3D Building Information Efficiently Acquired and Managed

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Motivation

Earthquake **Risk Analysis** and **Disaster Management** need accessible, reliable, actual and complete information on the **situation**.

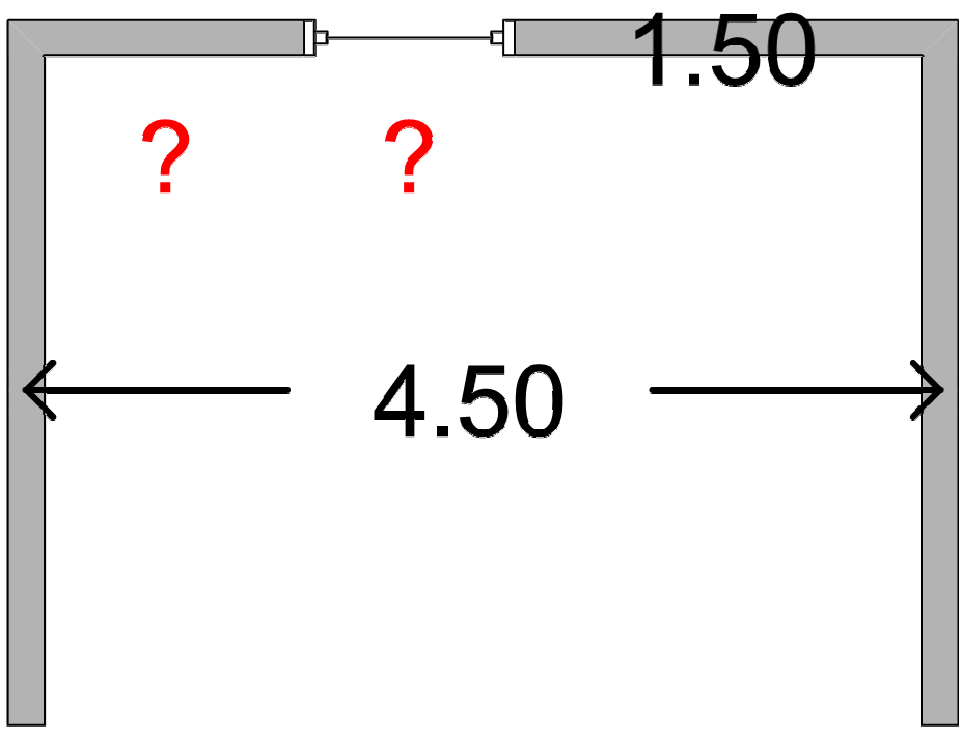
Study area: Gathering **3d indoor** models of the **as-built situation** efficiently.

Application: The 3d indoor model provides the **spatial frame-work** to the Building Information Model (BIM) used for risk analysis (e.g. **structural statics**) or rescue planning (e.g. **escape route planning**)

Motivation: **Practice of indoor mapping….**

Motivation

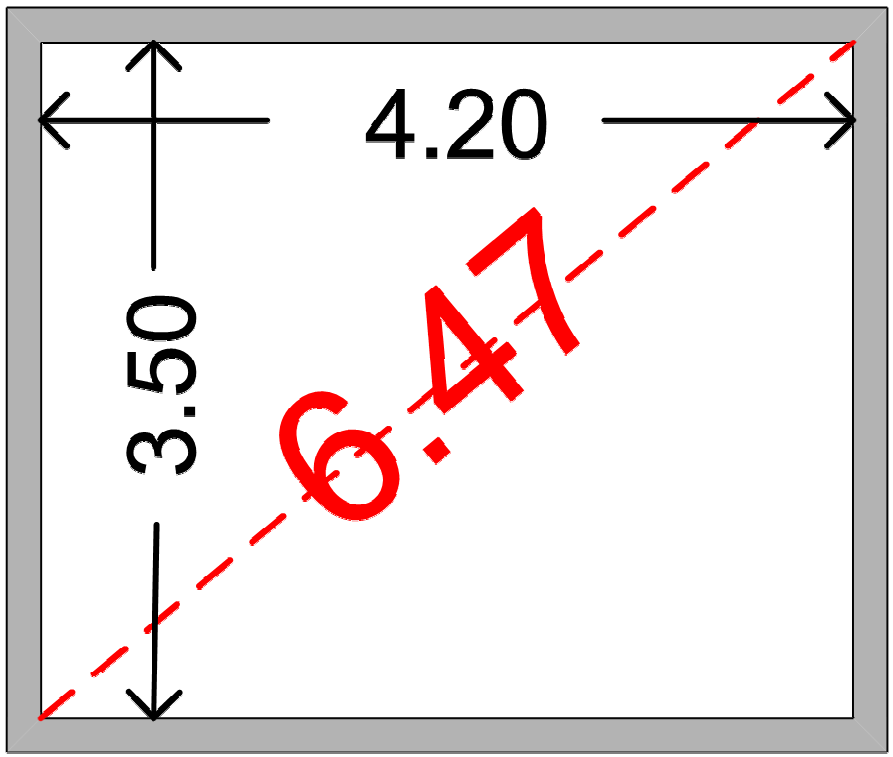
What if…



…measurements have been forgotten …

Motivation

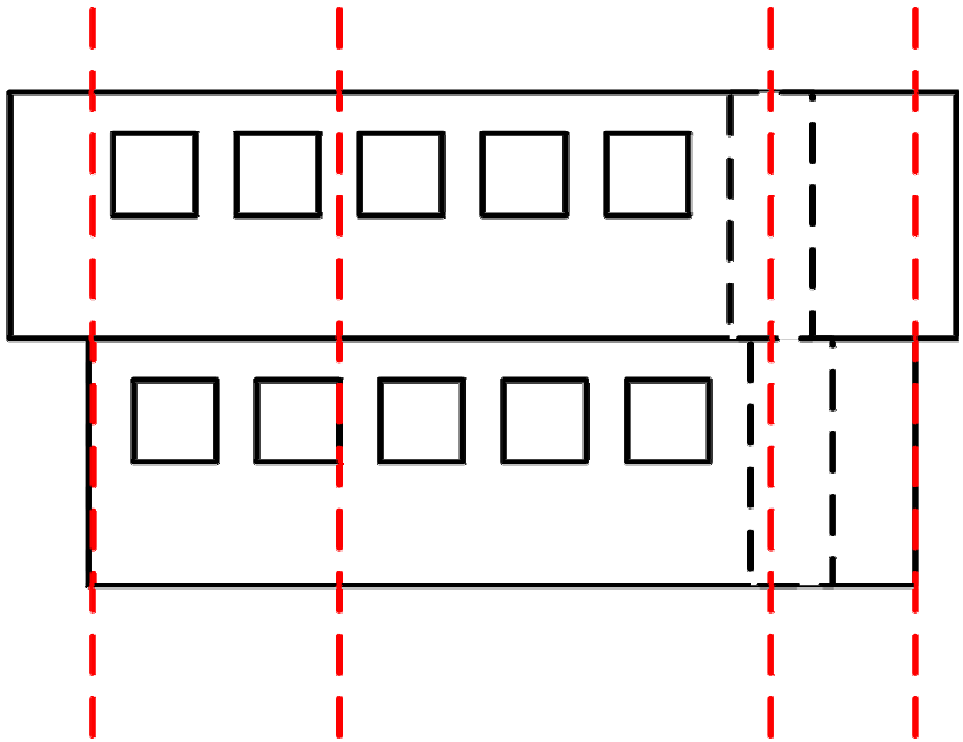
What if…



…measurements disagree

Motivation

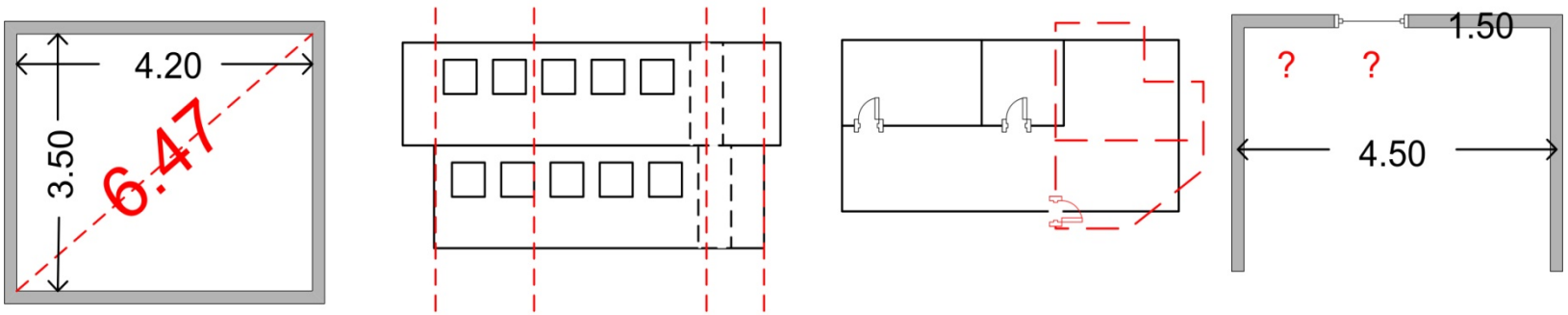
What if…



…resulting walls do not aligne

Motivation

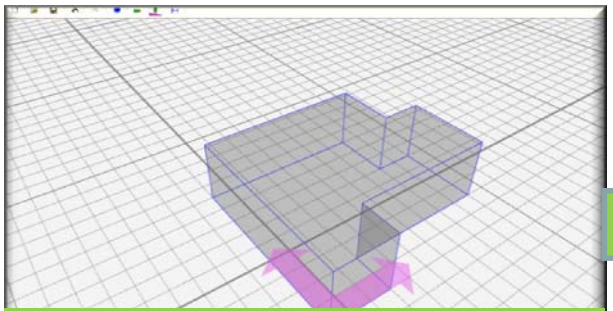
What if typical mistakes occur during 3D as-build-documentation ?



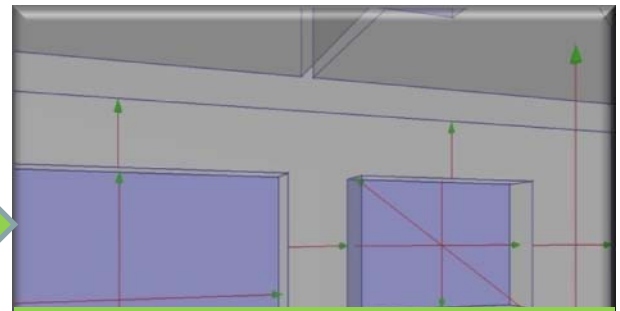
Staff has to return to the building for re-measuring.

Mistakes remain undetected, thus the resulting building geometry is wrong.

