3D Modeling
3D Geometry, Topology and Semantics

Outline

1. **BIM – What is a model ?**
2. **Geometry:** Diversity in solid models affect the way a surveyor works!
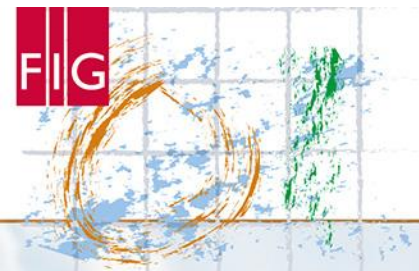3. **Topology:** Intelligent models help!
4. **Semantics:** Feel the power of the light side!
5. **Documentation:** Take care for the sidelined!

Christian Clemen (Germany): „**3D Geometry, Topology and Semantics**"

BIM != BIM

M

Three fundamental properties of a model

1. **Mapping**: Models are always models <u>of something</u>, i.e. mappings from, representations of natural or artificial originals

- Physical and Functional properties of a planned or excisting building …more general: built environment.
- Assets, needed to operate a building or infrastructure
- Planned or fulfilled work (process) of design, procurement and construction
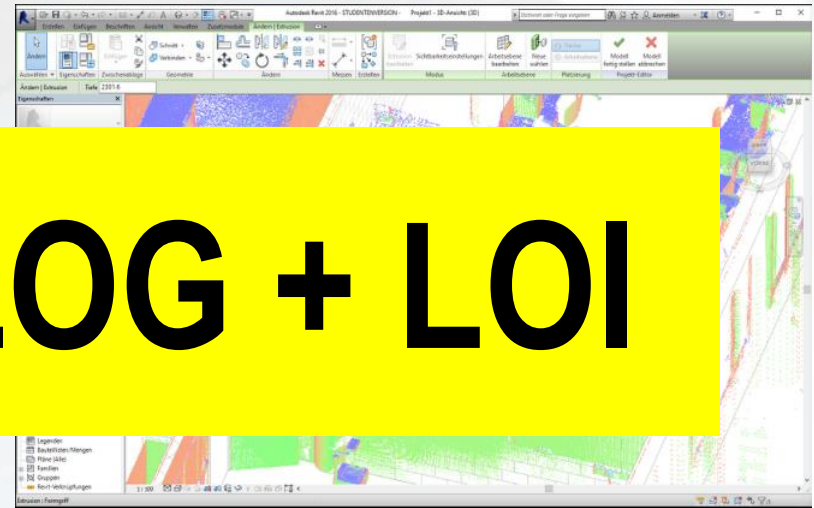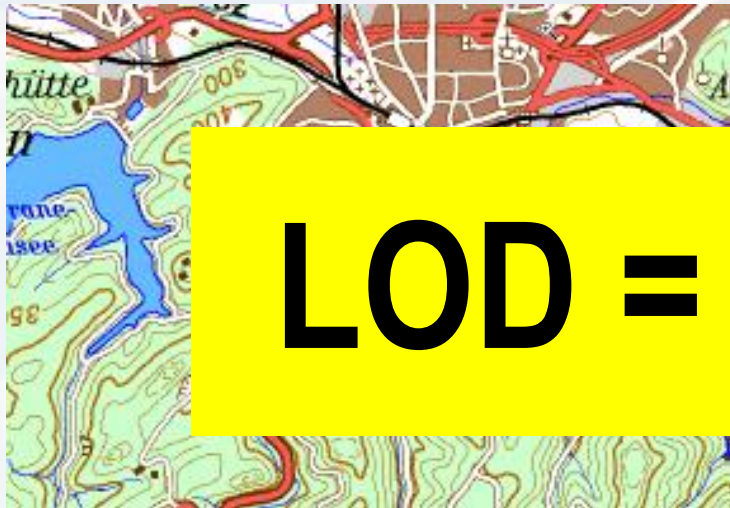- Costs and <u>profit</u>

Stachowiak, H., 1973, „Allgemeine Modelltheorie", translation from: https://modelpractice.wordpress.com/2012/07/04/model-stachowiak/
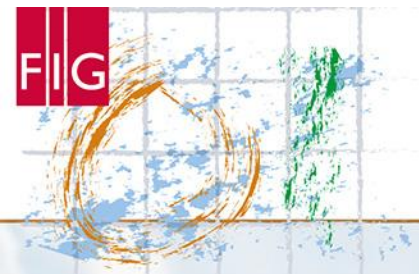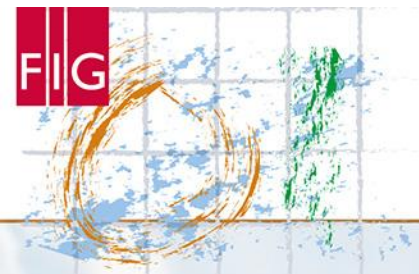
Three fundamental properties of a model

1. **Mapping**

2. **Reduction**: Models in general capture <u>not all</u> attributes of the original represented by them

https://www.bkg.bund.de/

Bundesamt für Kartographie und Geodäsie

LOD = LOG + LOI

Stachowiak, H., 1973, „Allgemeine Modelltheorie", translation from: https://modelpractice.wordpress.com/2012/07/04/model-stachowiak/
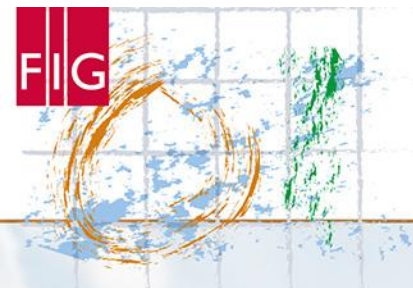
Three fundamental properties of a model

