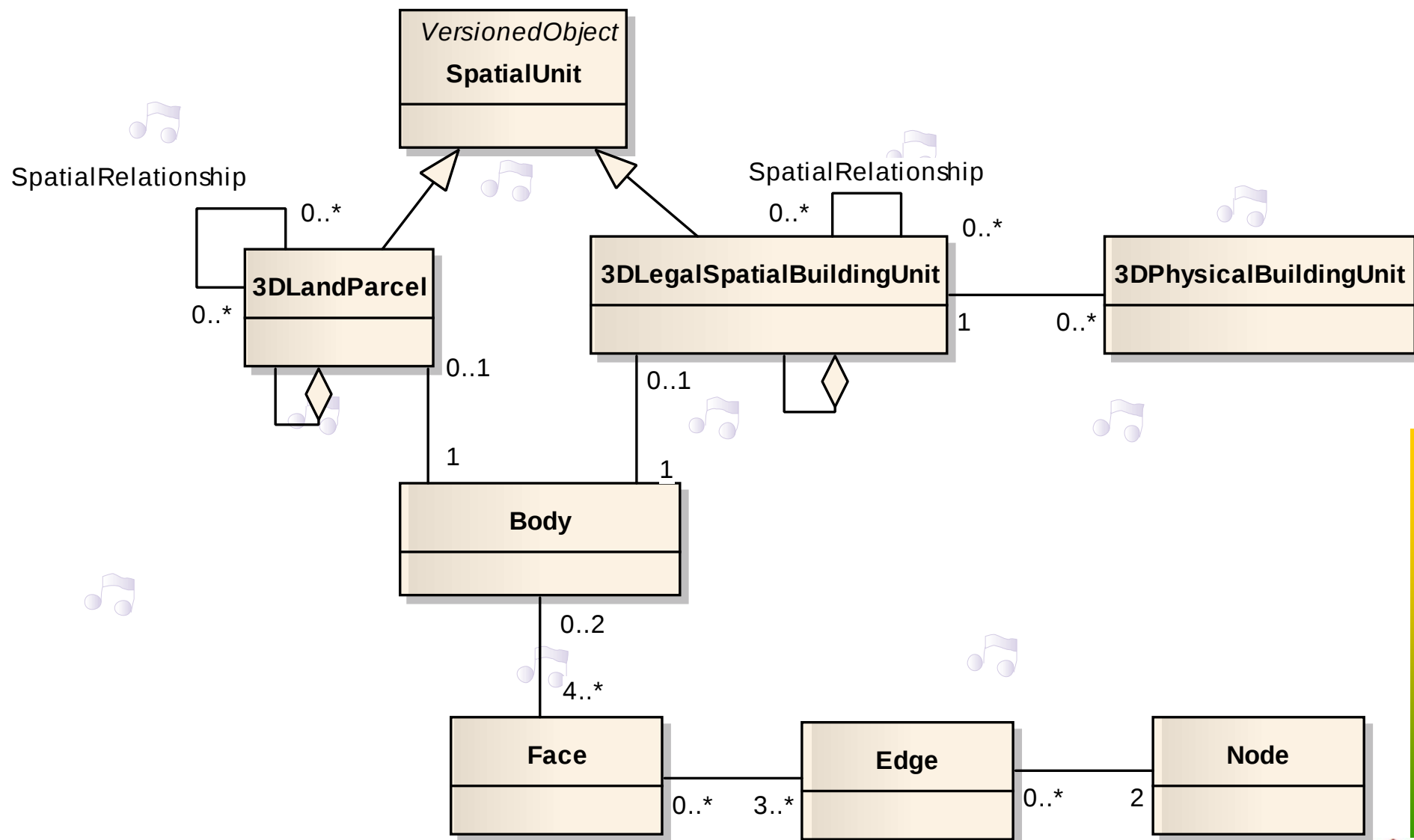
+su 0..*

LA_SpatialUnit

3D_Profile::3D_SpatialUnit

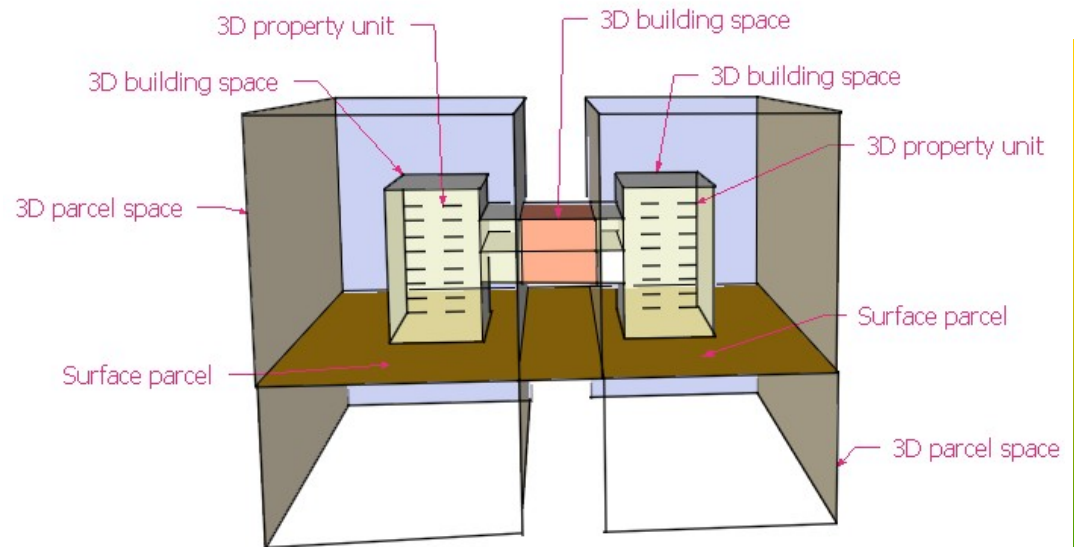
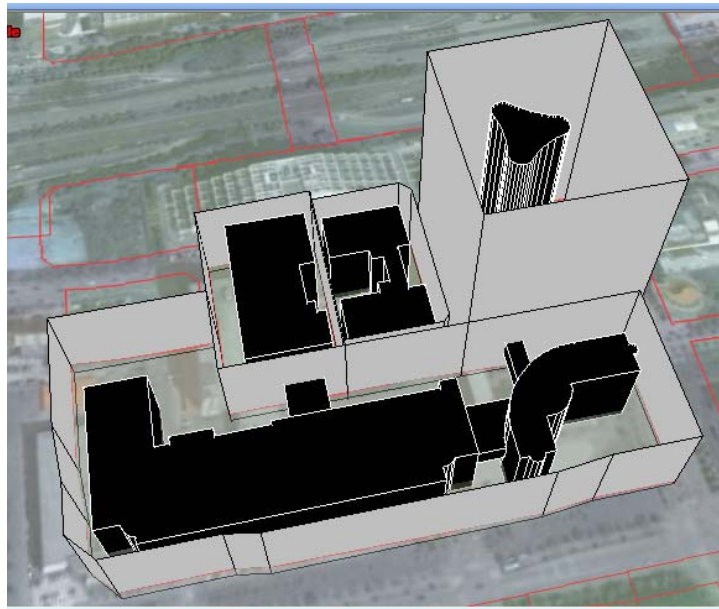
+ extAddressId: Oid [0..*]
+ dimension: LA_DimensionType = 3D
+ label: CharacterString [0..1]
+ referencePoint: GM_Point [0..1]
+ suID: Oid
+ surfaceRelation: LA_SurfaceRelationType [0..1]
+ volume: Volume [0..*]

Data model in prototype system



3D land parcel and 3D legal space building unit

- 3D **parcel space** and 3D **legal building unit space**, are defined to describe the 3D space represented by 3D solid/body.
- Both focus on 3D body construction with surveyed boundary edges and faces, to assure all 3D cadastral objects are **valid 3D bodies** with **precise descriptions and consistent topology**.