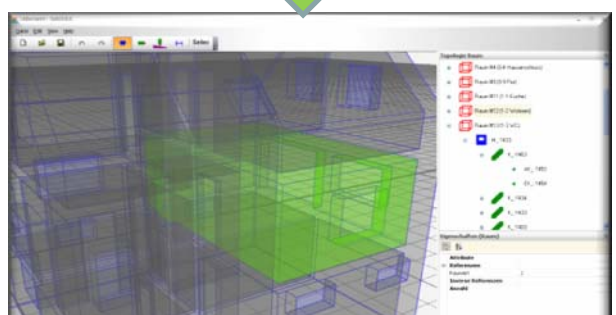
Motivation



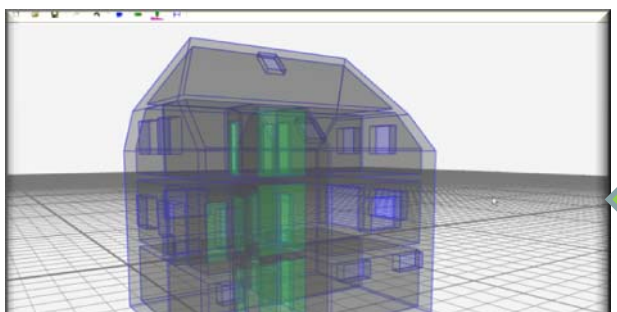
sketch



observe

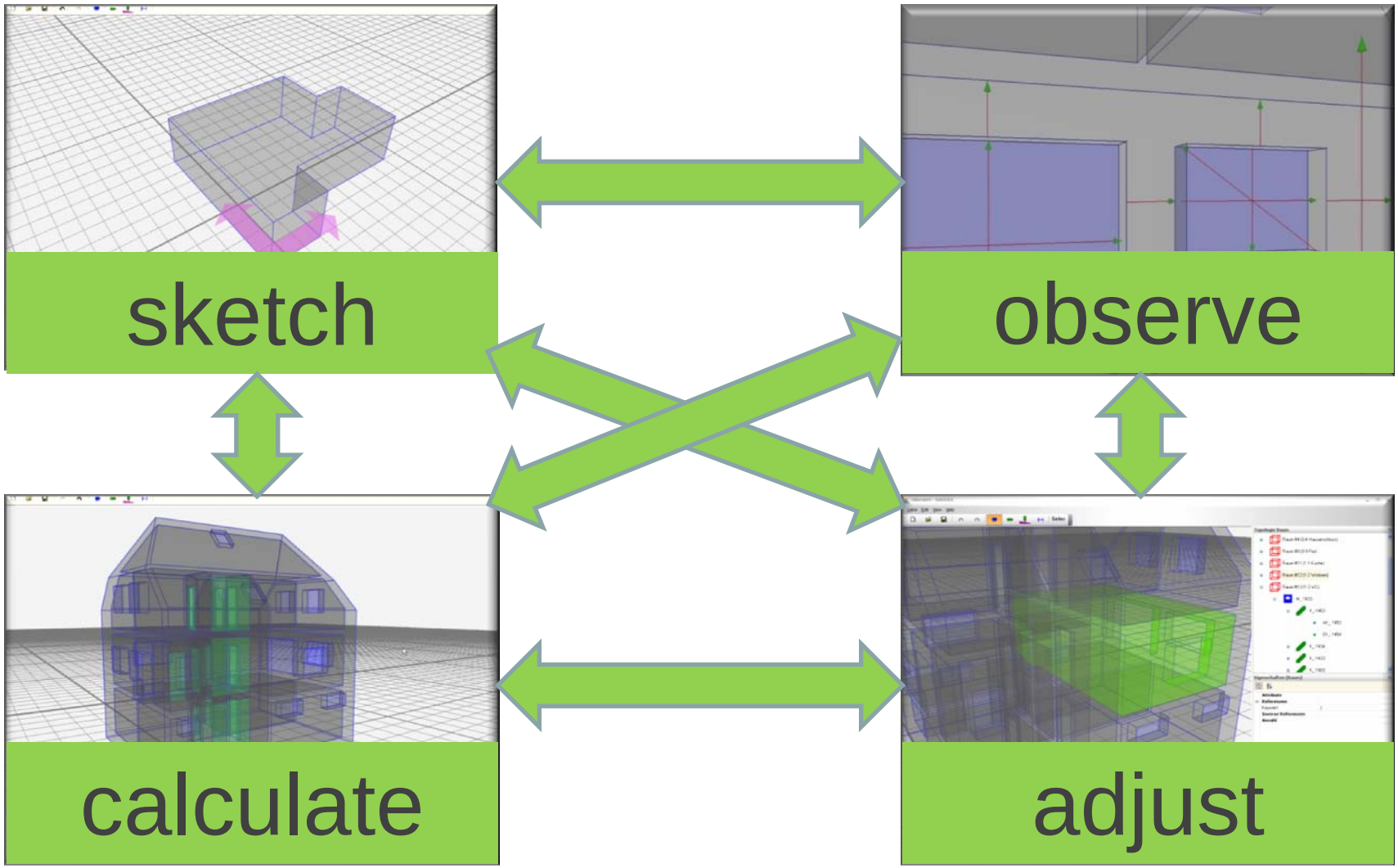


adjust

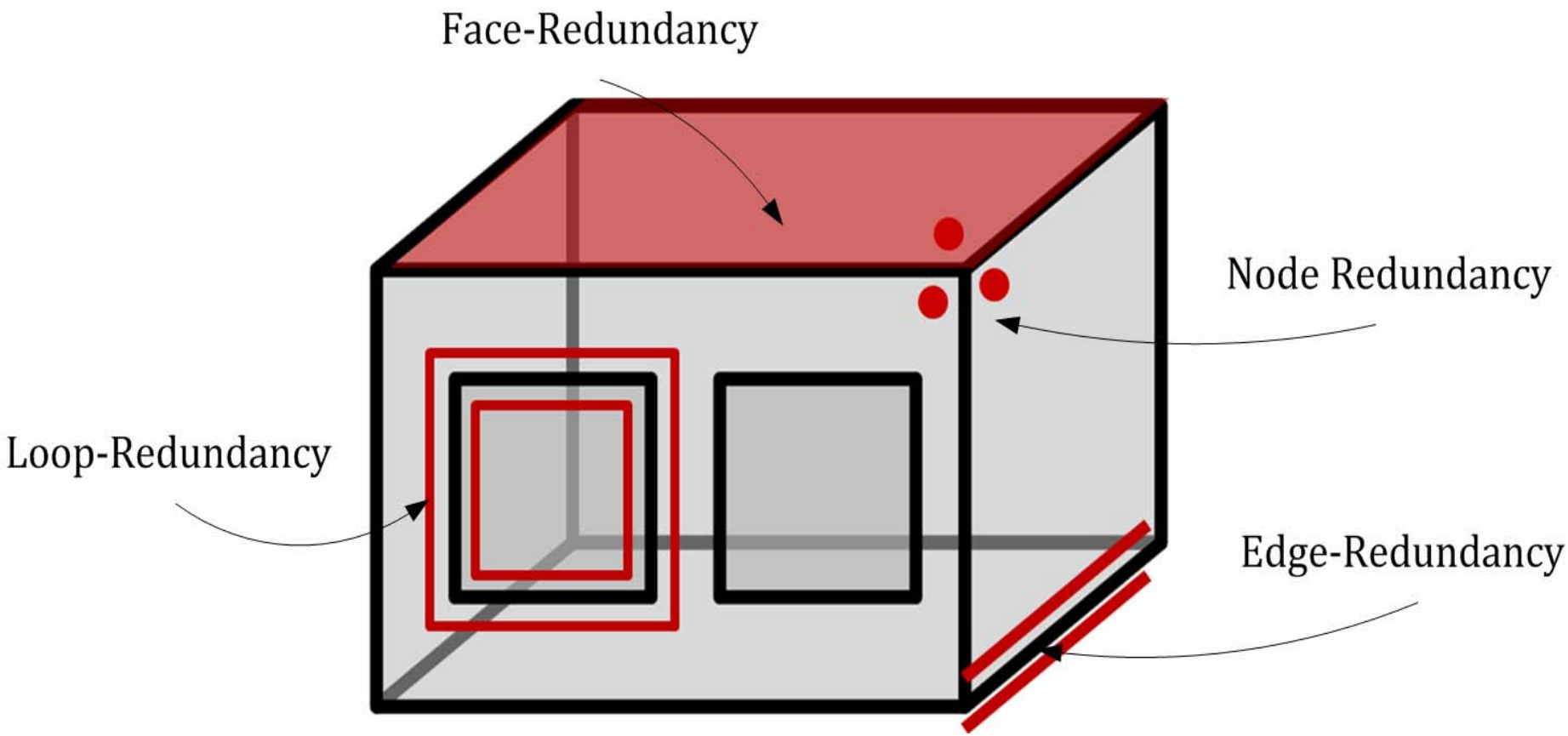


calculate

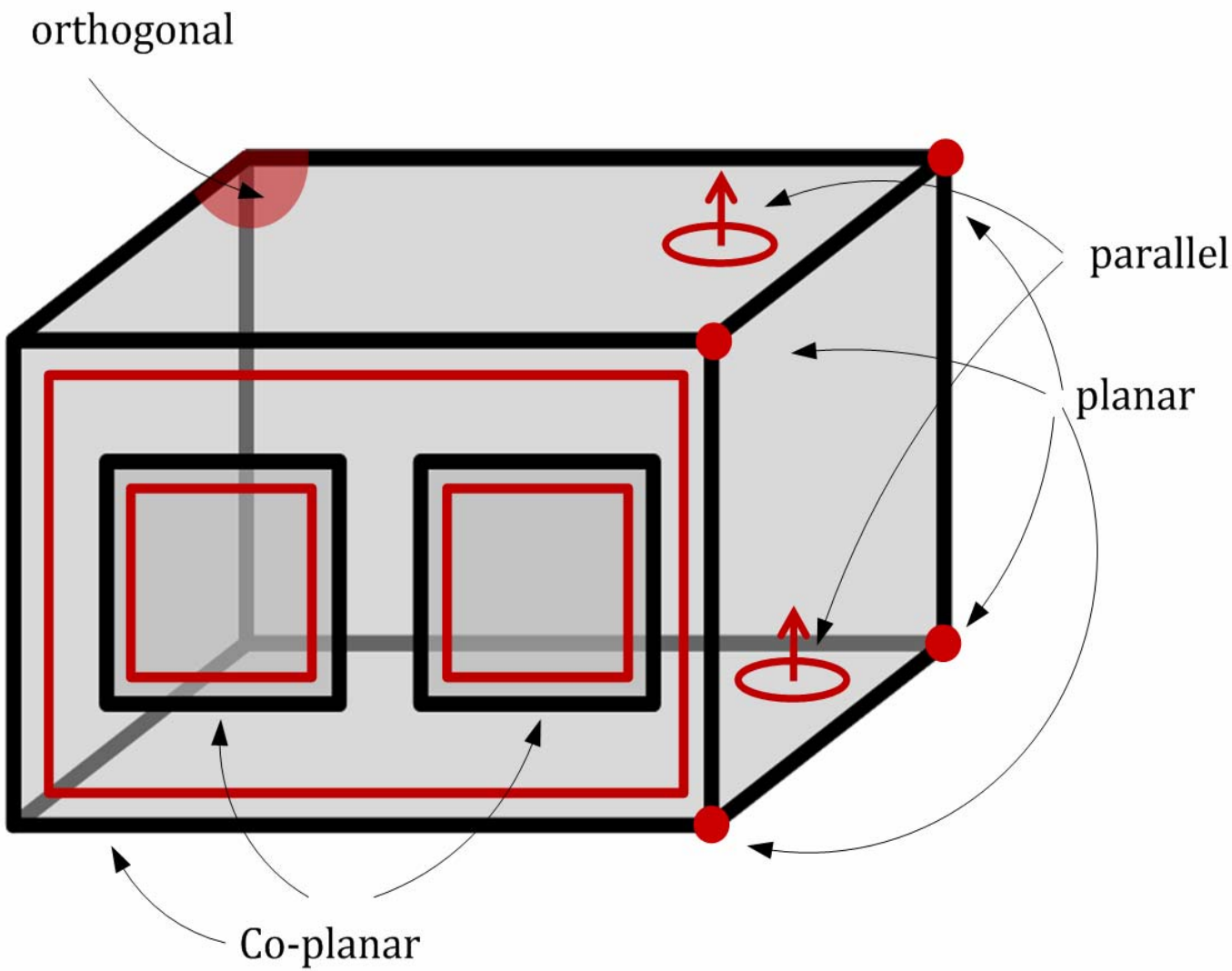
Motivation



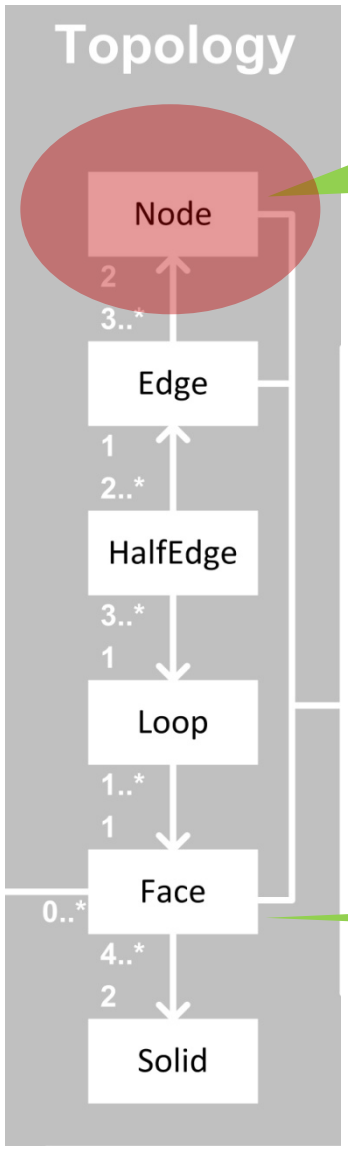
Topological Redundancy



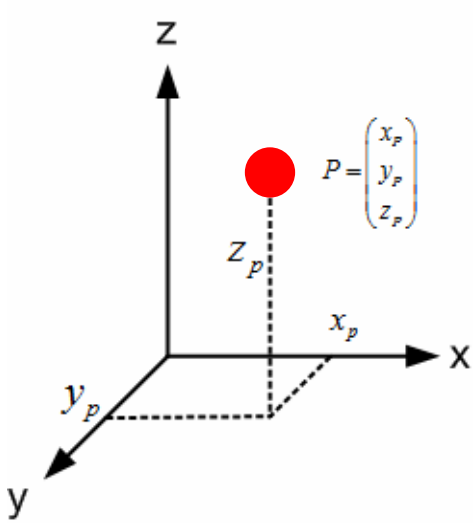
Geometrical Redundancy

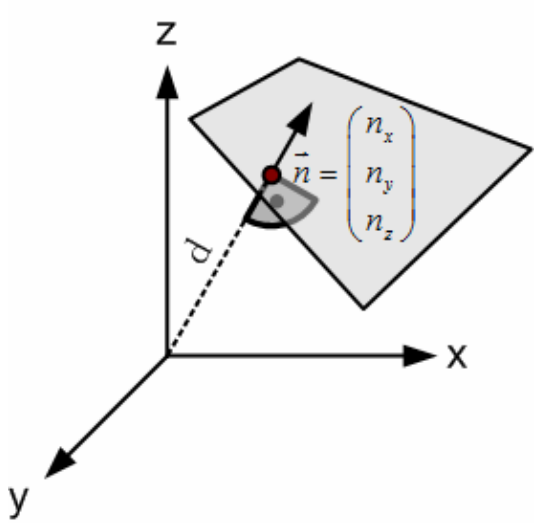


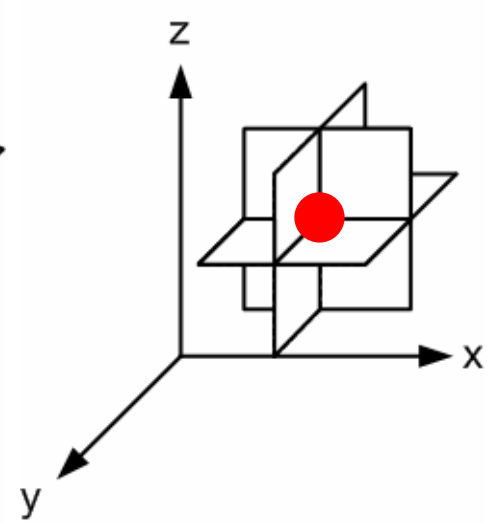
Plane-based parameterisation



Geometry:
x,y,z

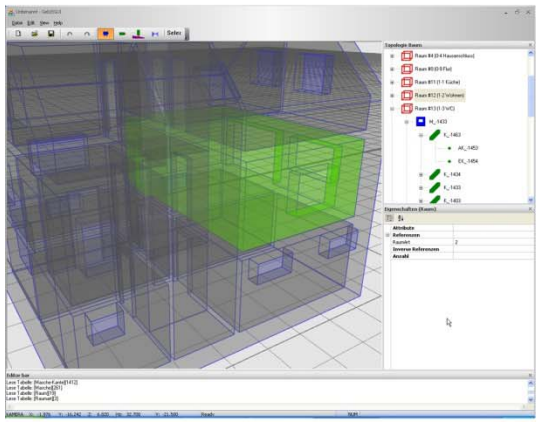


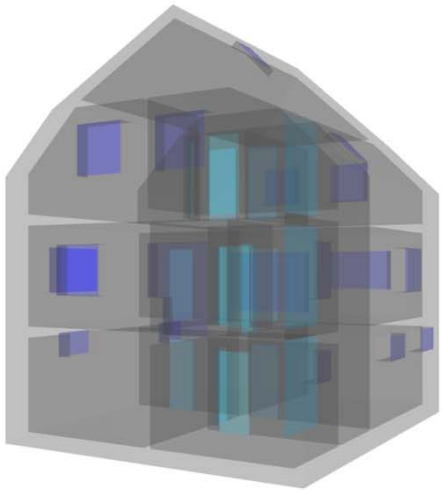


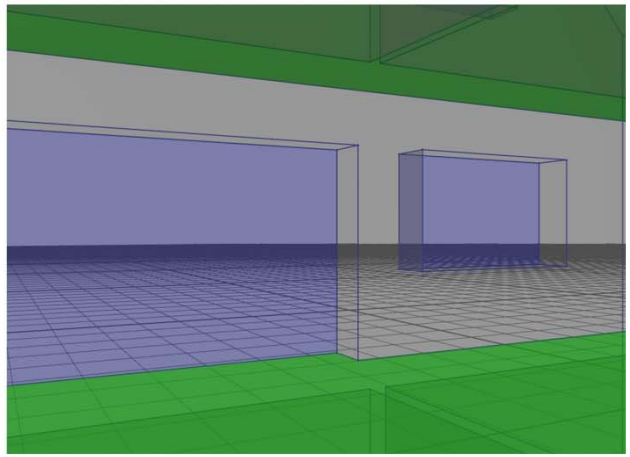


Geometry:
normal vector, rotation: n_x, n_y, n_z
translational displacement: d

Geometric normalization







Point based parameterization:
412 nodes -> **1236** coordinate values

Surfaced based parameterization:
104 d, **14** normal-vector values

Reduction: 91%

The fewer “unknowns” the fewer measurements

The three main concepts of a surveying 3d data model

1. Observations and Constraints are considered to be the primary data

- Geometric properties of 3d entities are derived (**estimated**) quantities
- Redundant observations allow for checking and optimisation
- Observations are modelled stochastically

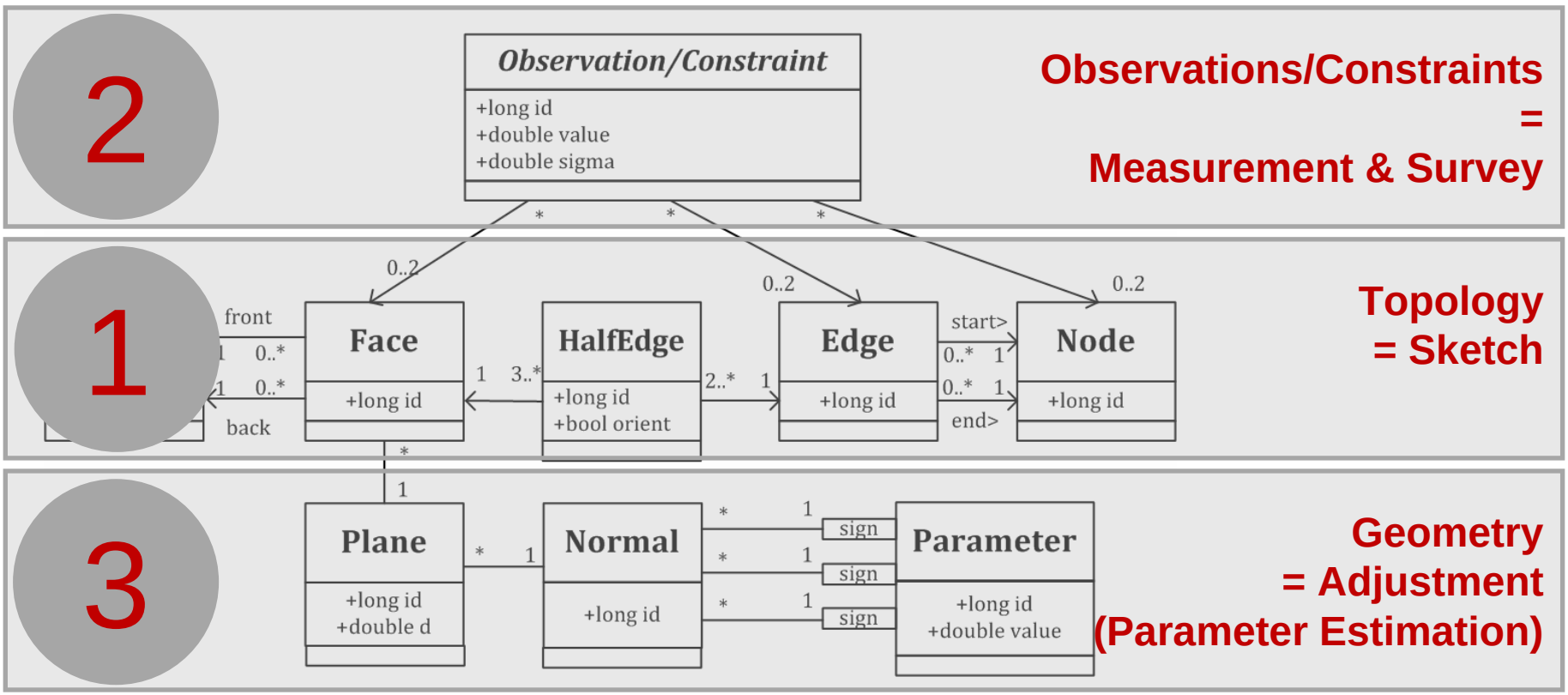
2. Surface-based (as apposed to point-based) parameterization