1. **Mapping**

2. **Reduction**

3. **Pragmatism**: Models are not uniquely assigned to their originals per se. They fulfill their replacement function …

   a) …for <u>particular</u> cognitive and/or acting model using <u>subjects</u>

   b) …within <u>particular time intervals</u> and

   c) …restricted to <u>particular mental or actual operations</u>.
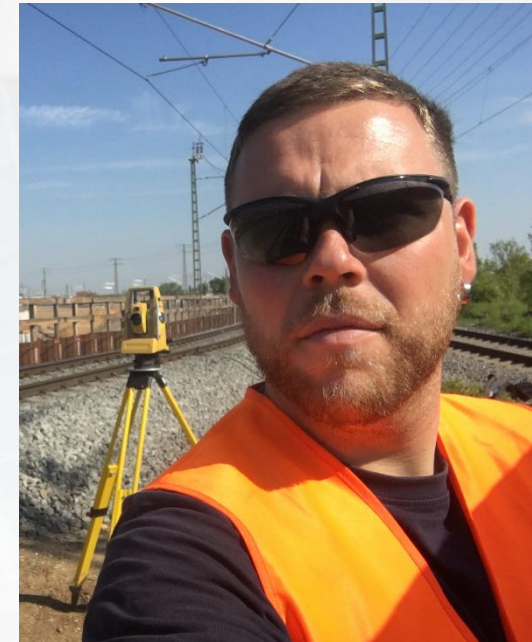
Stachowiak, H., 1973, „Allgemeine Modelltheorie", translation from: https://modelpractice.wordpress.com/2012/07/04/model-stachowiak/
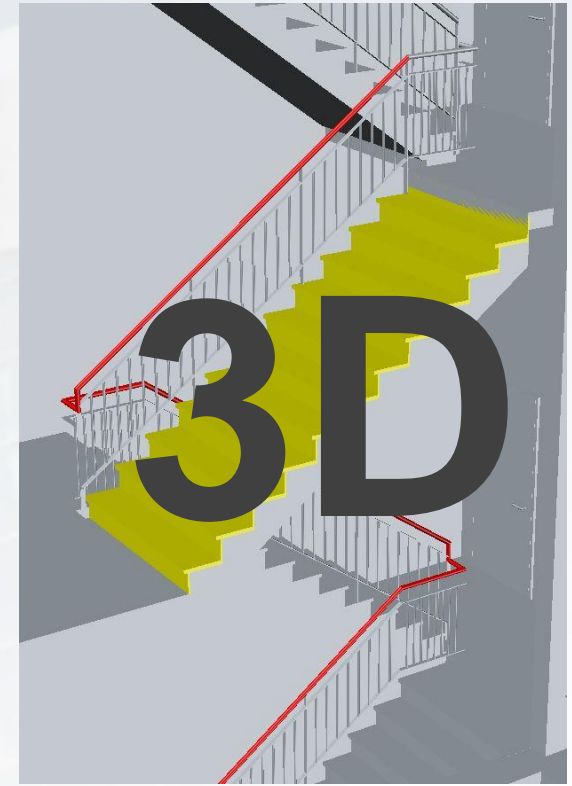
BIM == 3D

3D?

1D

2D

3D

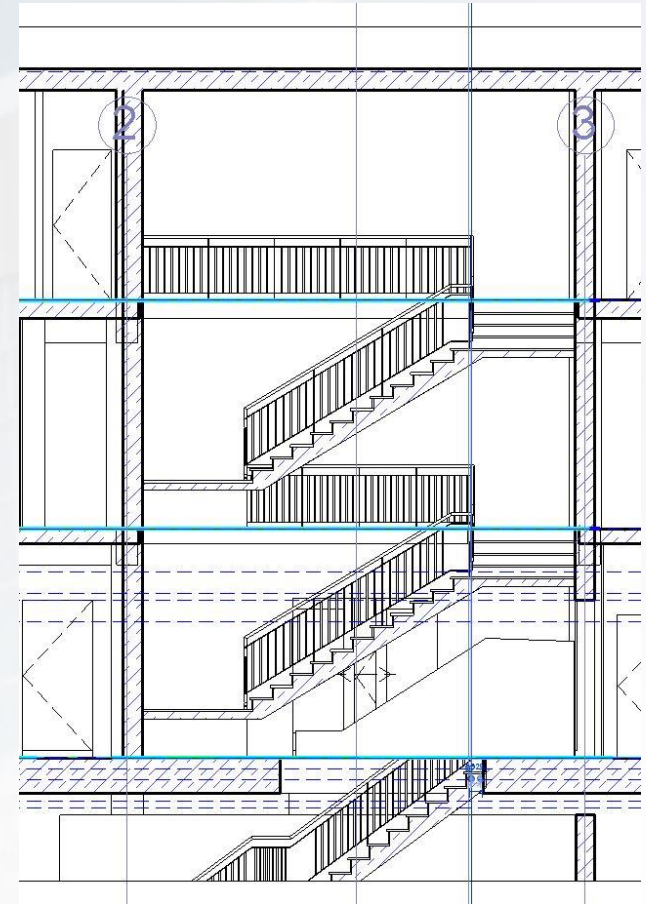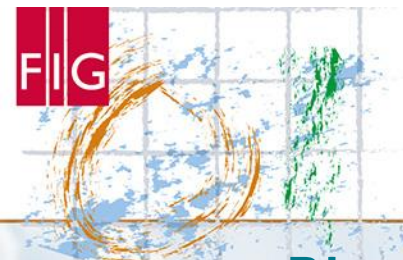**Wireframe**
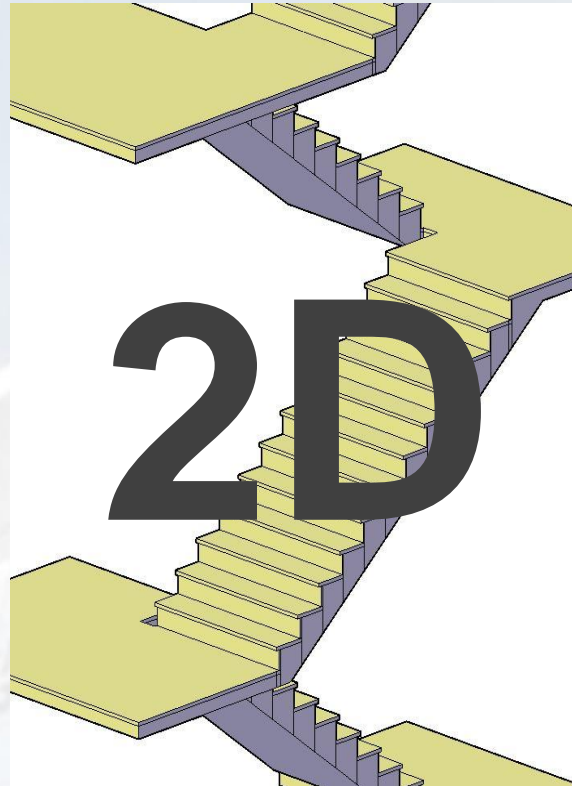
Surface

Solid

Diversity in solid models affect the way surveyors work!