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3. Body construction based on SketchUp

3.1 Definition of solid model and topology

3.2 Utilization of the topological model based SketchUp

3.3 Solid construction

3.3.1 Initial conditions and constraints

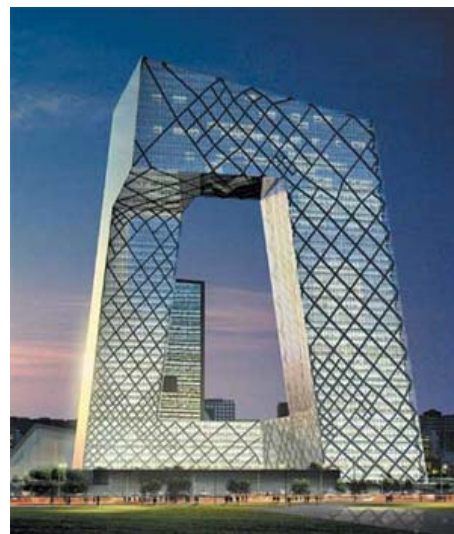
3.3.2 Sorting faces around edges

3.3.3 Reconstruction of the solids

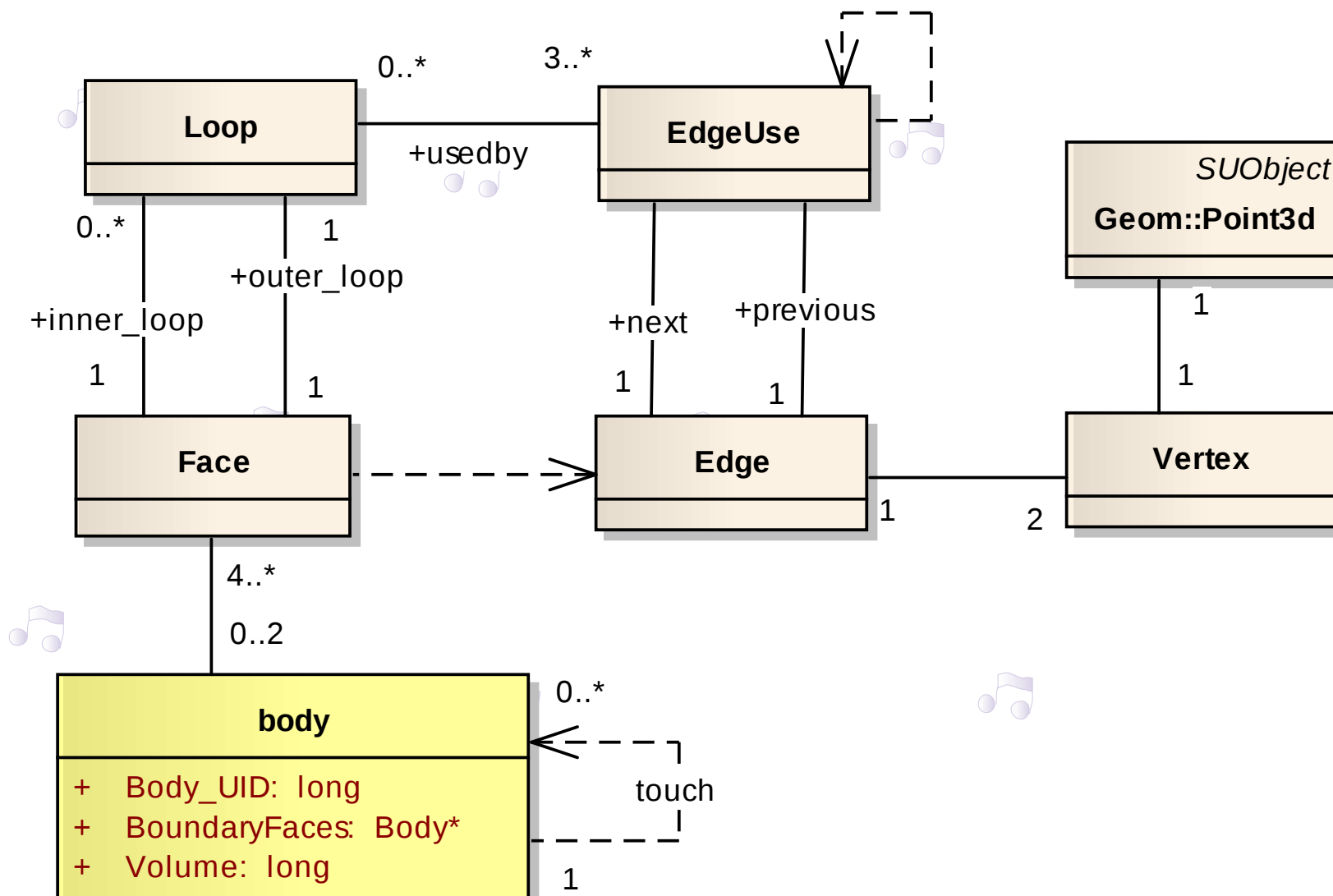
3.4 Handling complex configurations

3. Body construction based on SketchUp

- A solid is **defined** as a seamless 3D space with interior orientation and its shell, which is closed and is made up of the faces.
- Unfortunately, many tools are not intelligent enough to recognize and define the closed body with the sets of faces.
- Some software (SUv8) know to check whether there is a correct solid / body with the selected faces, but do not know how detect and find the body from the “messed” faces, let alone the assembled bodies or bodies with holes.

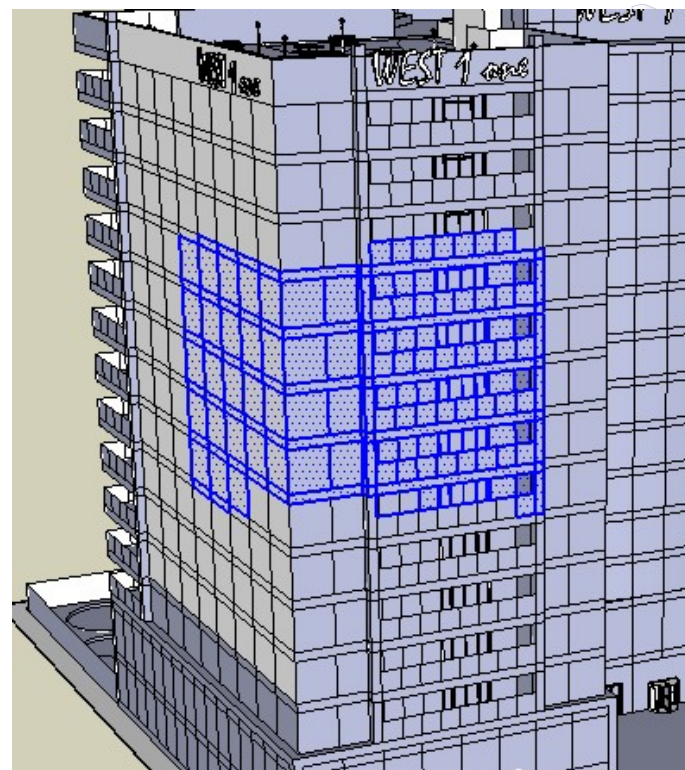


3.2 Topological model based SketchUp

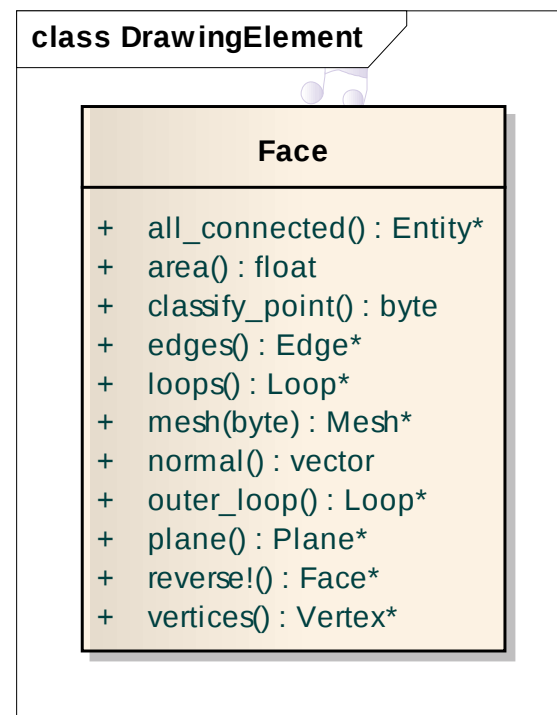
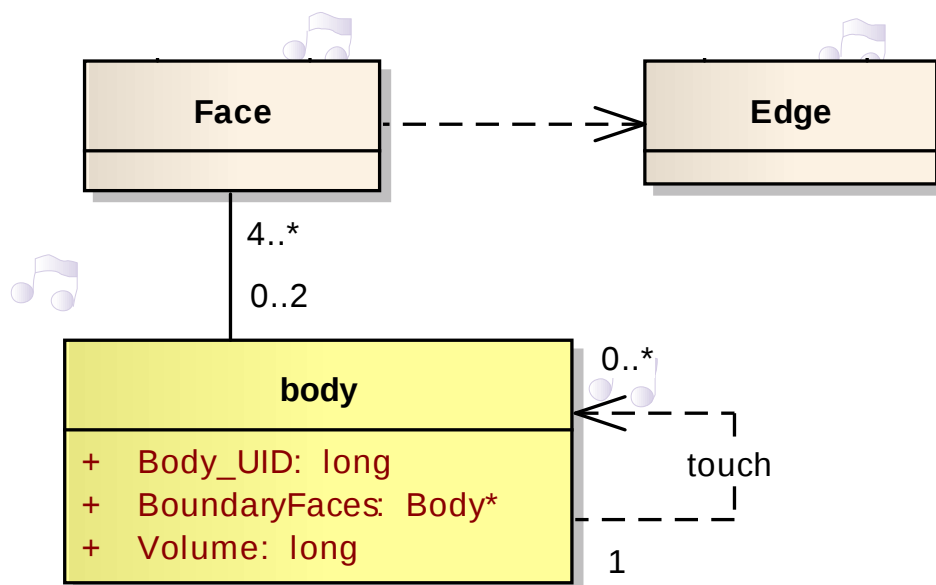