- Decreases geometric redundancy
- The fewer “unknowns” the fewer measurements

3. B-Rep Model with explicitly specified topology

- Topologic entities (nodes, edges, faces, solids) are used for surveying reasons (**identification**) and for geometric calculations i.e. **derivation of point co-ordinates**

Data Model - Workflow



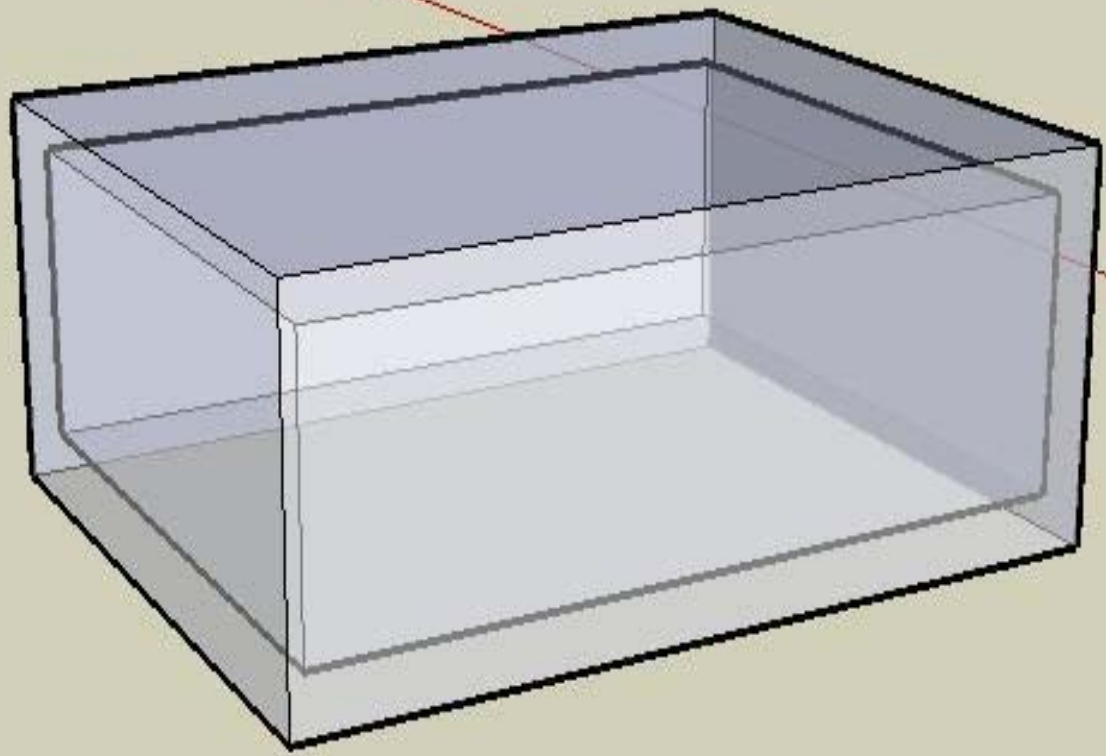
Topology = Sketch

The 3d-Designtool **Google SketchUp** is used for the sketch (Specification of the topologic primitives (node, edge, face) and topological structure)

Advantages:
- Free Software
- Easy to use for non-engineers
- Extensible (Ruby-Scripts)
- Open C/C++ API

Disadvantage:
- Not as restrictive as need for “real” CAD Model
- No surveying (measuring with geodetic instruments) capabilities

Topology = Sketch



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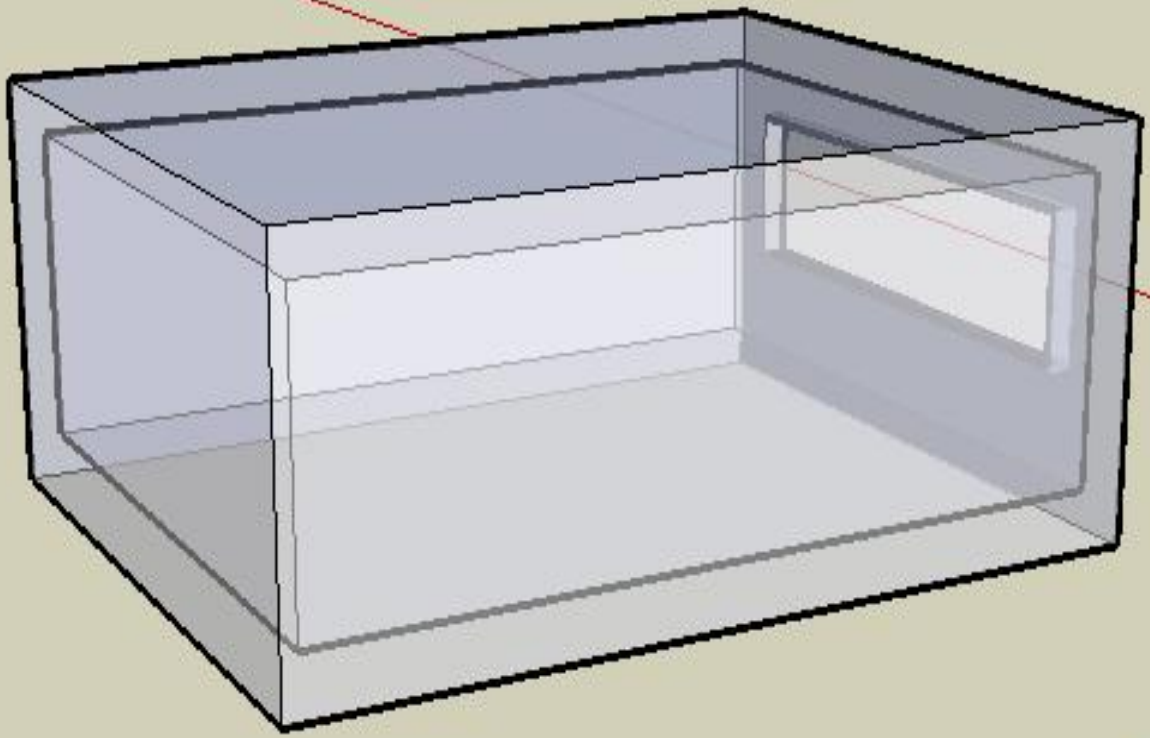

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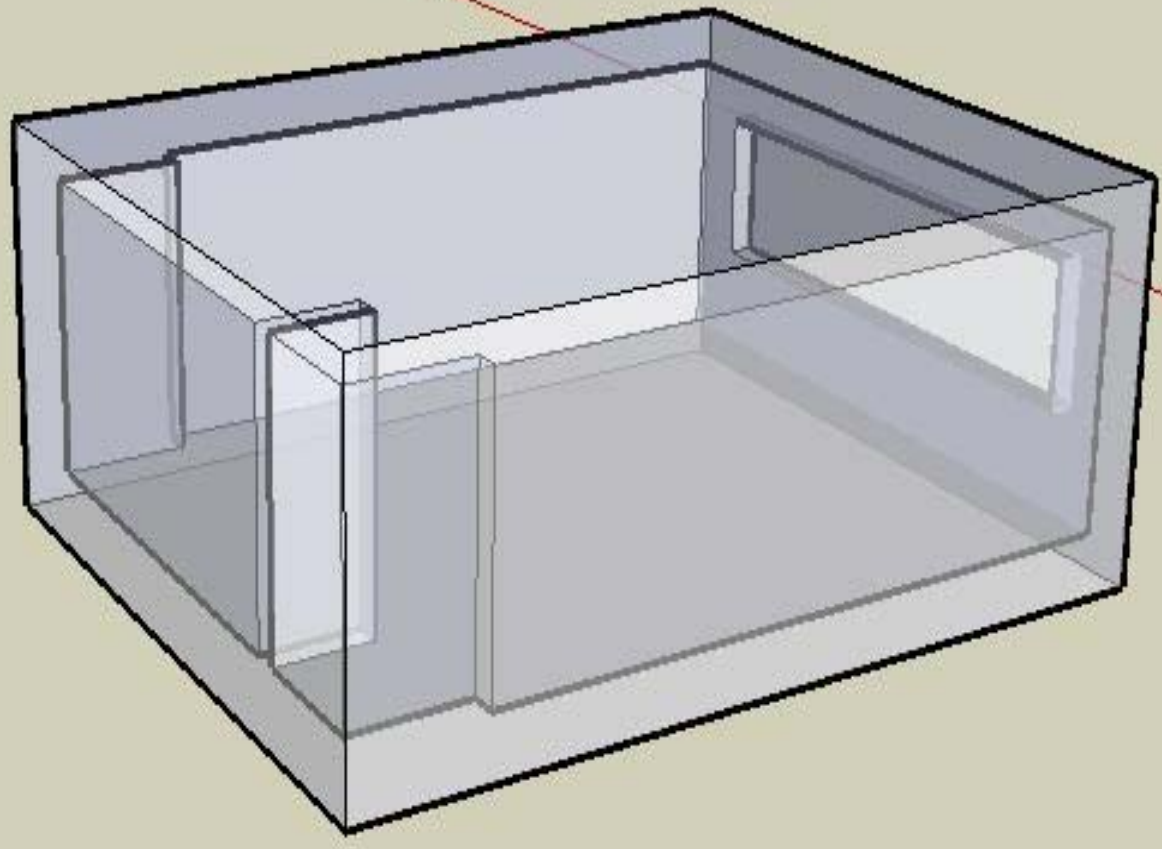