Why solid modeling ?

a) Derivation of **quantities** (e.g. concrete volume) for technical reasons and cost estimation

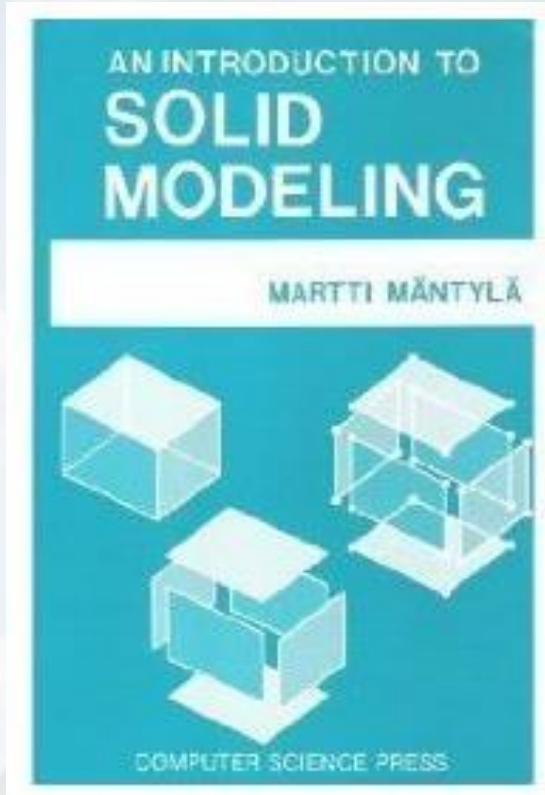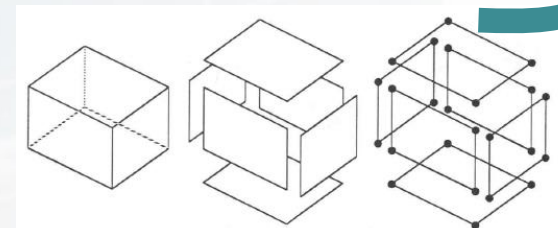b) Derivation of **2D-drawings** e.g. floorplans, section views, elevations with proper hatching

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Diversity in solid models affect the way surveyors work!

Taxonomy for solid models
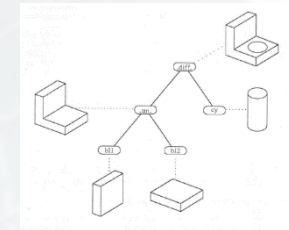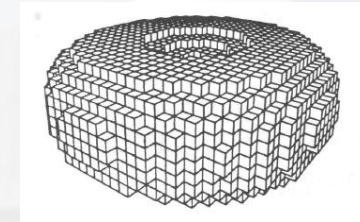
hybrid!

Mäntylä, M: An Introduction to Solid Modeling, Computer Science Press, 1988

Christian Clemen (Germany): „**3D Geometry, Topology and Semantics"**

Diversity in solid models affect the way surveyors work!

Decomposition models:
- Set of n-cells (e.g. voxel)
- Objects are created by „glueing"
- <u>Coordinates</u> by space partitioning schema (voxel number)
- e.g.Geology, <u>not used </u>in BIM
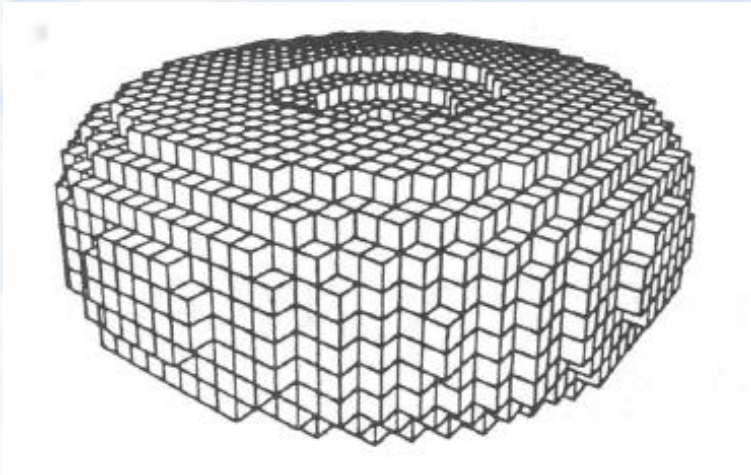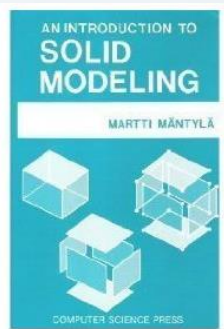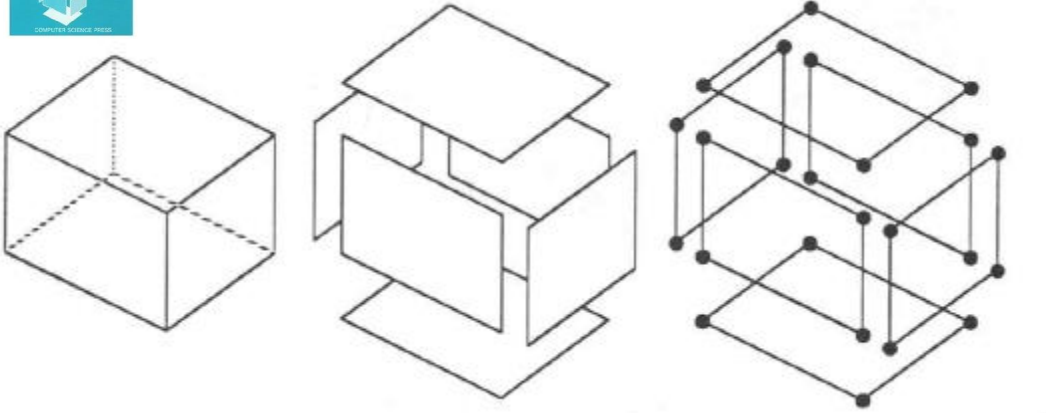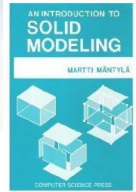

Mäntylä, M: An Introduction to Solid Modeling, Computer Science Press, 1988

Diversity in solid models affect the way surveyors work!