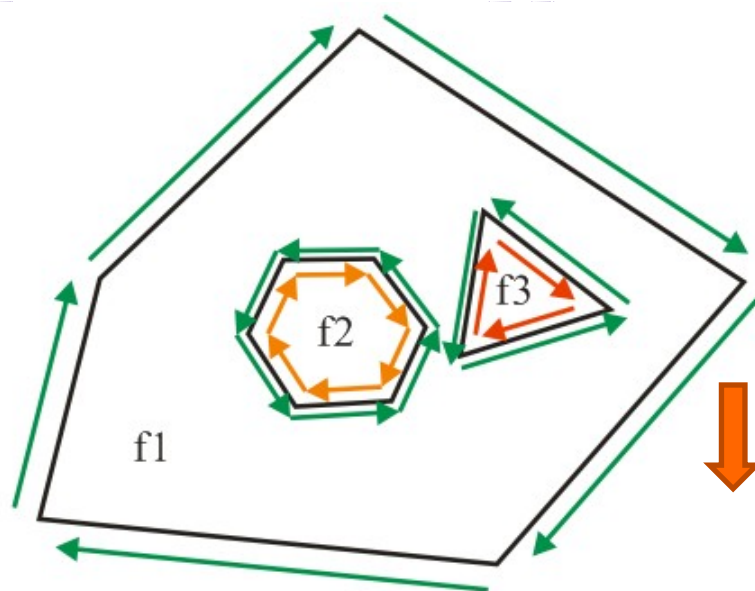
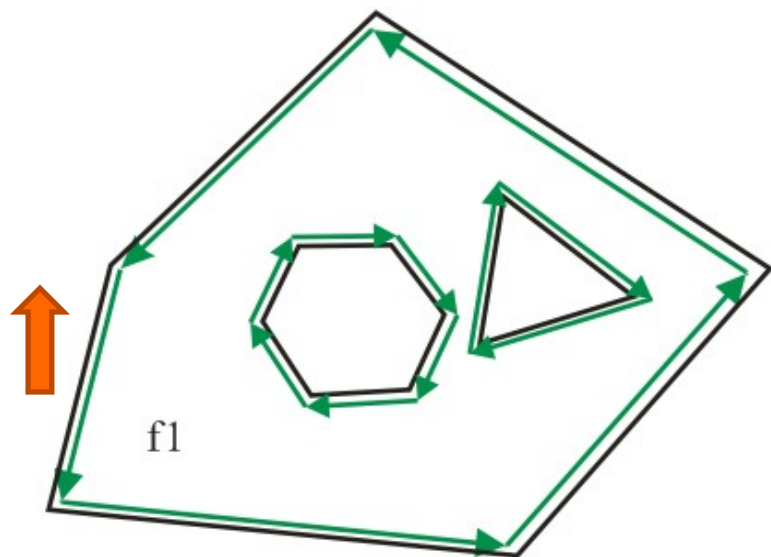
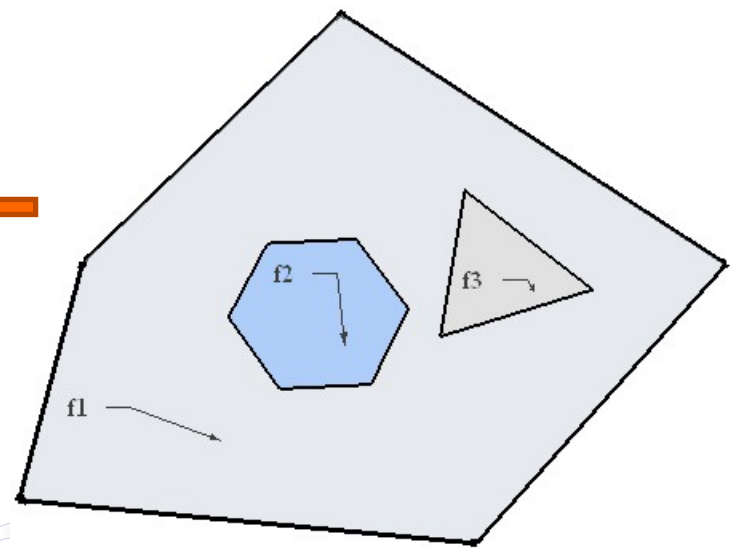
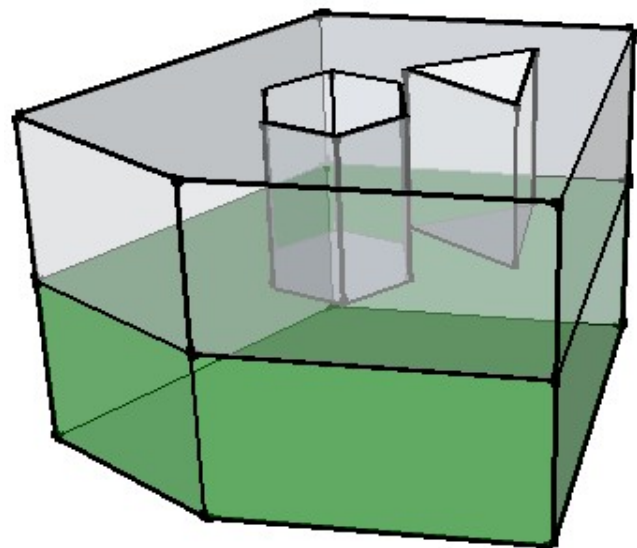
Google SketchUp



- A 3D body is a 3D primitive and is basically incident to faces. So the class *Face* is the focused element to be handled to create the 3D body.
- class *Face* is a oriented facet/facets with one outer loop, and zero or more inner loops.



Hole in 2D and 3D



-
- ```

classDiagram
 class Loop
 class EdgeUse
 class Face
 class Edge
 class Vertex
 class Body
 class SUObject
 class SUObject_Geom_Point3d["SUObject::Geom::Point3d"]

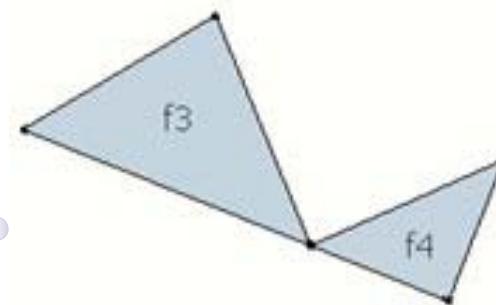
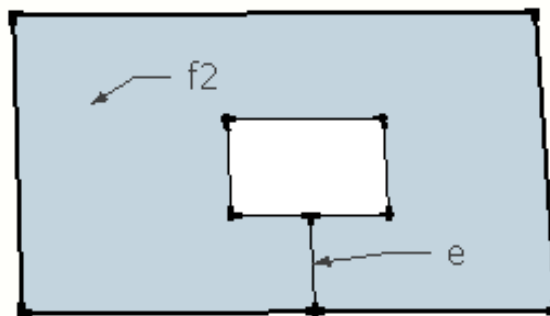
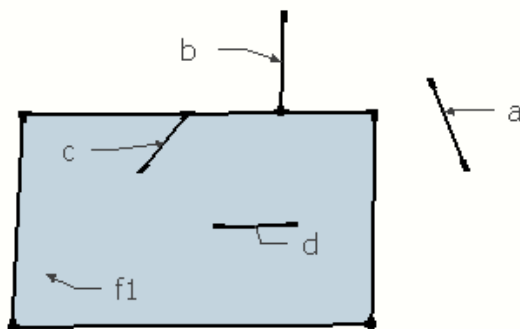
 Loop "0..*" -- "3..*" EdgeUse : +usedby
 Loop "0..*" -- "1" Face : +inner_loop
 Loop "1" -- "1" Face : +outer_loop
 Face "1" -.-> "1" Edge
 EdgeUse "1" -- "1" Edge : +next
 EdgeUse "1" -- "1" Edge : +previous
 Edge "1" -- "2" Vertex
 Face "4..*" -- "0..2" Body
 Body "+ Body_UID: long"
 Body "+ BoundaryFaces: Body*"
 Body "+ Volume: long"
 EdgeUse "0..*" -- "1" EdgeUse : touch
 SUObject <|-- SUObject_Geom_Point3d