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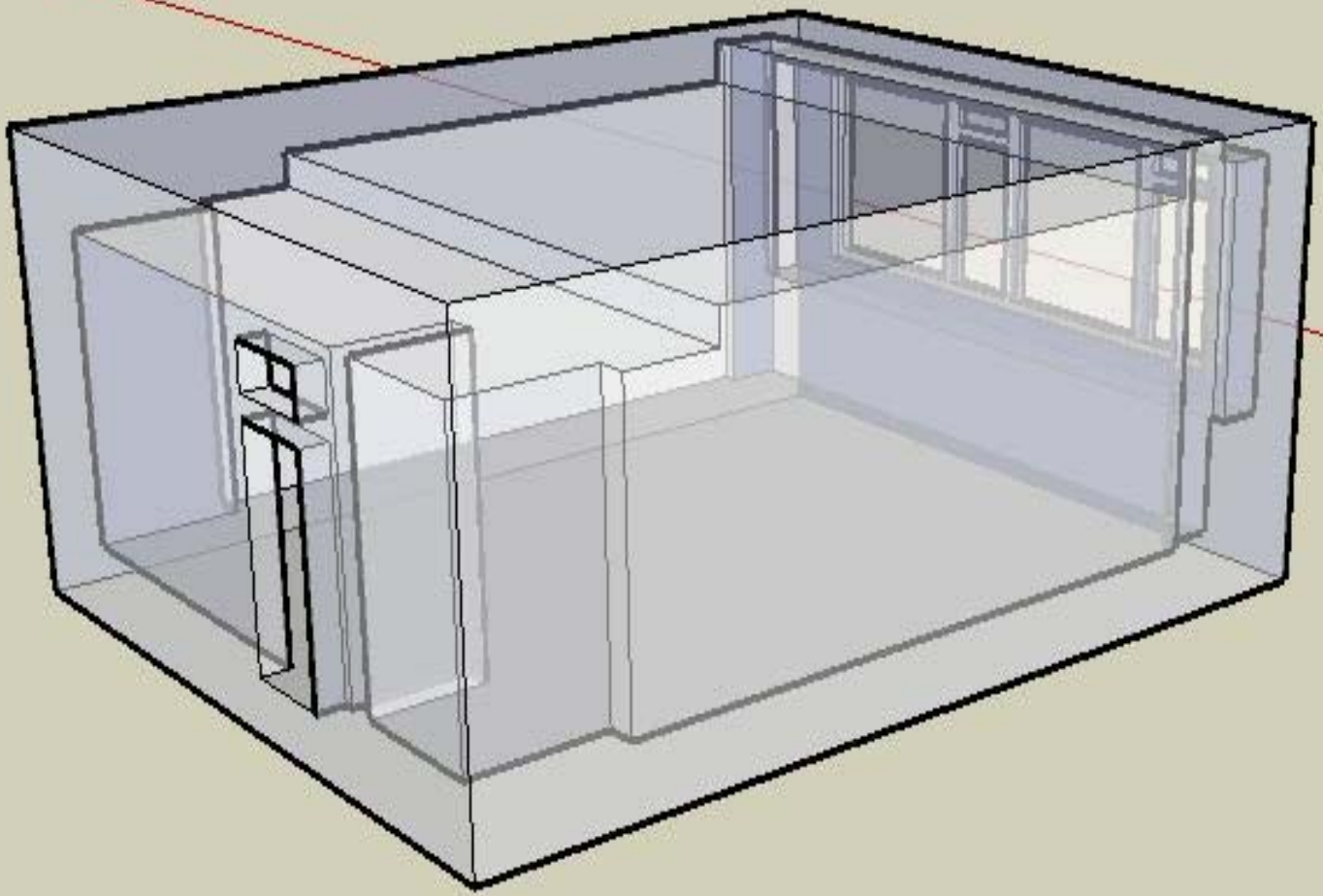
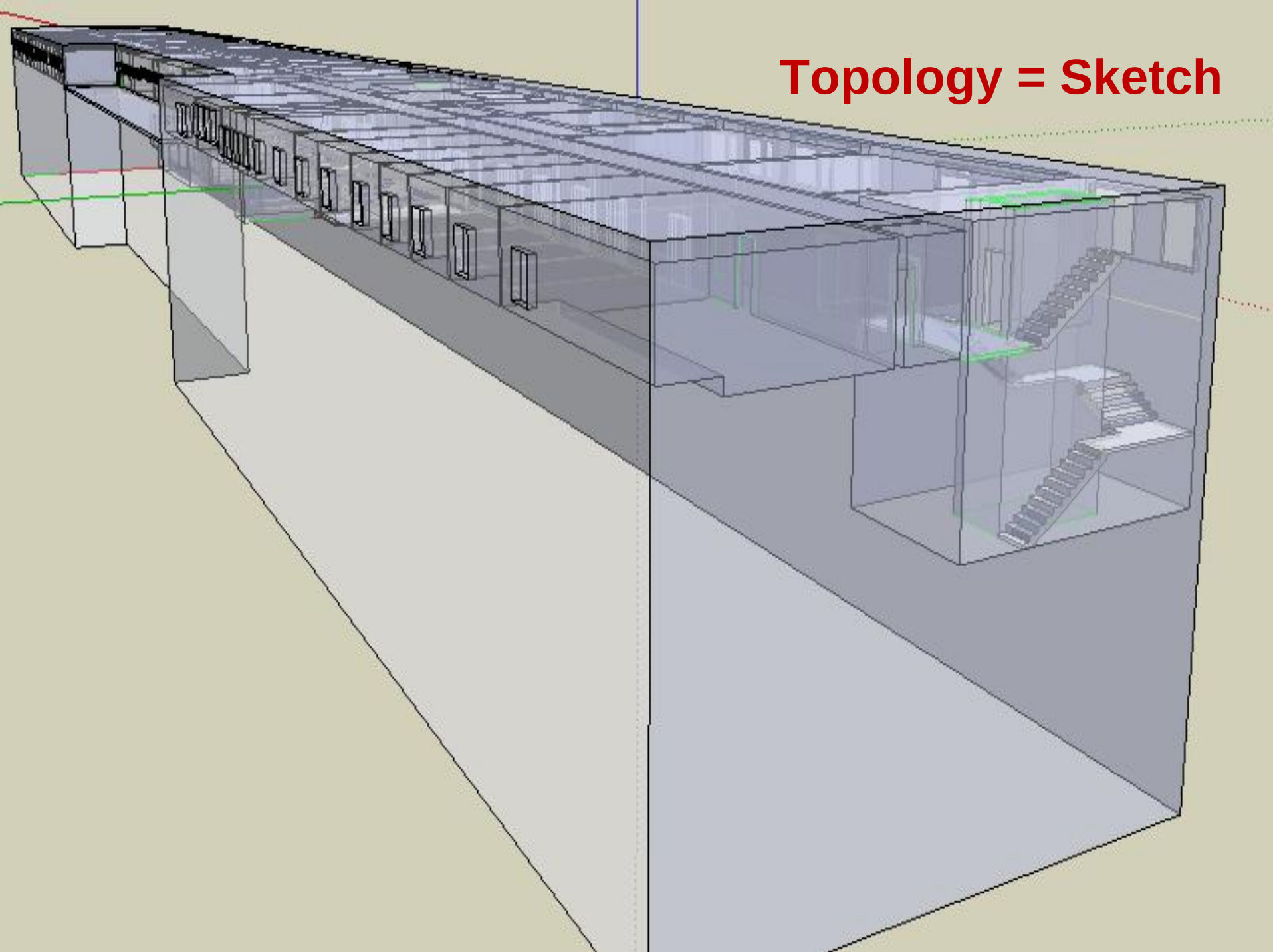
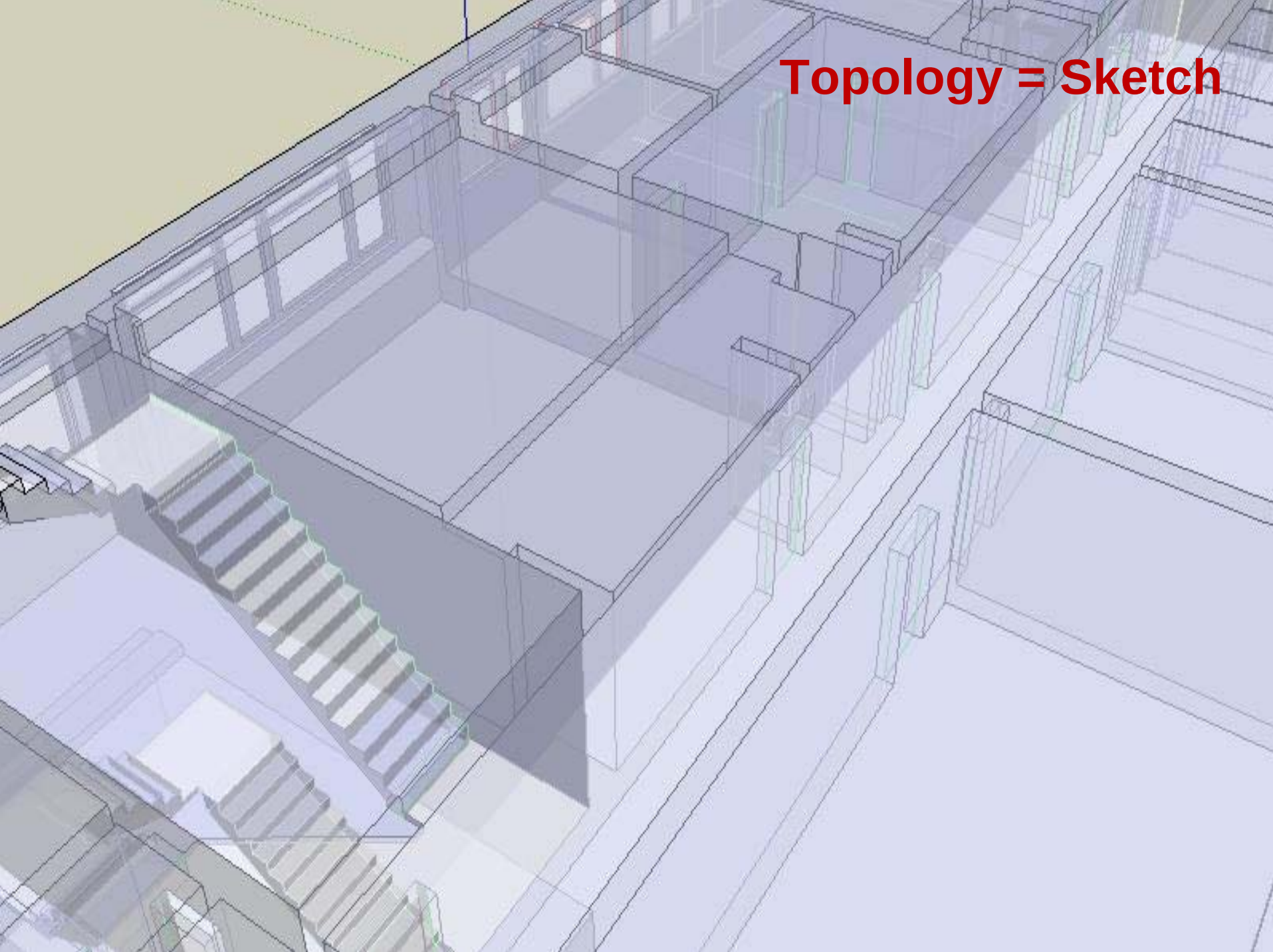
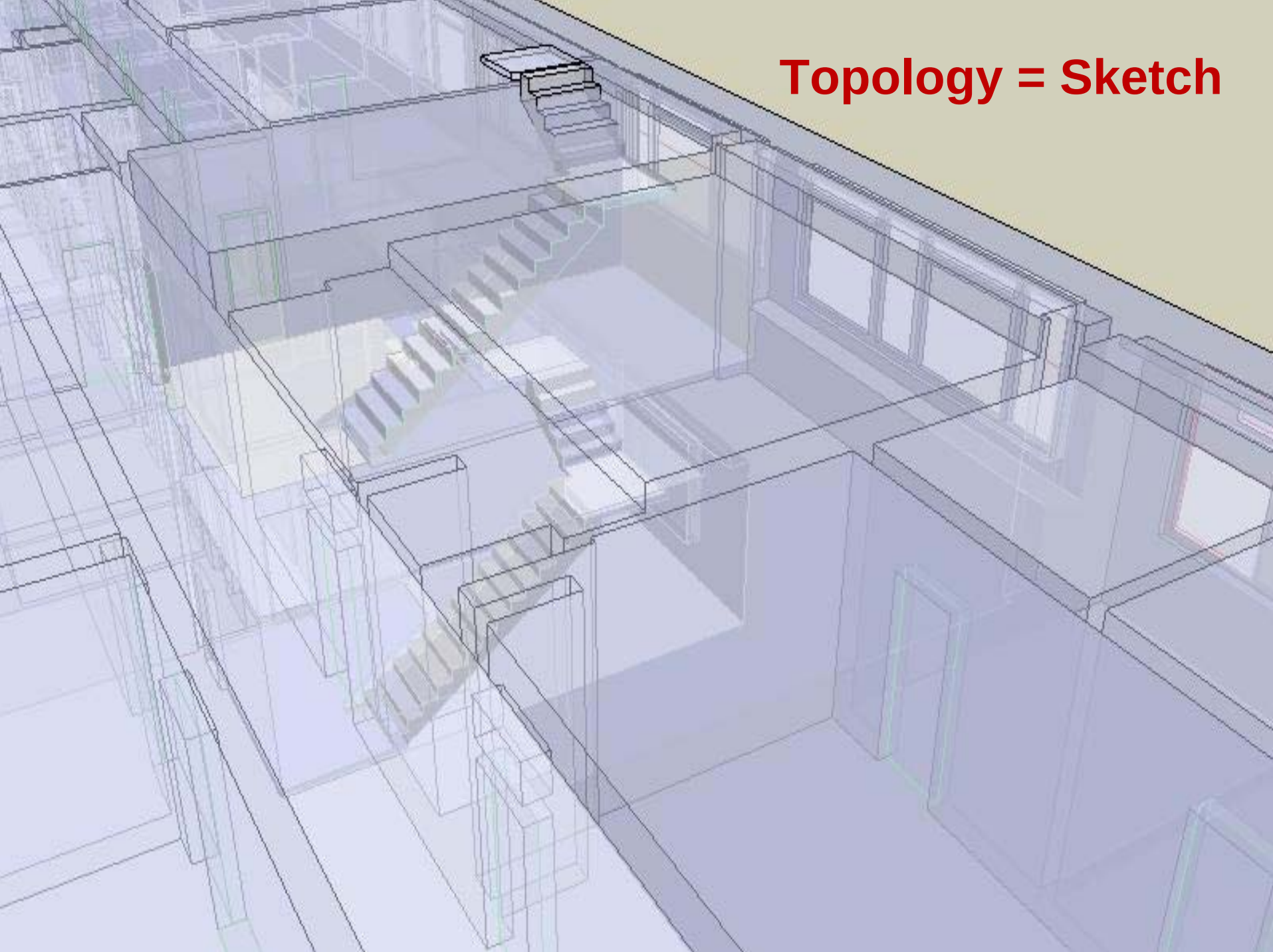