Boundary models:
- B-Rep
- Solid
  - Surface
    - Curve
      - Point

- 3D-<u>Coordinates</u> are given in points (absolut or relativ)
- Surfaces can be <u>measured</u> (TLS)
- <u>Seldomly</u> used in BIM (e.g. to discribe a volume of a single room, not for components (like walls)

Mäntylä, M: An Introduction to Solid Modeling, Computer Science Press, 1988

Christian Clemen (Germany): „**3D Geometry, Topology and Semantics**"

Diversity in solid models affect the way surveyors work!

Constructive models:
- Combination of <u>primitives</u> and <u>operations</u>
- The <u>generation</u> of the model is stored, not the result
- Only a <u>few coordinates </u>are directely given
- <u>Invisible</u> elements are modeled (e.g. voids for windows)
- <u>The BIM solid model type </u>!!!!!!!

Mäntylä, M: An Introduction to Solid Modeling, Computer Science Press, 1988
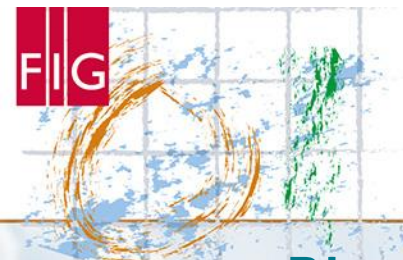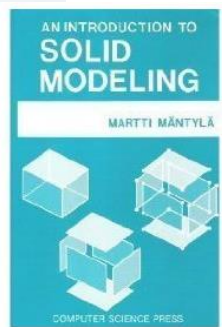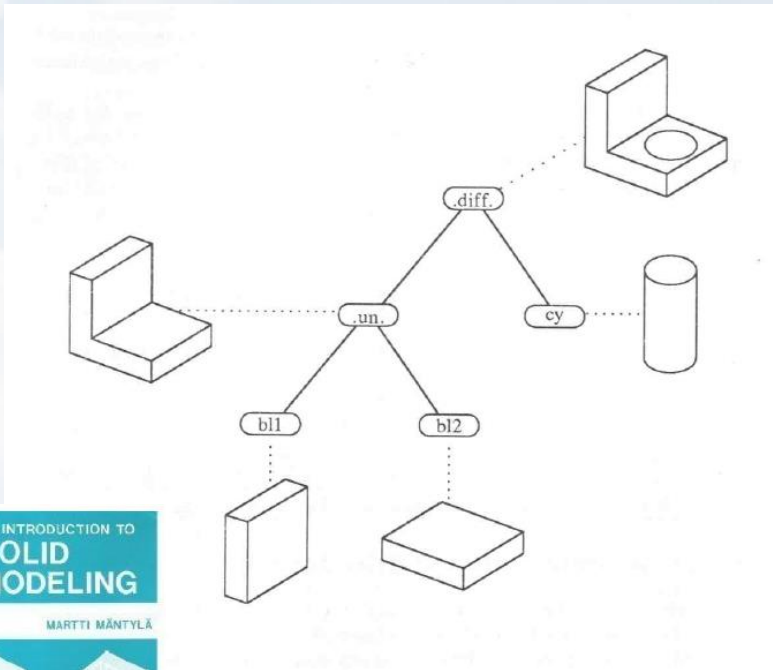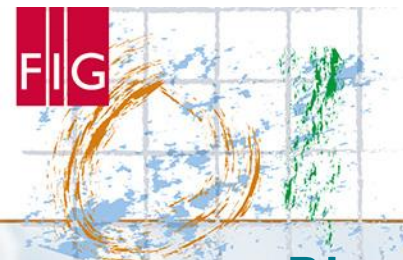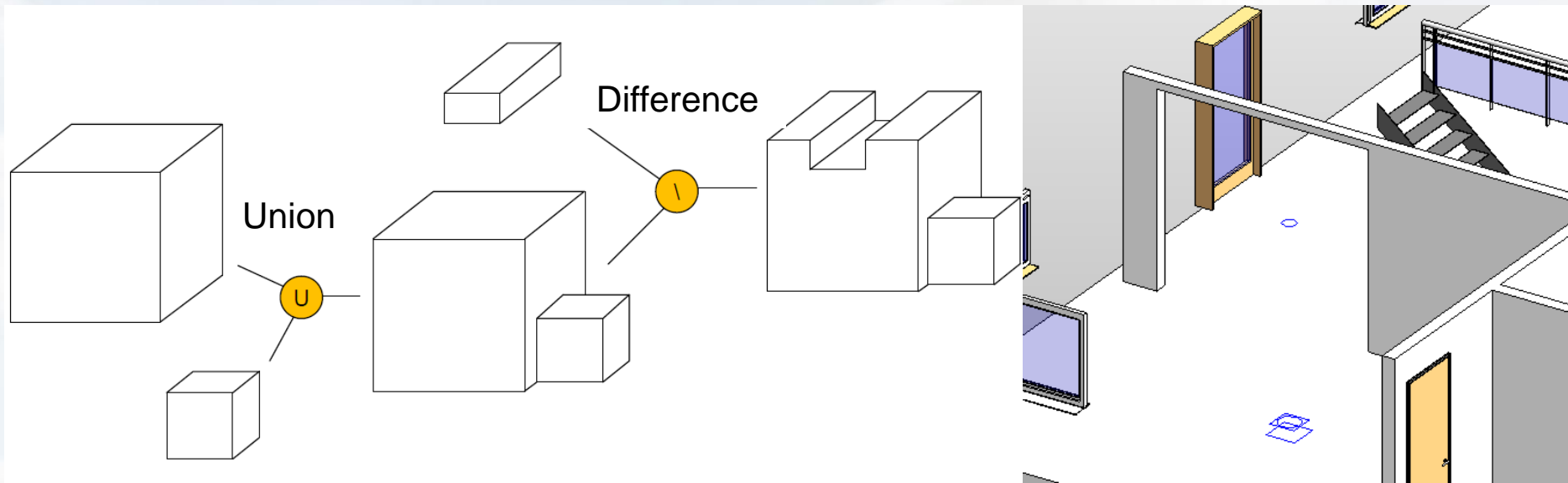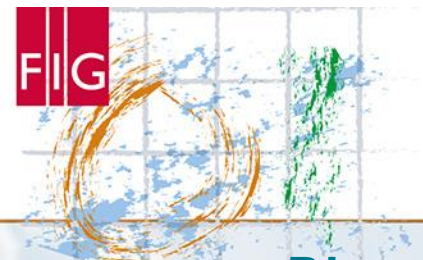
Diversity in solid models affect the way surveyors work!
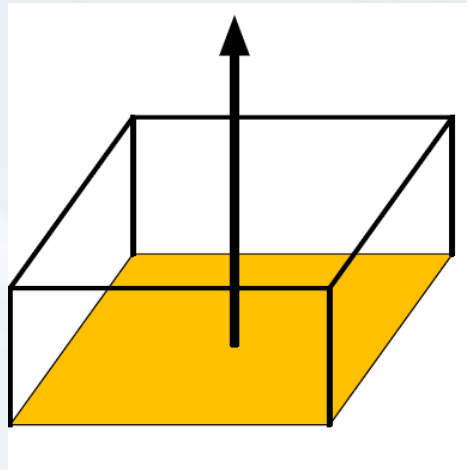
Constructive Solid Geometry (CSG)