```

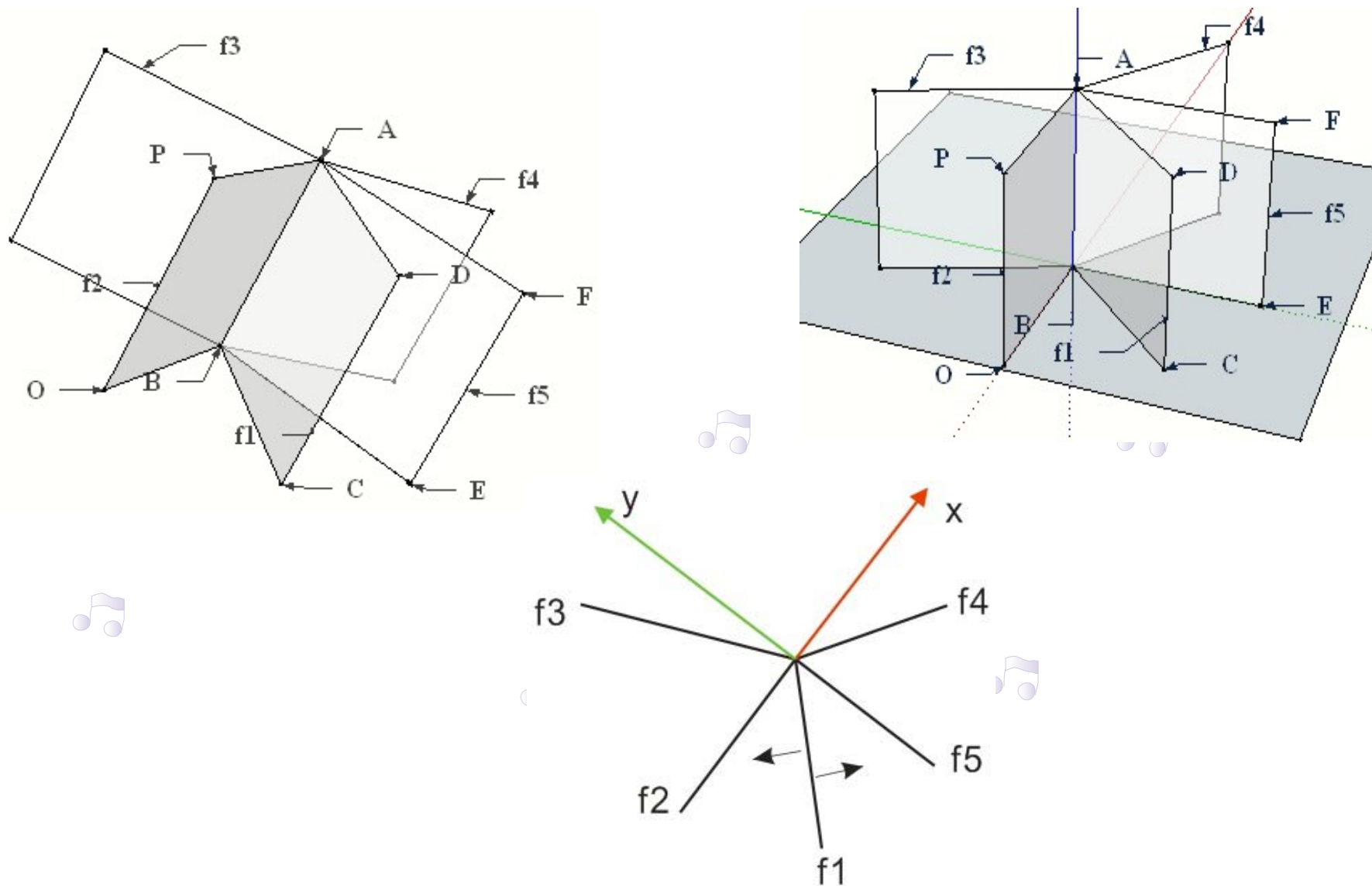


### 3.3.1 Initial conditions and constraints

- Each polygon is closed.
- Each face is a flat polygon and the curve face should be divided into several flat faces.
- No self-intersection with lines and no overlay between polygons.
- No isolate, hanging or dangling point and edge.

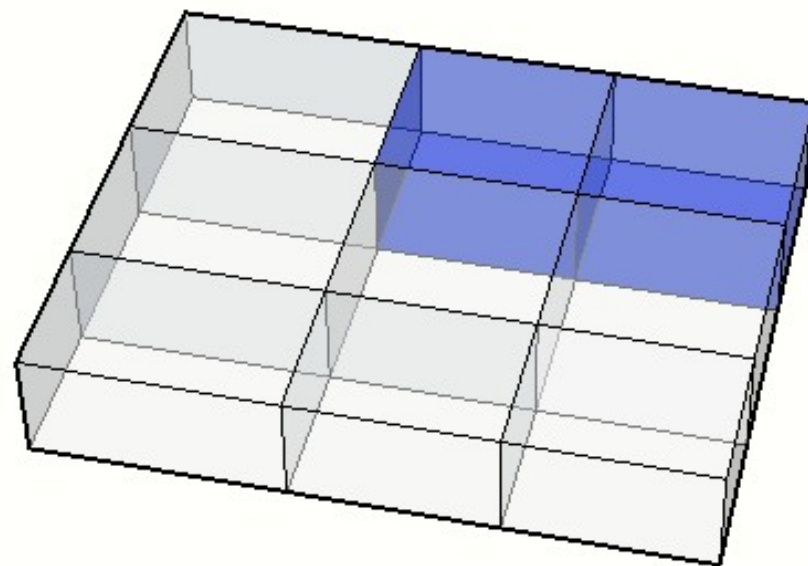
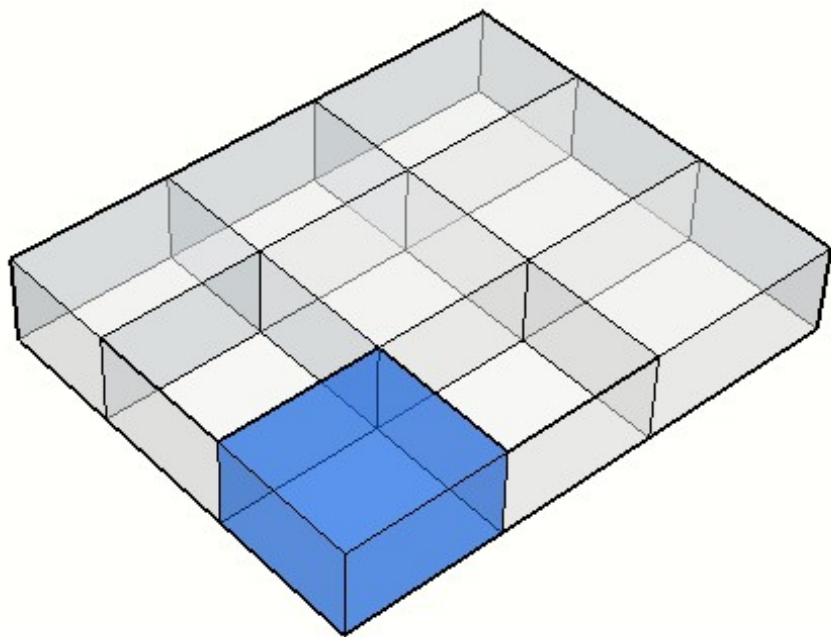


## 3.3.2 Sorting faces around edges



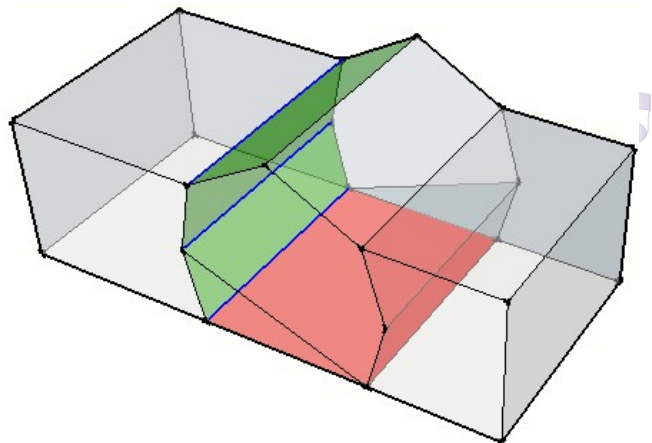
### 3.3.3 Reconstruction of the solids

- Minimum body
- uniqueness and homogeneity (cadastral object)