Topology = Sketch


Topology = Sketch


Topology = Sketch

Topology = Sketch

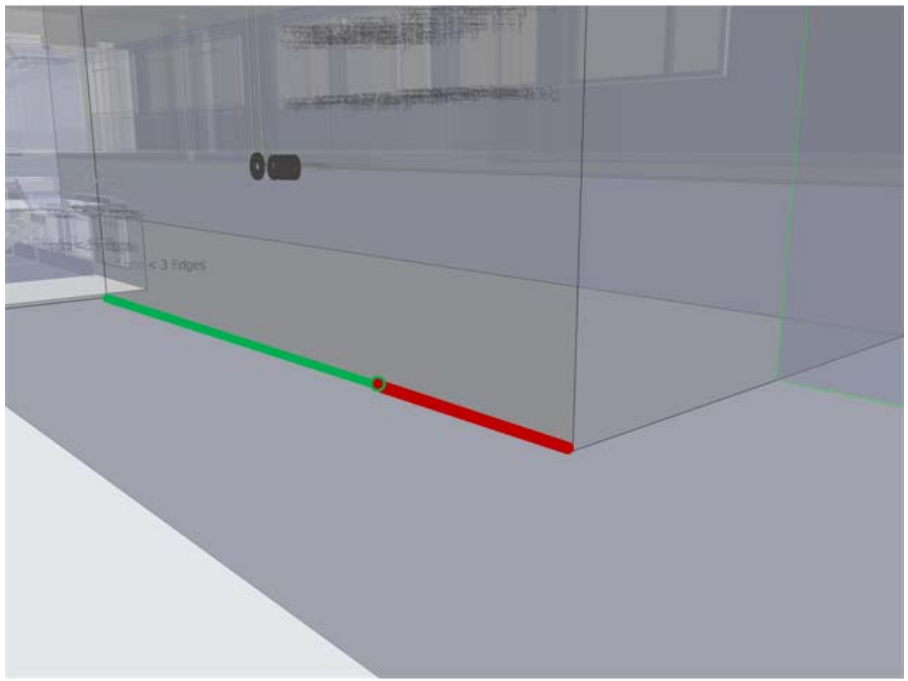
What do we have now?

- Topological structure of the (visible part of the) building

What do we have not?

- Topological consistent (CAD-like) model
- Correct Geometry (Model is a sketch!)

Topology = Sketch



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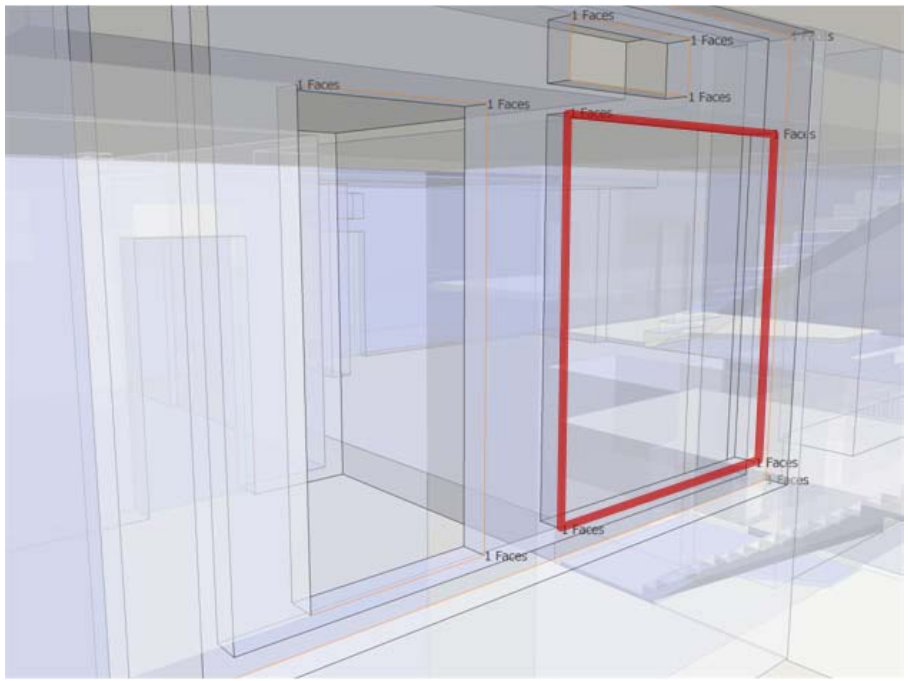
Added user support for **validation** of topology

- each node is connected to at least 3 edges -

Topology = Sketch



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What do we have **not**?

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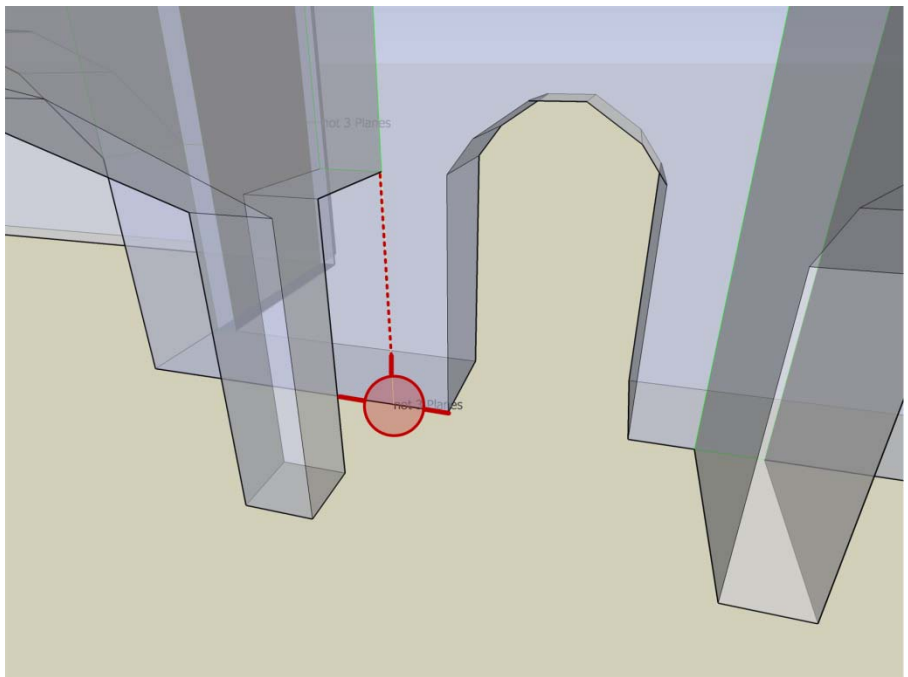
Added user support for **validation** of topology

- each edge is connected to at least 2 faces -

Topology = Sketch



What do we have now?