e.g.: Wall (solid) \ void (solid) = Wall with opening (solid)

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Diversity in solid models affect the way surveyors work!
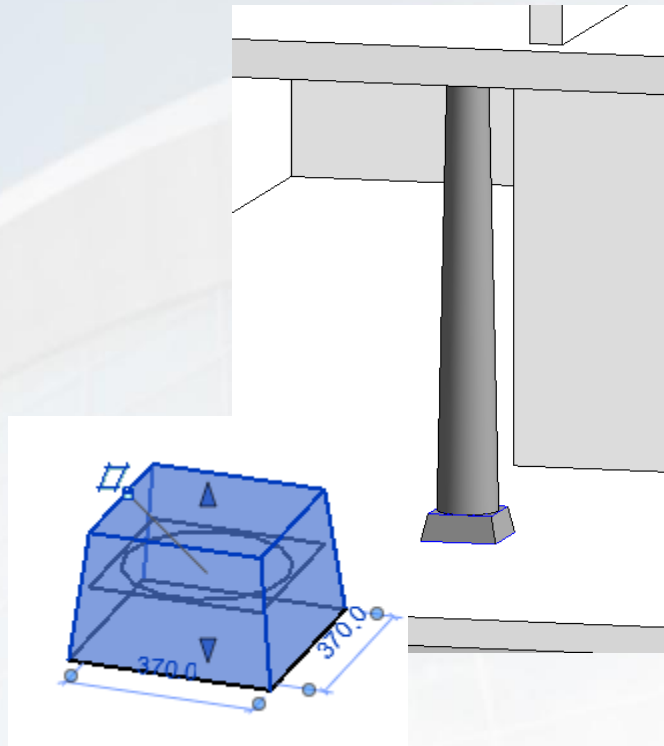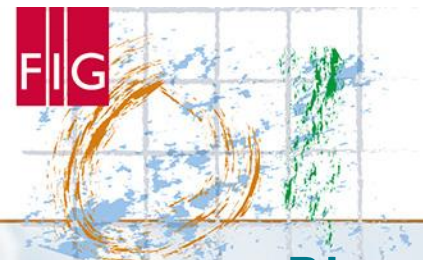
Sweep

extrusion and rotation

Primitive = surface
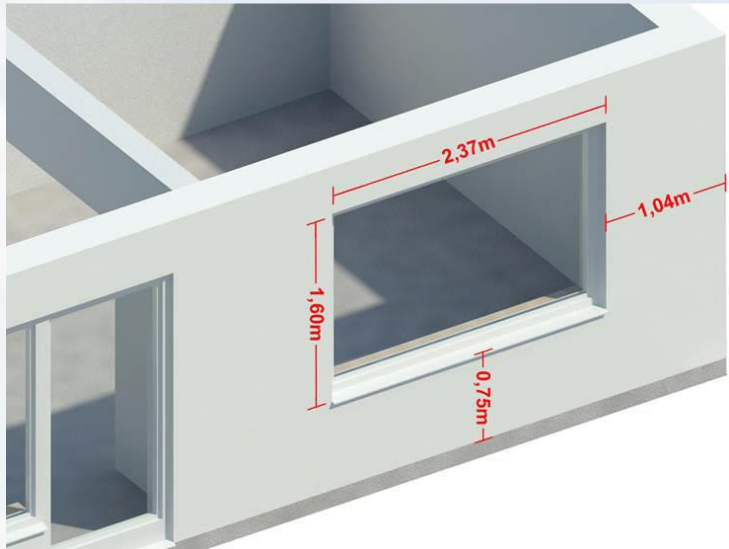
Operation = movement along a given vector or path

**Primitive** = Polygons (Plinth) and circels (column), **Operation** = fusion, close

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Diversity in solid models affect the way surveyors work!

Parametric modedeling

Parametric Modeling:

- <u>The major BIM solid model construction type</u> !!!!
- Solid (volumetric) objects with a given set of parameters (width, height, length,….)
- …. but limited number of parameters
- Parameter <u>values</u> are related to the type <u>or</u> the instance of a type
- Designing and managing paramerizised components is a major task in BIM project

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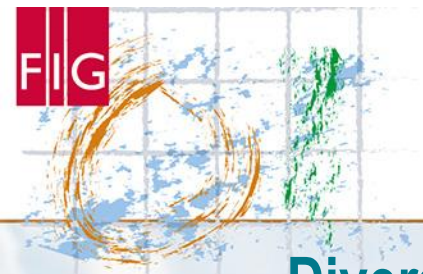
Diversity in solid models affect the way surveyors work!
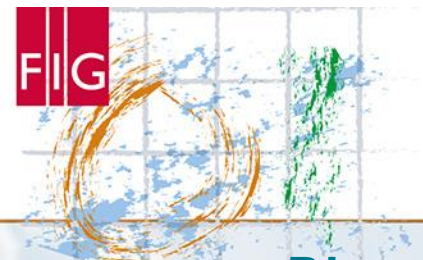
Parametric Modeling (cont.):
- Based in rules
- Stongly connected to the semantic (Is the object a wall or a window?)