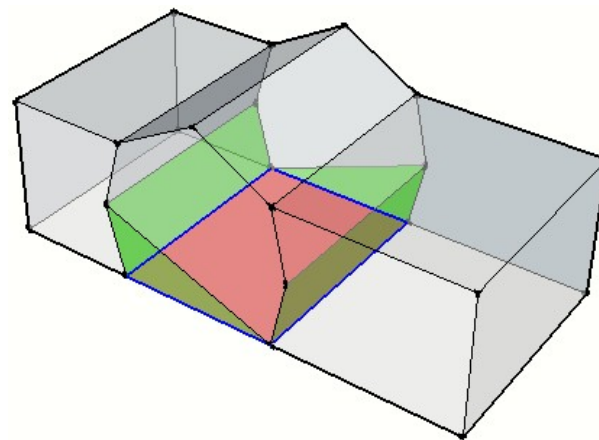


### 3.3.3 Reconstruction of the solids

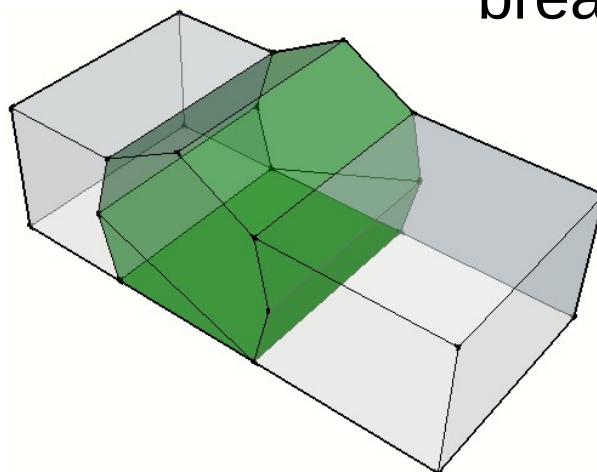
#### ■ Connect the faces



depth-first search

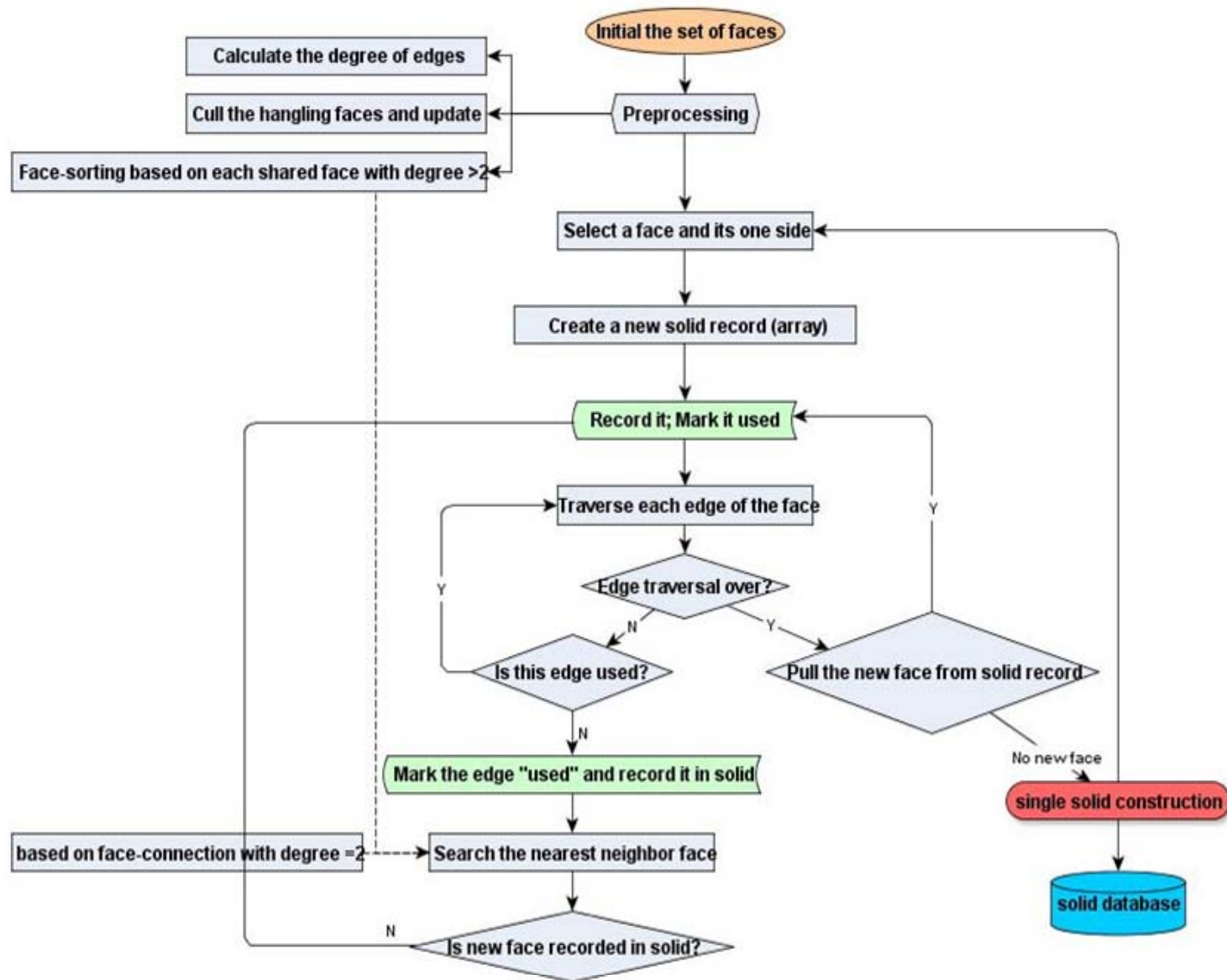


breadth-first search



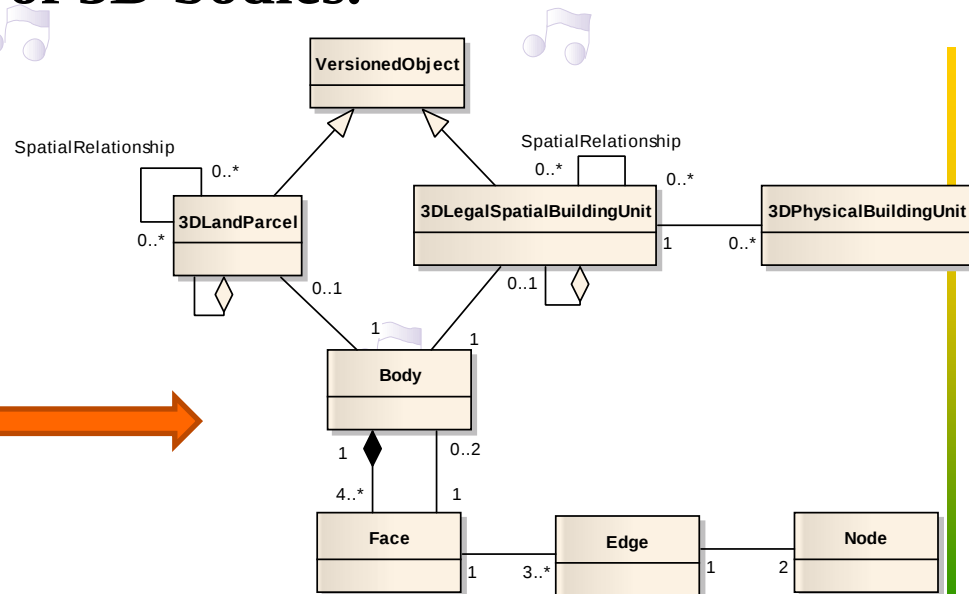
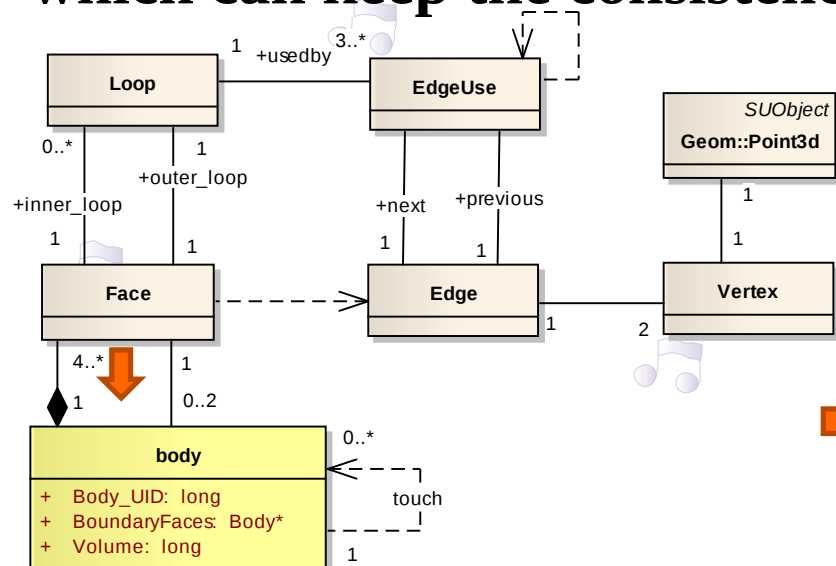
the unicity of the result