- Topological structure of the (visible part of the) building

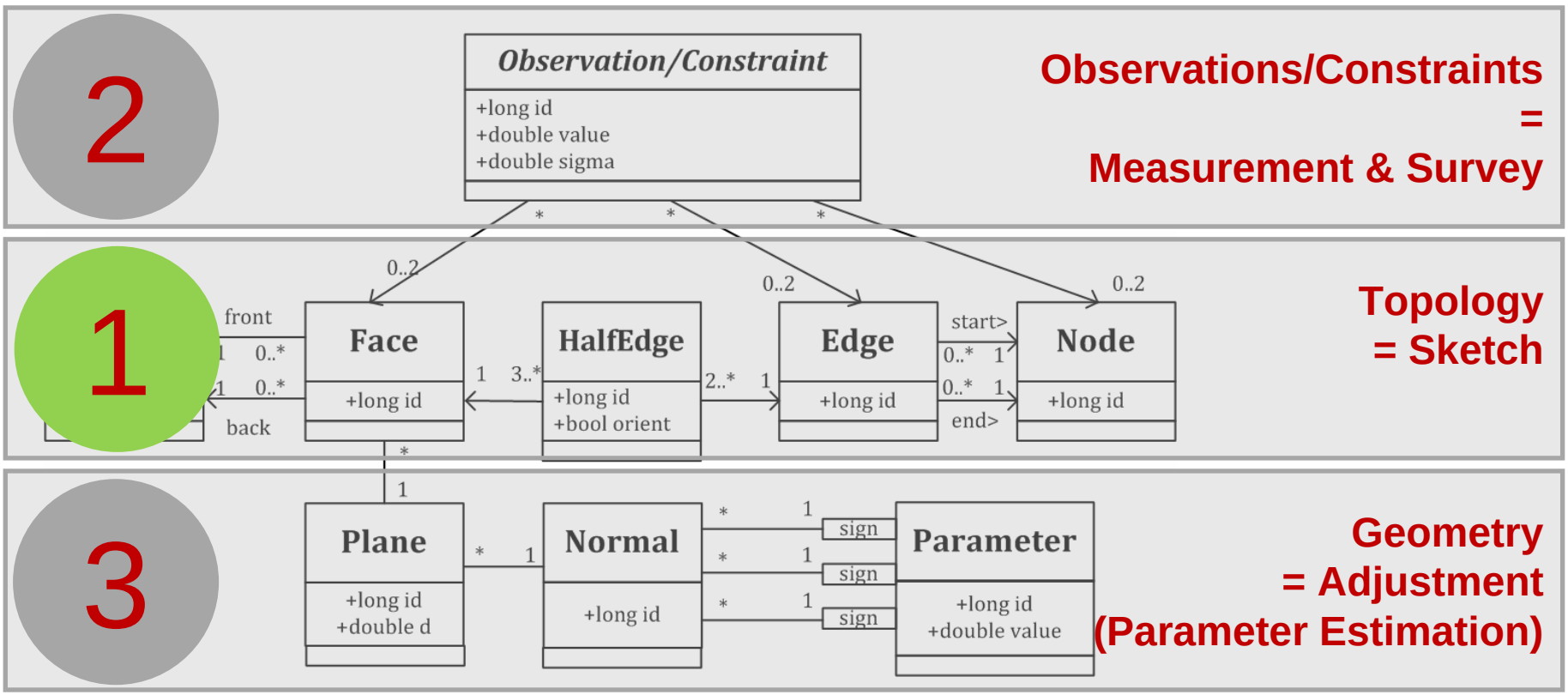
What do we have **not**?

- Topological consistent (CAD-like) model
- Correct Geometry (Model is a sketch!)

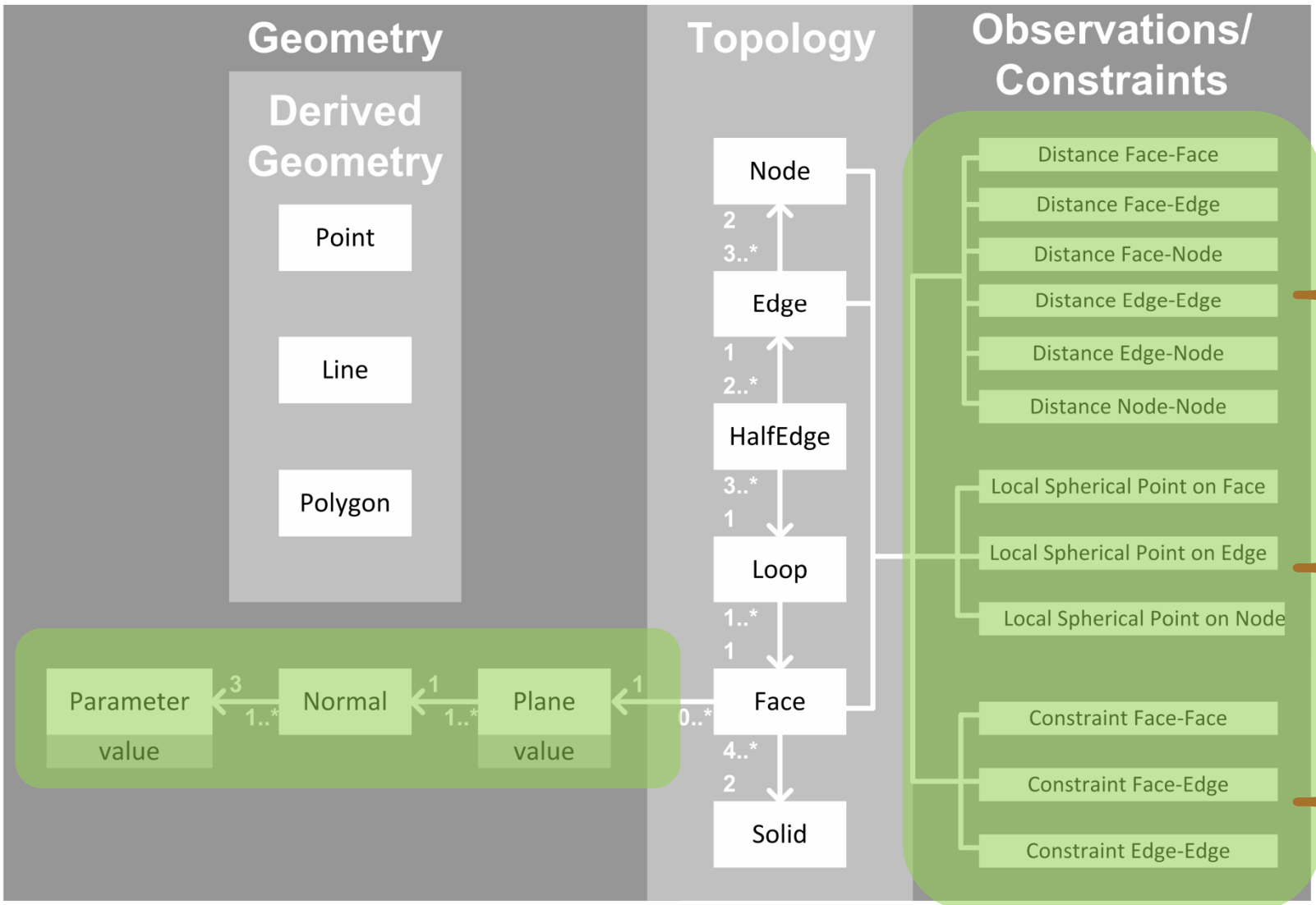
Added user support for **validation** of topology

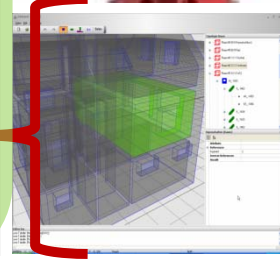
- each **edge** is an **intersection** of two non parallel planes -

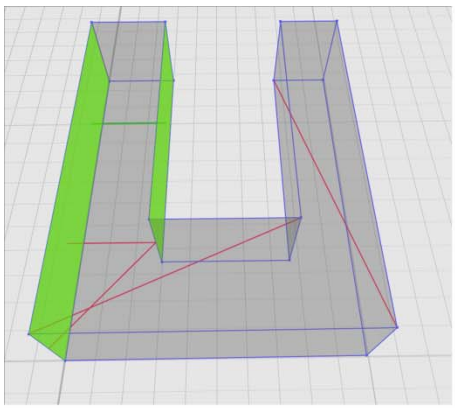
Data Model - Workflow



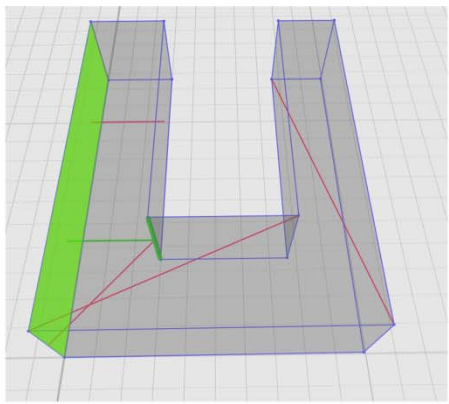
Adjustment – Integration to data model



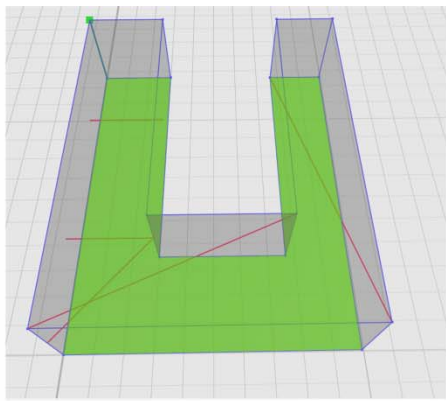




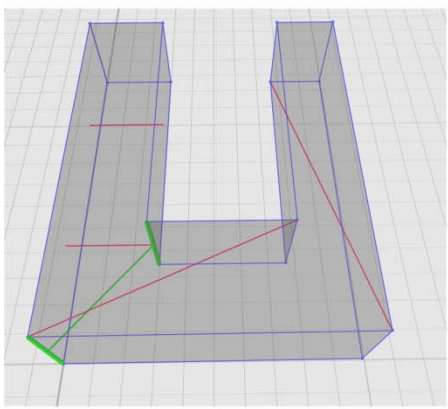
a)



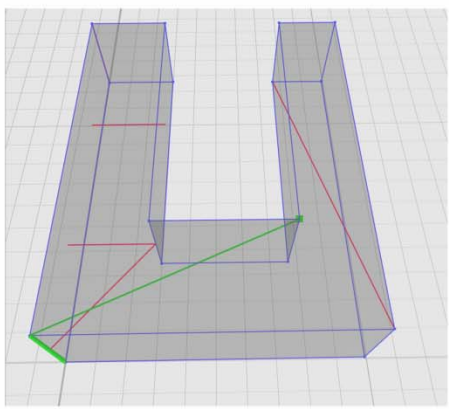
b)



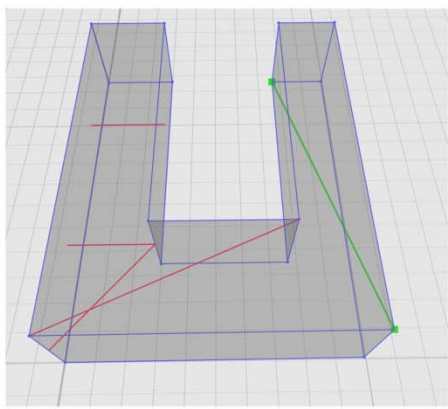
c)



d)