Surveyor:
- Rules can be used for <u>survey/model control</u> (clash detection)
- Has to <u>deliver closed</u> solid components (… with the „back" of solids, although these sides have not been measured)

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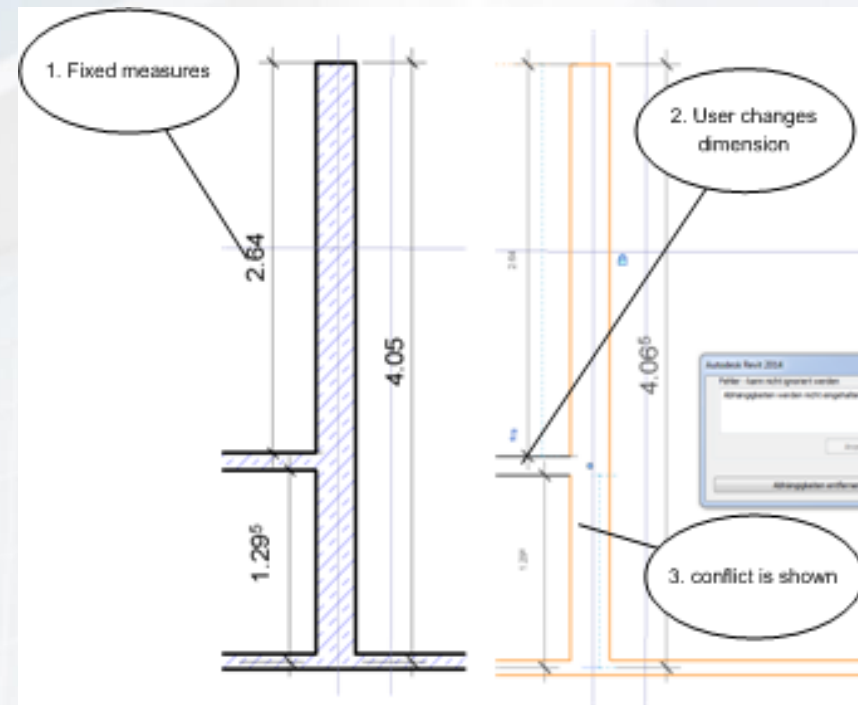
Diversity in solid models **complicates information exchange in general !!!**

A single slide on IFC:

#97 = IFCOPENINGELEMENT('2LcE7', #2, 'xyz','Description of xyz', $, #98, #103, $);

#98 = IFCLOCALPLACEMENT(#46, #99);   **Relative Placement**

#103 = IFCPRODUCTDEFINITIONSHAPE($, $, (#110));   **Voids**
#109 = IFCRELVOIDSELEMENT('3lR5ko', #2, $, $, #45, #97);
#110 = IFCSHAPEREPRESENTATION(#20, 'Body', 'SweptSolid', (#111));
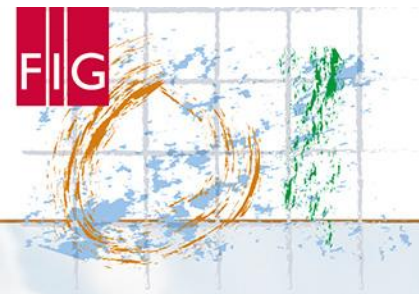   **Sweep**

#108 = IFCRELDEFINESBYPROPERTIES('2UEO1', #2, $, $, (#97), #104);

#104 = IFCELEMENTQUANTITY('2xwA', #2, 'BaseQuantities', $, $,(#105, #106, #107));
#105 = IFCQUANTITYLENGTH('Depth', 'Depth', $, 3.000E-1);
#106 = IFCQUANTITYLENGTH('Height', 'Height', $, 1.400);   **Parameter**
#107 = IFCQUANTITYLENGTH('Width', 'Width', $, 7.500E-1);
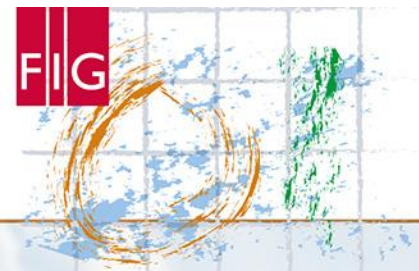
Outline

1. **BIM – What is a model ?**

2. **Geometry:** Diversity in solid models affect the way a surveyor works!

3. **Topology:** Inteligent models help!

4. **Semantics:** Feel the power of the light side!

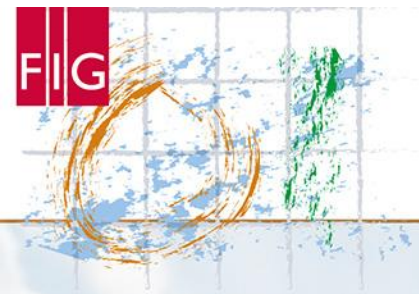5. **Documentation:** Take care for the sidelined!

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Topology - Intelligent models help!