# 3.3.3 Reconstruction of the solids

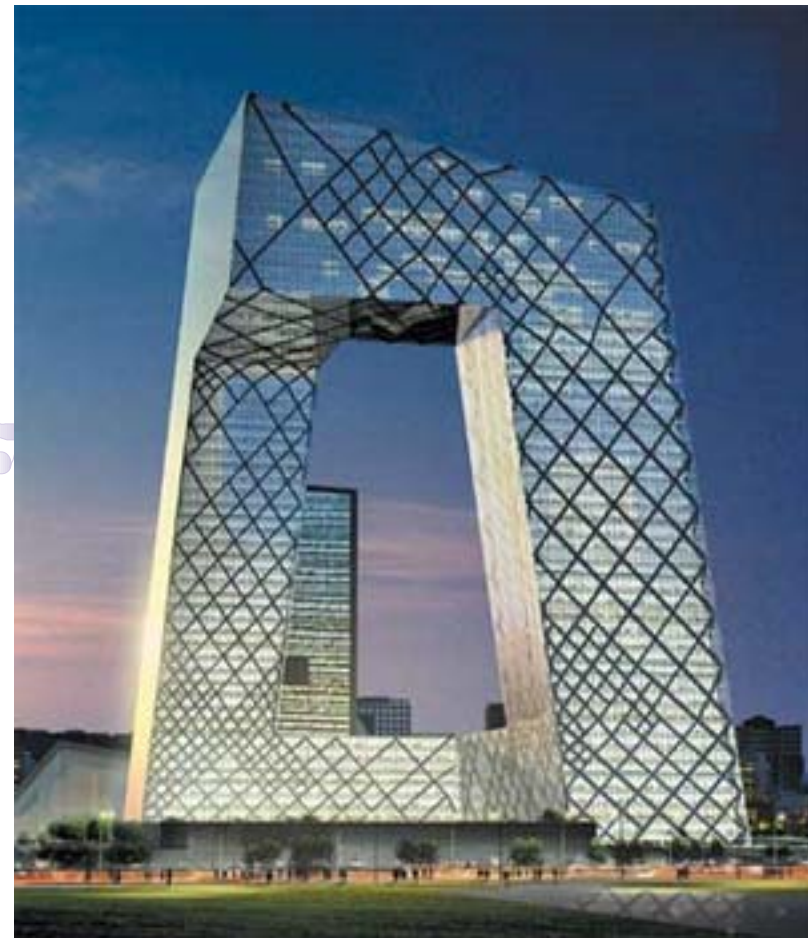


### 3.3.3 Reconstruction of the solids

- The approach records the direction of the faces and the interior of the body/solid.
- It is easy to get the neighbour bodies with the shared face/edge and build the topologic relationships among bodies.
- So the relationships of data model is implemented and filled in, which can keep the consistence of 3D bodies.



## 3.4 Handling complex configurations





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## 5. Conclusion and prospective outlook



## 4. Prototype system

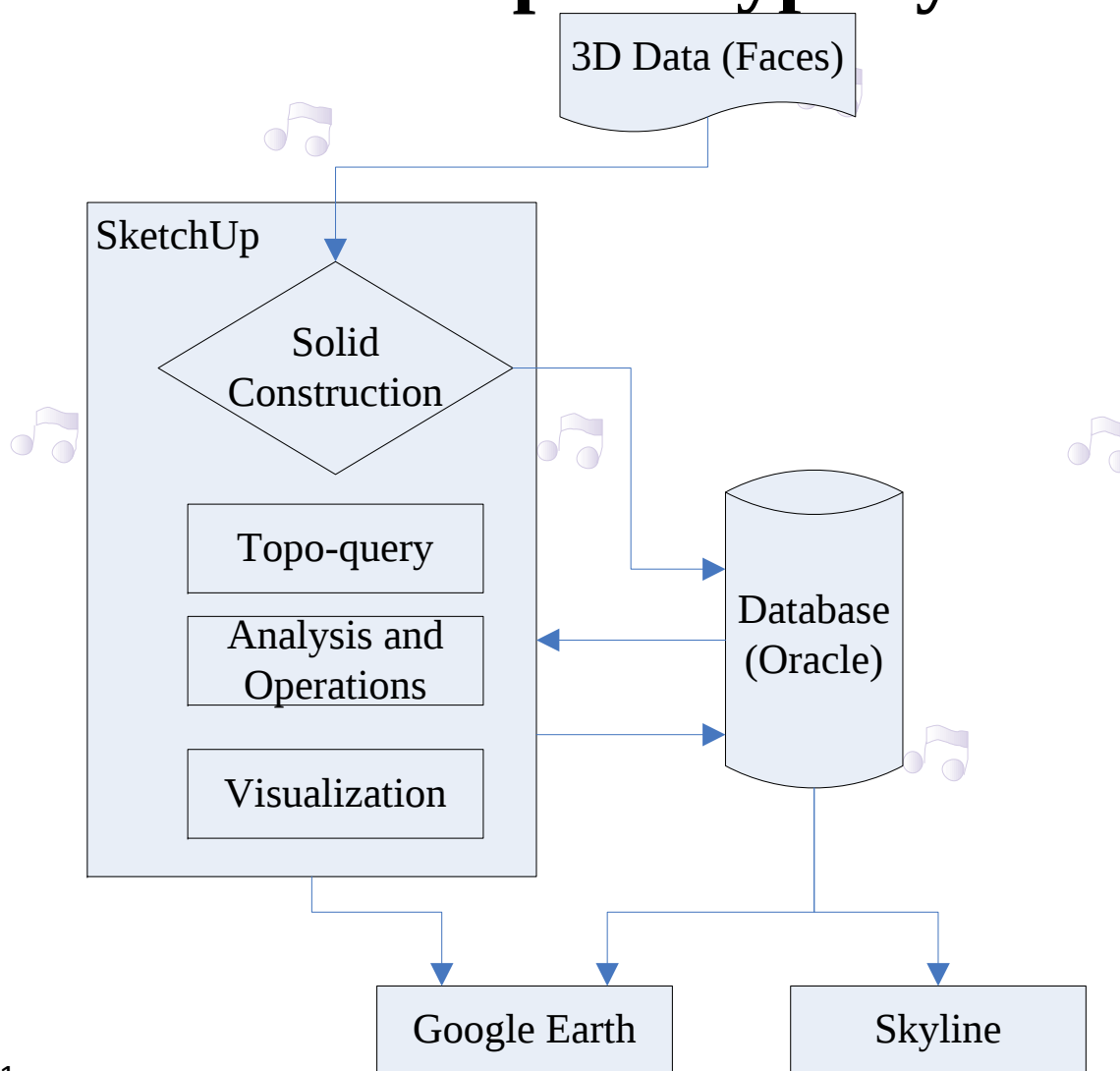
- Framework of the prototype system

- Topological query

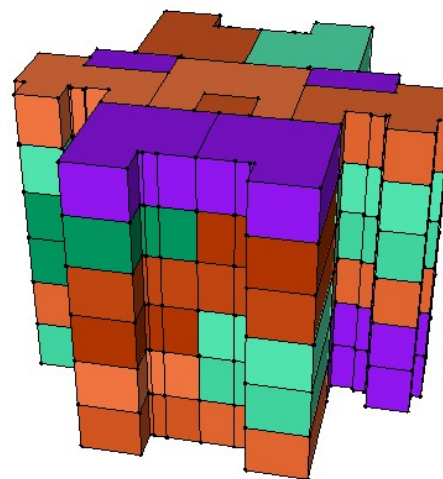
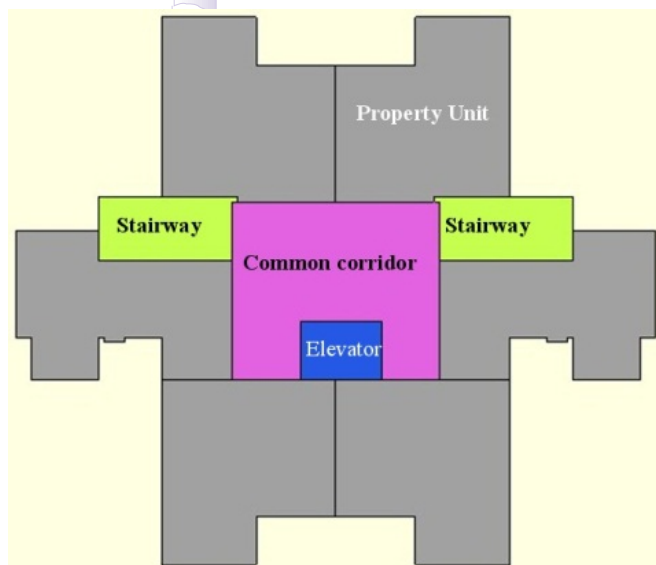
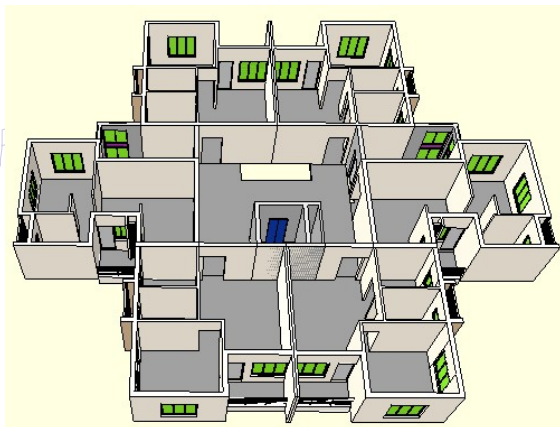
- Spatial operations