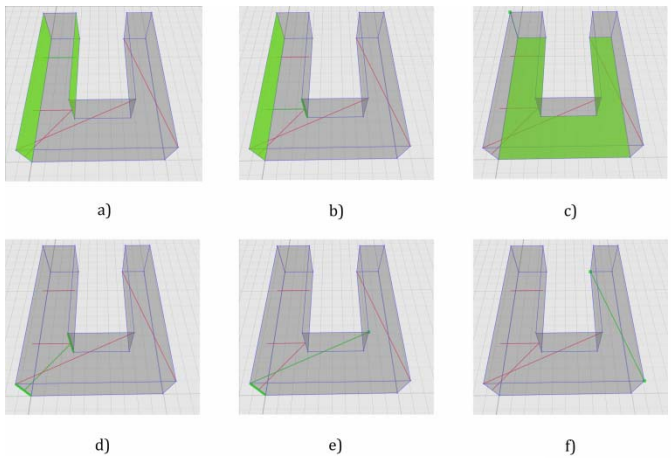


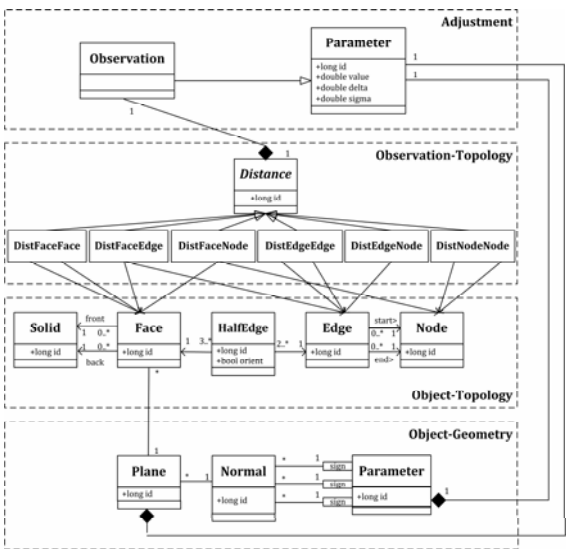
e)



f)

Measurement & Survey





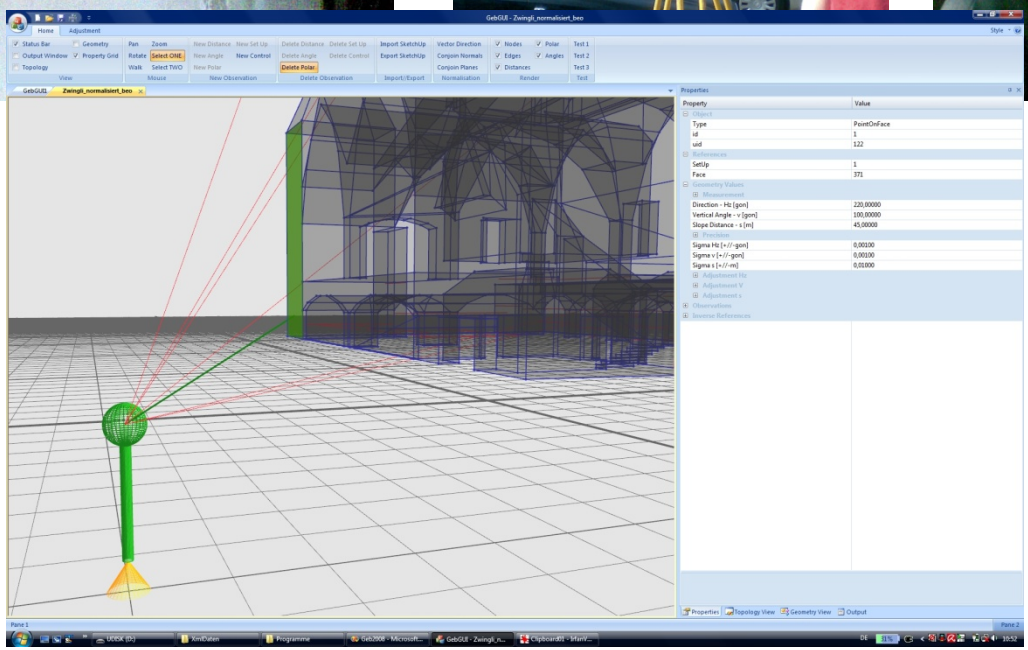
Integration to

- Data model
- Functional model (observation equation)
- GUI

$$l + v = d_i - (\overrightarrow{n_i}, \overrightarrow{p_{jki}})$$

$$\overrightarrow{p_{jki}} = \left[(\vec{n}_j, \vec{n}_k, \vec{n}_i)^T\right]^{-1} (d_j, d_k, d_i)^T$$

Measurement & Survey



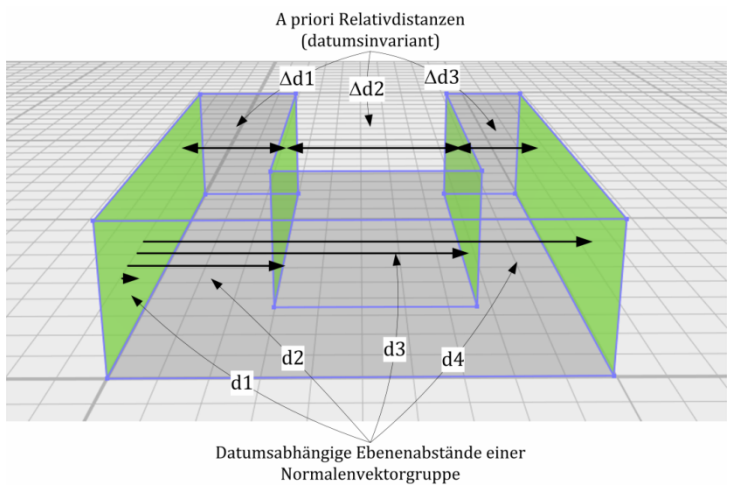
Soft Constraints (a priori)

Soft constraints are derived from the sketch

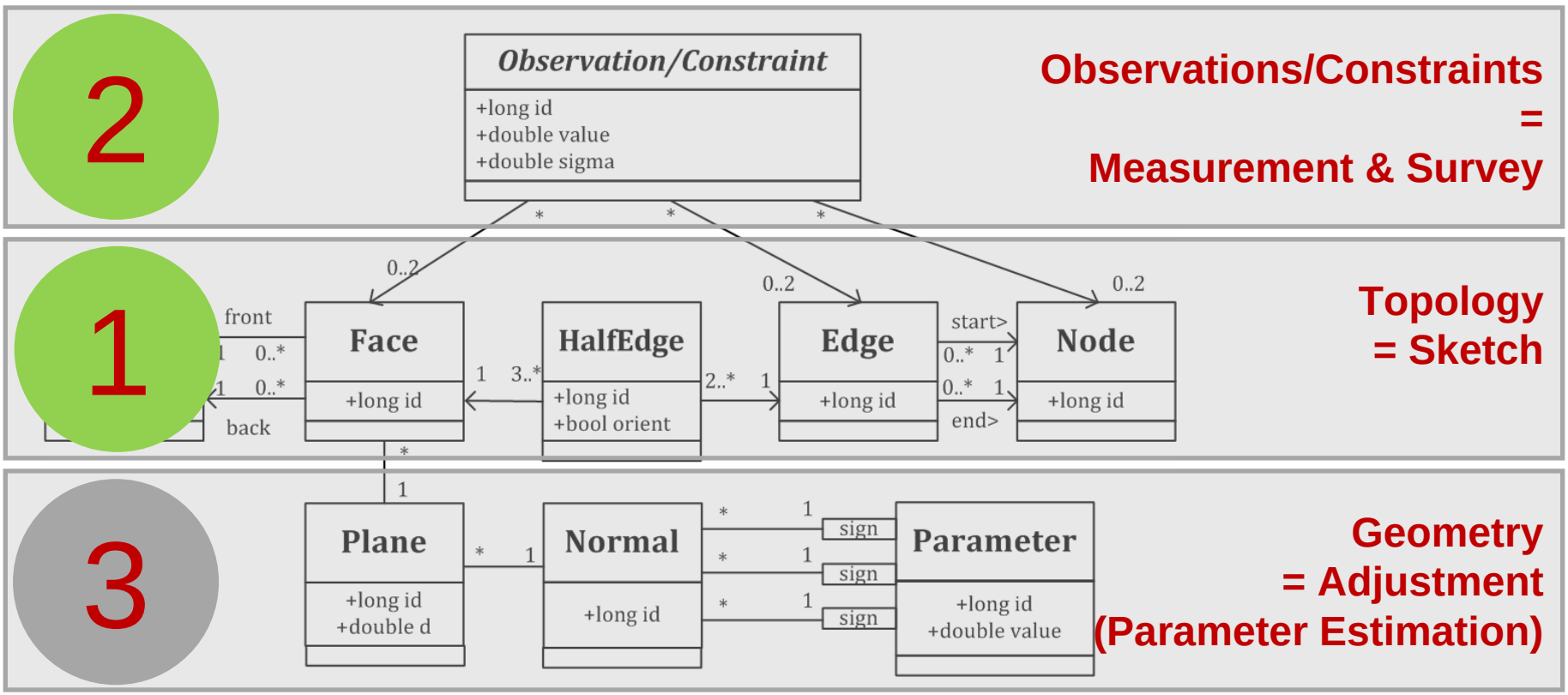
- A priori relative distances of parallel planes
- A priori relative angles between normals (in all combinations)

Why?

- Partial/selected improvement of geometric parameters

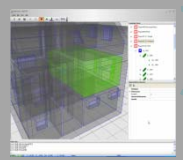


Data Model - Workflow



Adjustment – Input and Output

Measurements and Constraints



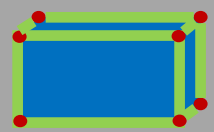
Random variables

Redundant

Stochastically modelled

explicitly specified

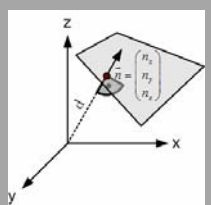
Topology



“best” result

Least-Squares Adjustment

Plane Parameters

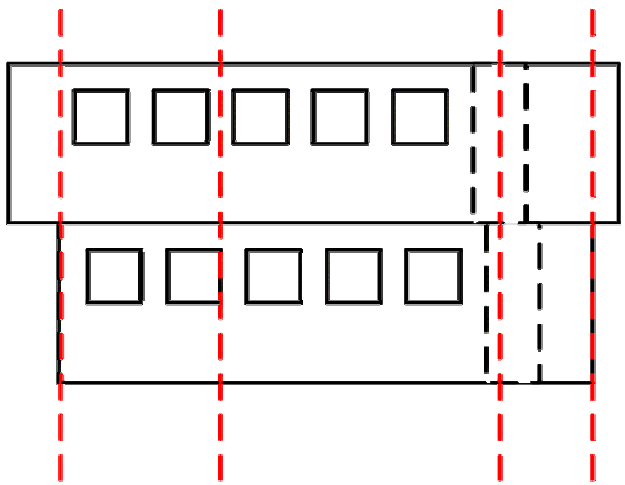


3d Model

Post Adjustment

Post Adjustment Statistics:

- Test the general goodness of fit and detect whether mistakes occur in observations or the functional/statistical model.
- Can help to transform 2d floor planes into **geometrically valid 3d models**
- Check the **geometric quality** of existing models (KML, CityGML, IFC) with just a few (or more, redundant) measurements.



The three main concepts of a surveying 3d data model

1. Observations and Constraints are considered to be the primary data

- Geometric properties of 3d entities are derived (**estimated**) quantities
- Redundant observations allow for checking and optimization
- Observations are stochastically uncorrelated

2. Surface-based (as apposed to point-based) parameterization

- Decreases geometric redundancy
- The fewer “unknowns” the fewer measurements

3. B-Rep Model with explicitly specified topology

- Topologic entities (nodes, edges, faces, solids) are used for surveying reasons (identification) and for geometric calculations i.e. derivation of point co-ordinates

...Thank you for your attention !