Simple definition: Topology describes the **spatial relations** that are invariant against geometric transformations like translation, rotation and scaling. **Typical topological relations** are,

- "is contained in",

- "is the boundery of" or

- "touches"

Topological relations might be <u>calculated from</u> geometric information as a request on the BIM <u>or</u> the topological relations are <u>stored explicitly</u> in the model.
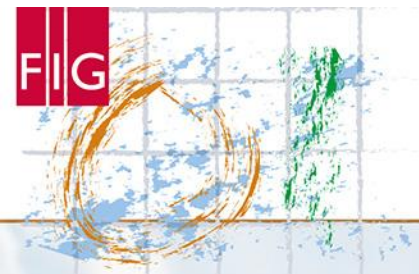
Topology

- **... of a single component**

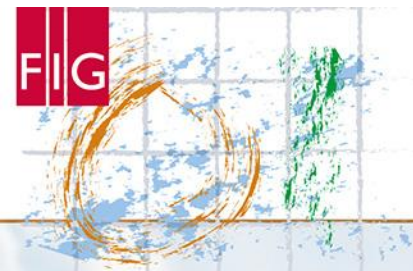- **... of components**

- **... as space partitioning**

Topology of a single component
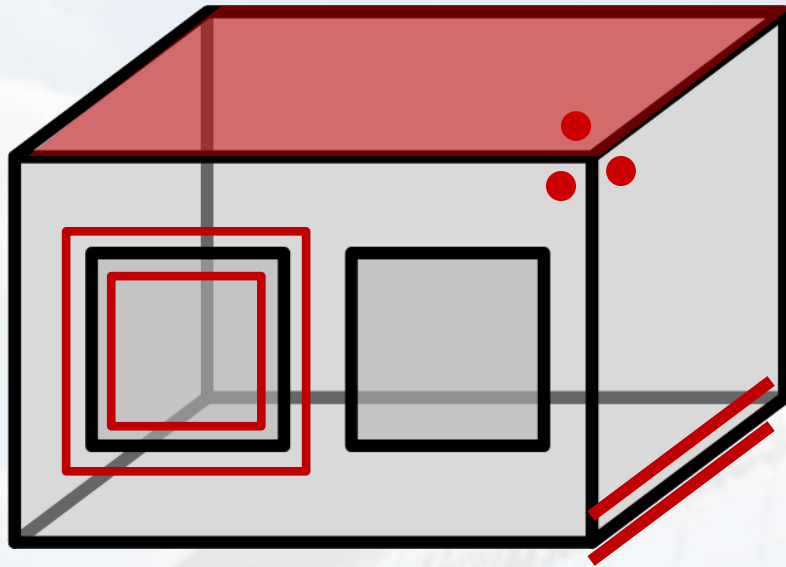
Redundancy of **Nodes**
Same „real world vertex/point" is stored in several polygons

Redundancy of **Edges/Loops**
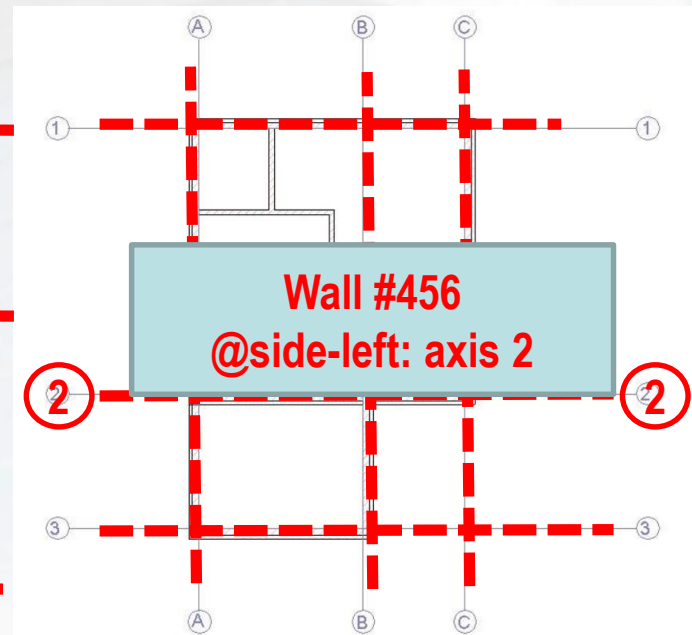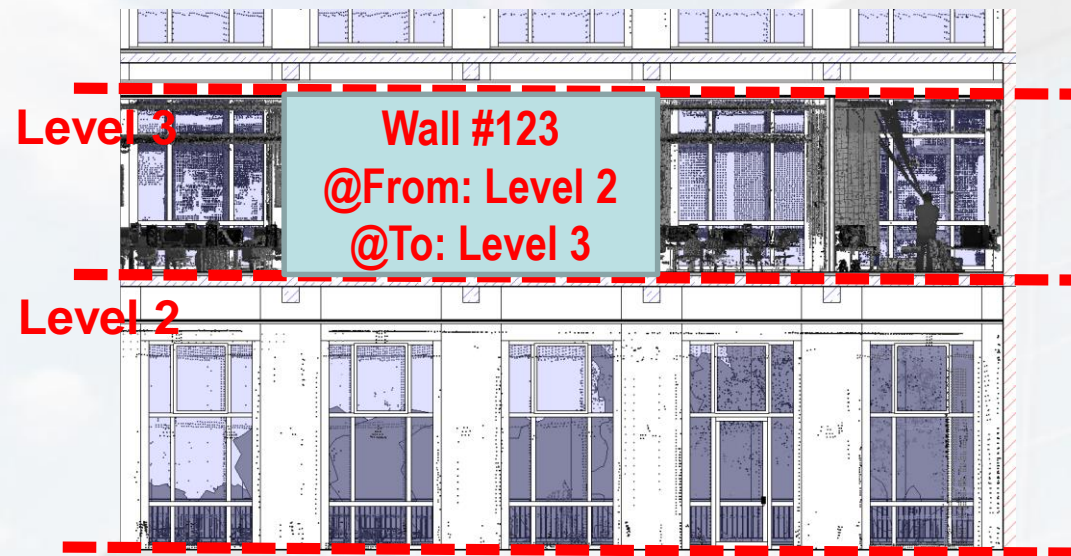Same „real world edge/line" is stored in several polygons

Redundancy of **Faces**
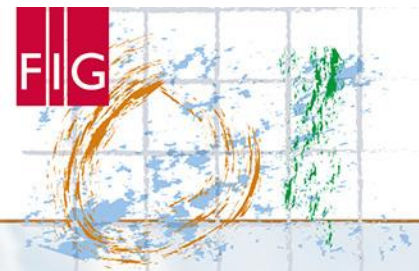Same „real world face" is stored in several solids