## 4. Prototype system

### 4.1 Framework of the prototype system

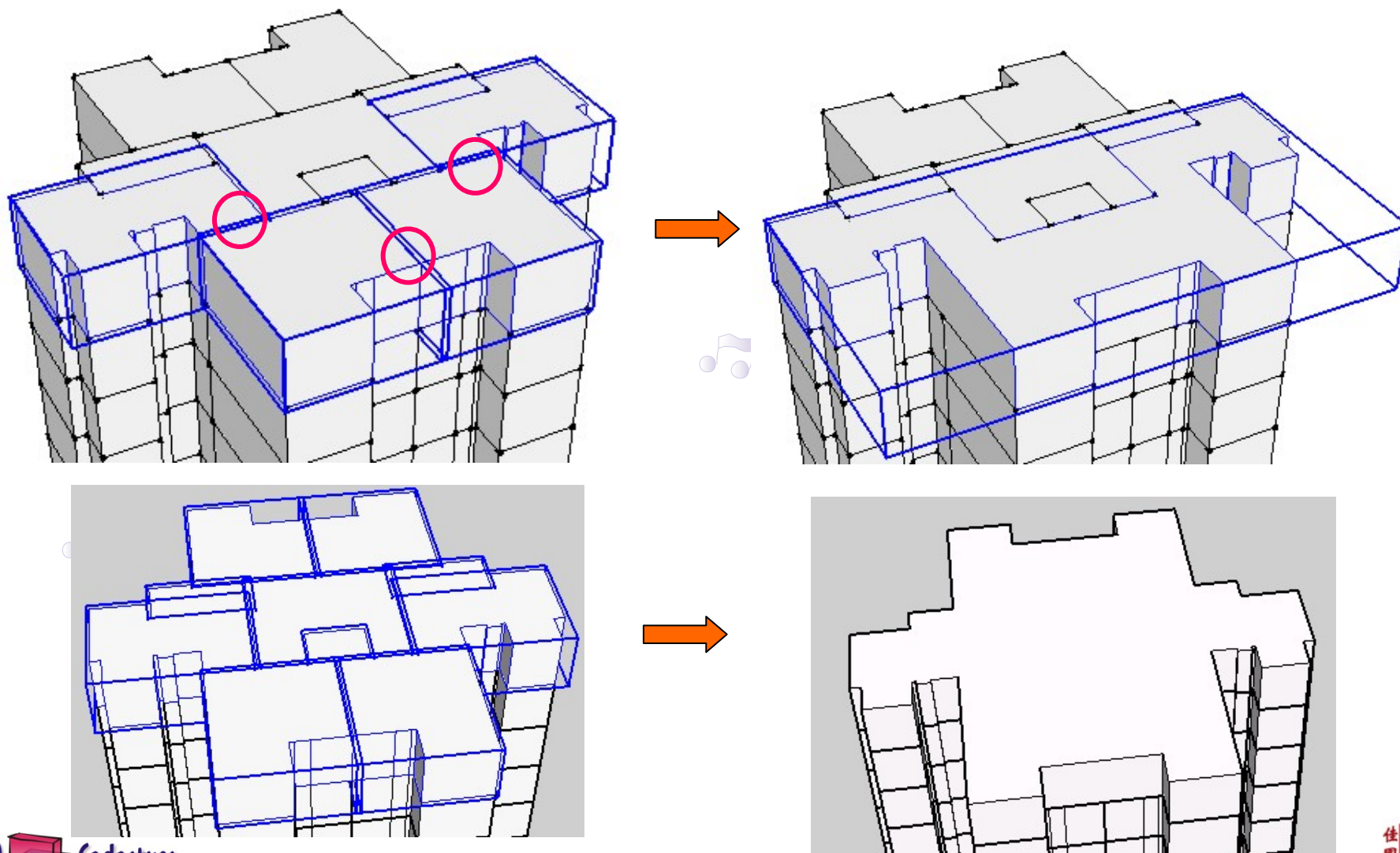


# Test data

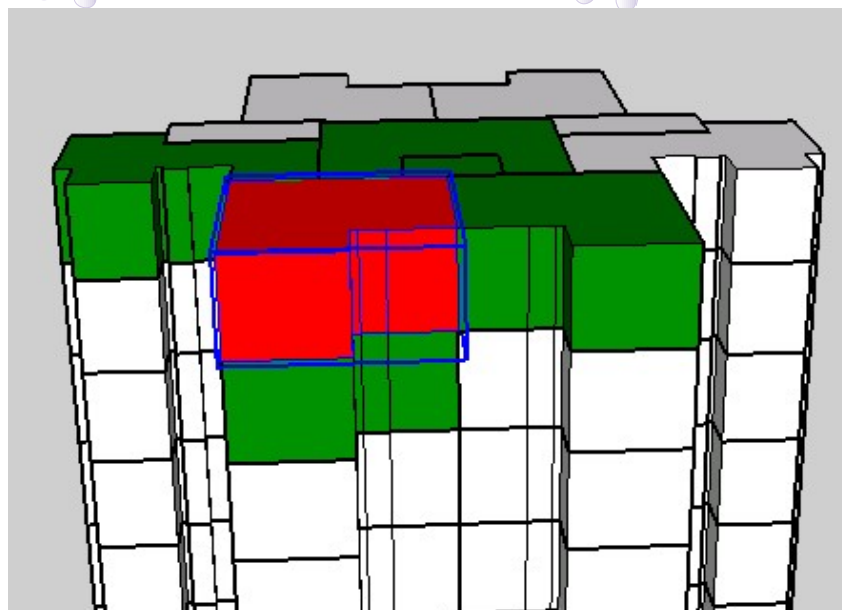
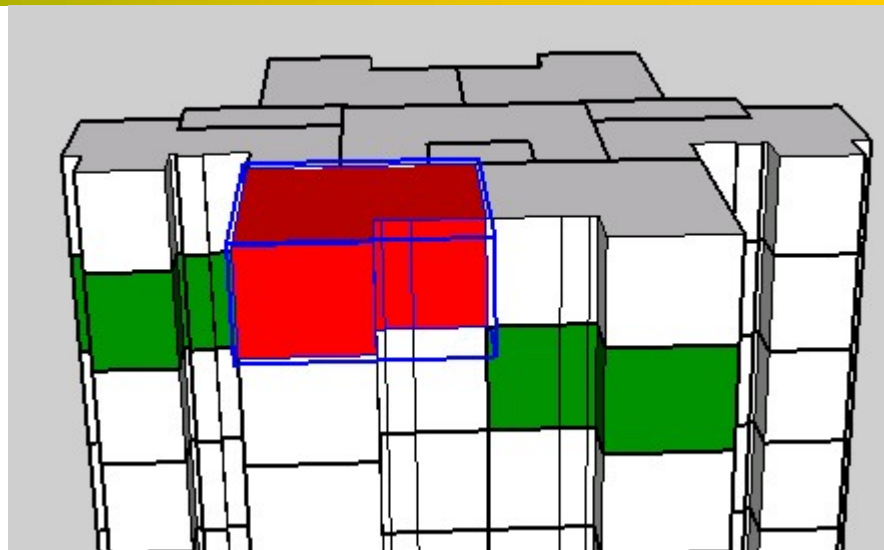
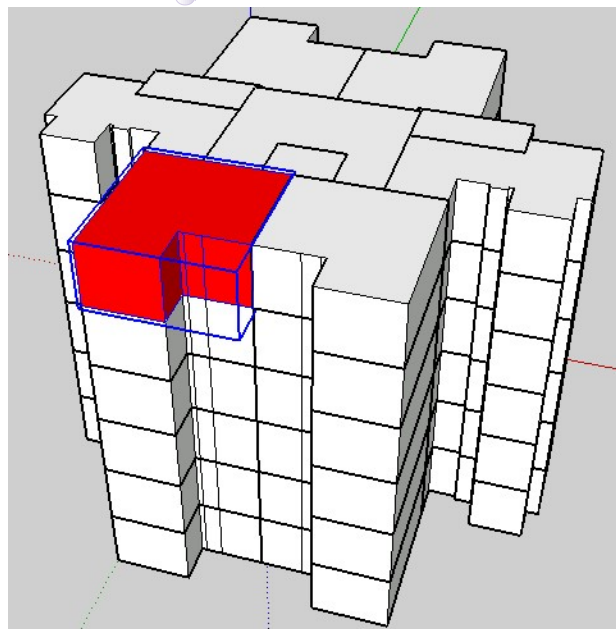


## 4.2 Operations and topological query

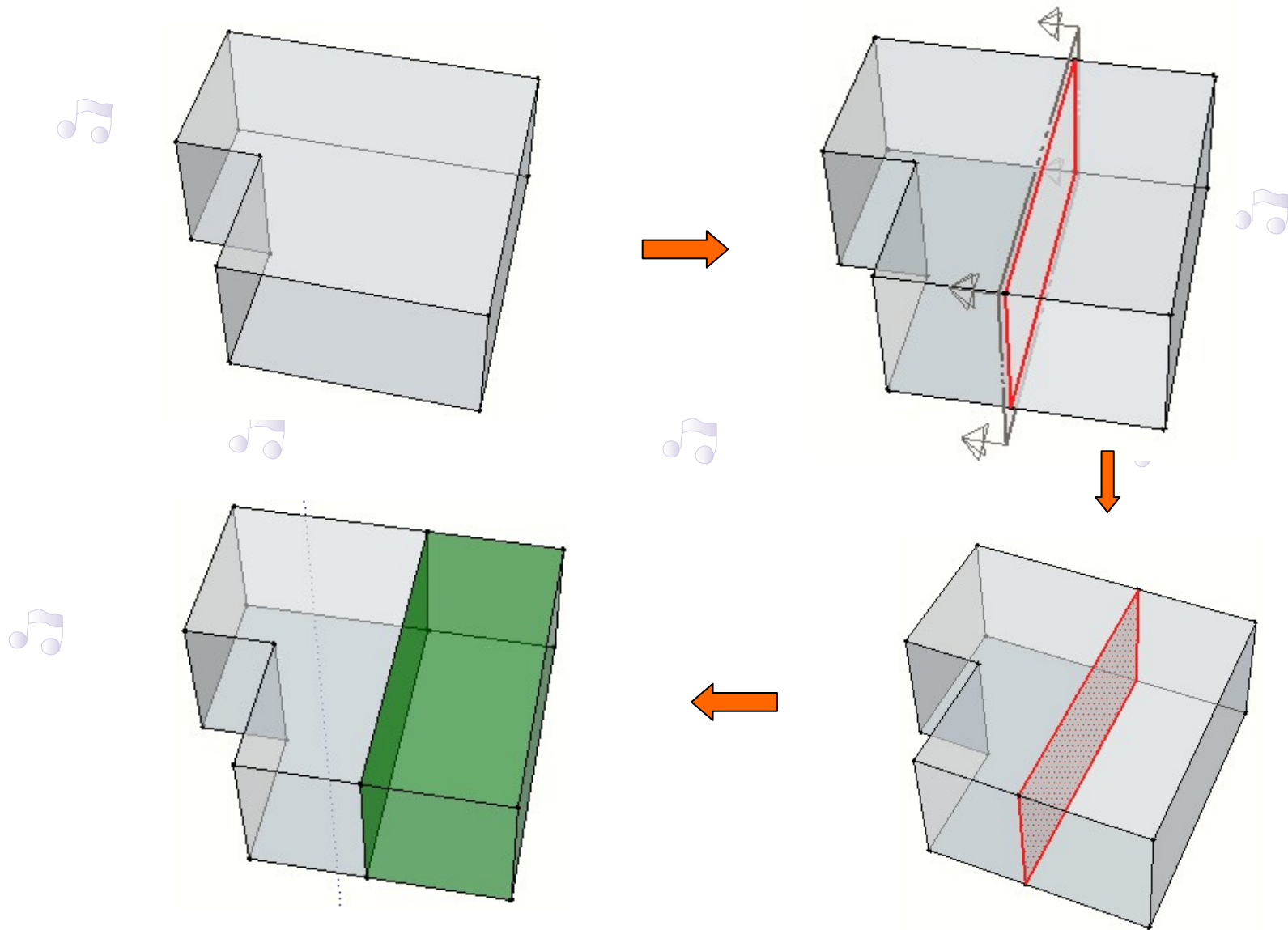
- Mergence operator of four bodies



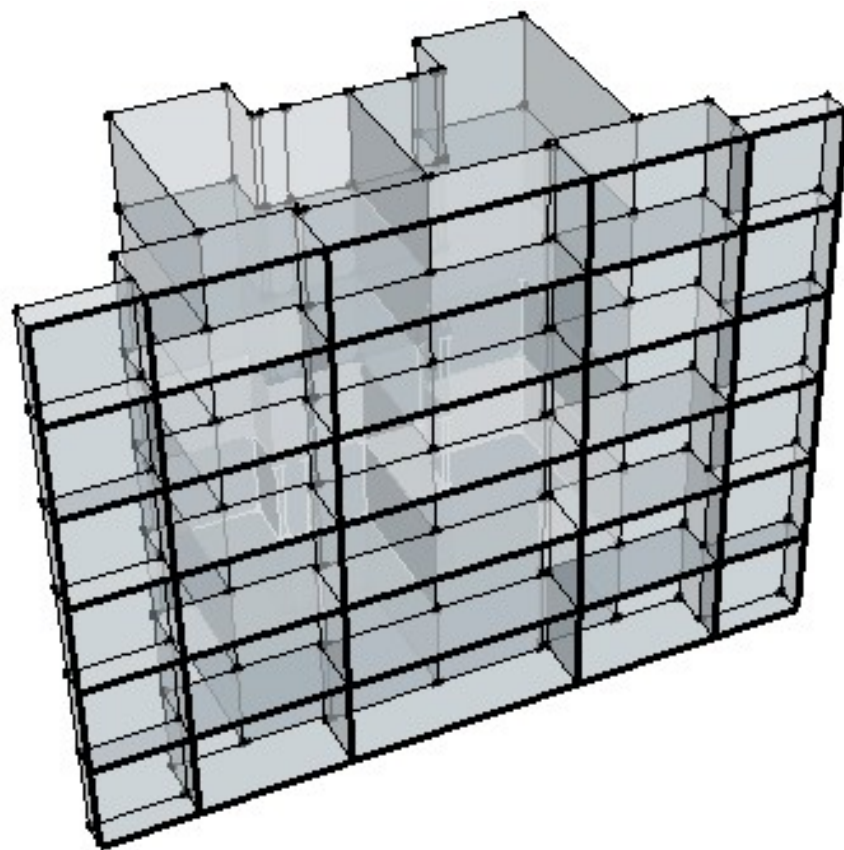
# Topological query



# Process of splitting one unit into two units



## ■ Splitting section view



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## 5. Conclusion and prospective outlook

- A 3D topology based on LADM is delivered.
- Real 3D bodies are constructed with the input faces and stored the references in the 3D topological model.
- Next, the faces can be extended to be surfaces that would support the curve surface and maintain the topology with other geometric elements (solid, edge).

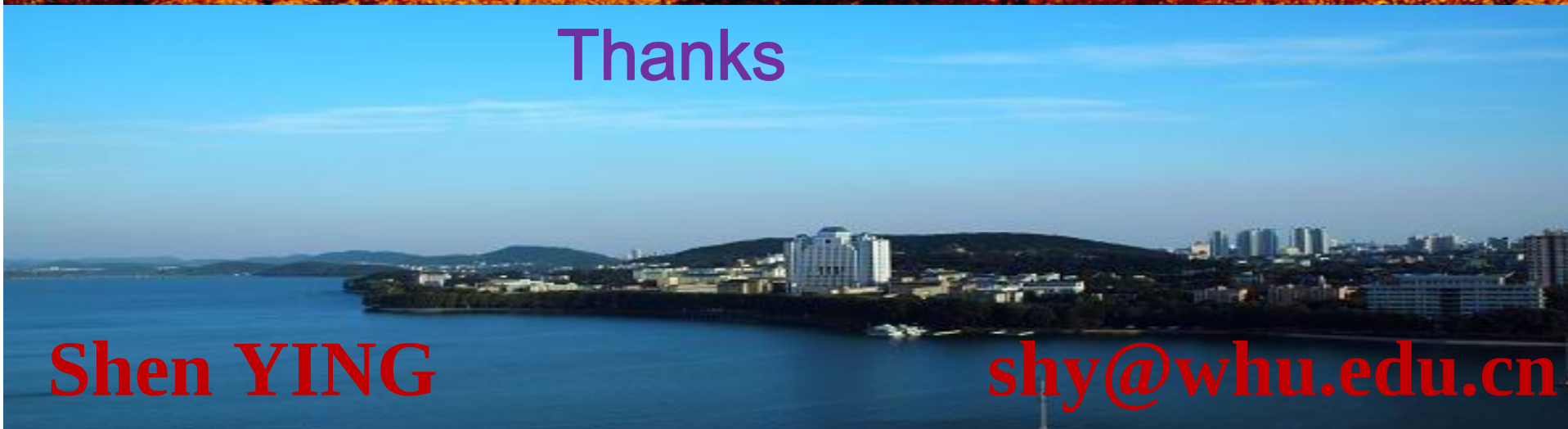


## 5. Conclusion and prospective outlook

- The attention in the context of 3D cadastre is concentrating on the geometries, topological relationships, and the operations on the cadastral objects.
- when all these techniques are solved, associated with the registration and management, the complete 3D cadastre can be implemented and realized.



Thanks



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