Topology between building elements

Indirect topology with reference elements
- vertical level
- horizontal raster/grid
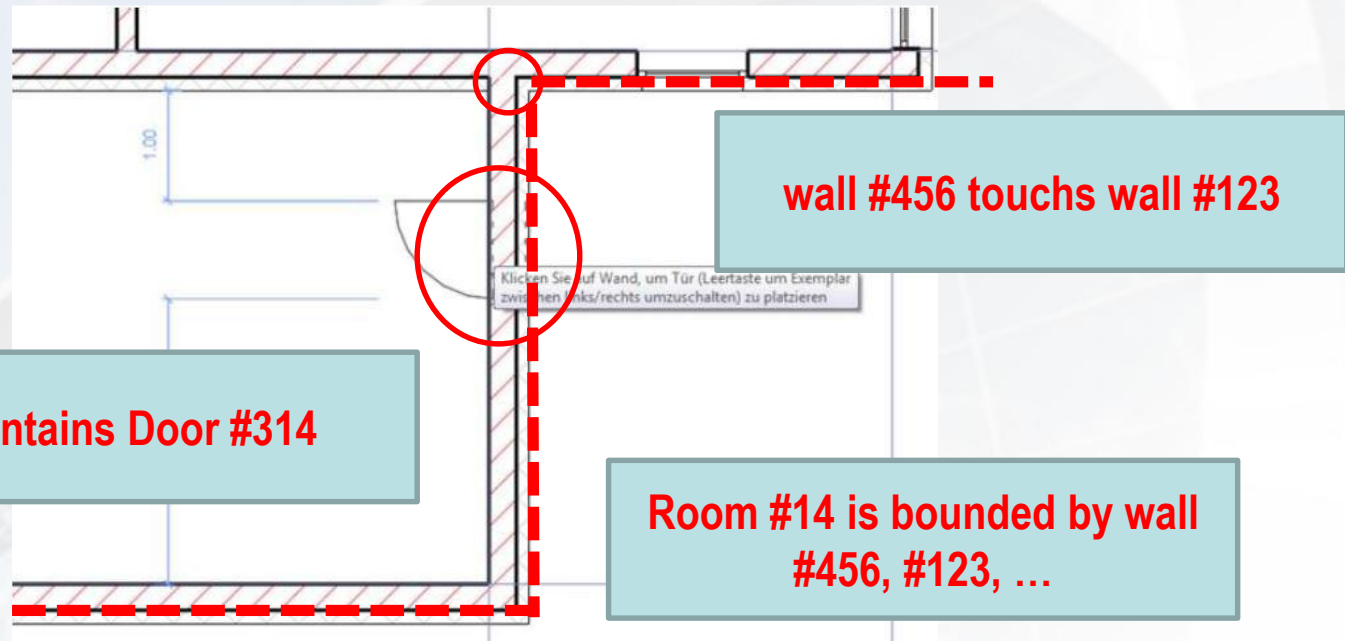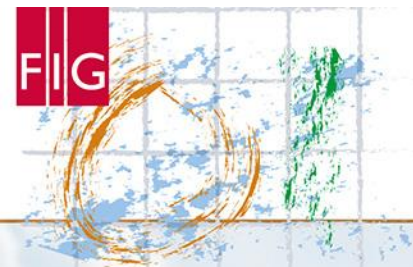

Level 3

Wall #123
@From: Level 2
@To: Level 3

Level 2

Wall #456
@side-left: axis 2

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Topology between building elements

Direct topology:

- based on rules,

- rules are specified for element types (semantic model)

wall #456 touchs wall #123

Wall #123 contains Door #314
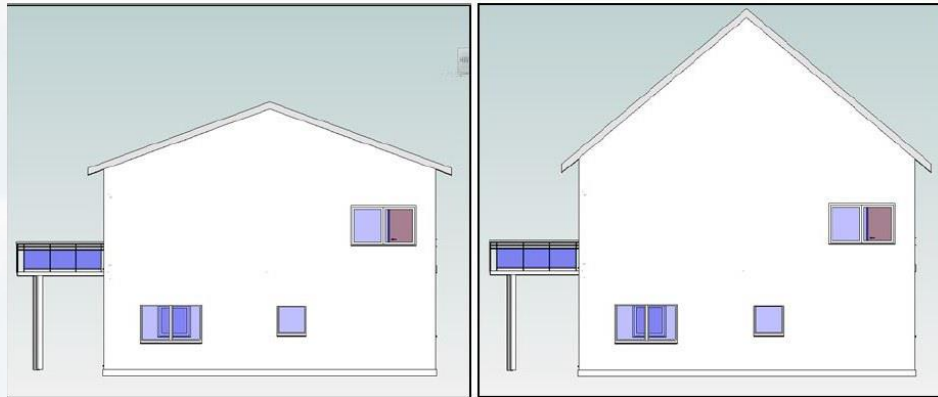
Room #14 is bounded by wall #456, #123, …
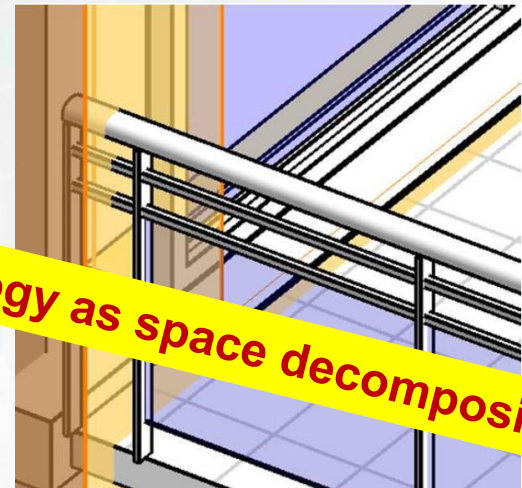
Topology between building elements

Benefit (planning)

Valid models (no gaps) also when geometry changes.
Good for design and planing.
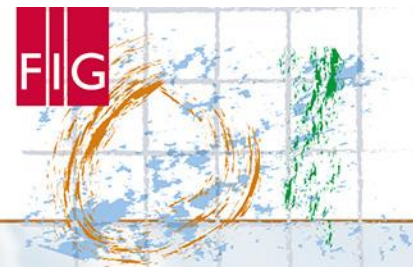

Benefit (merging)

If solids violate the rule of unique space partitioning, gaps and clashes may be detectable. Good for merging models.

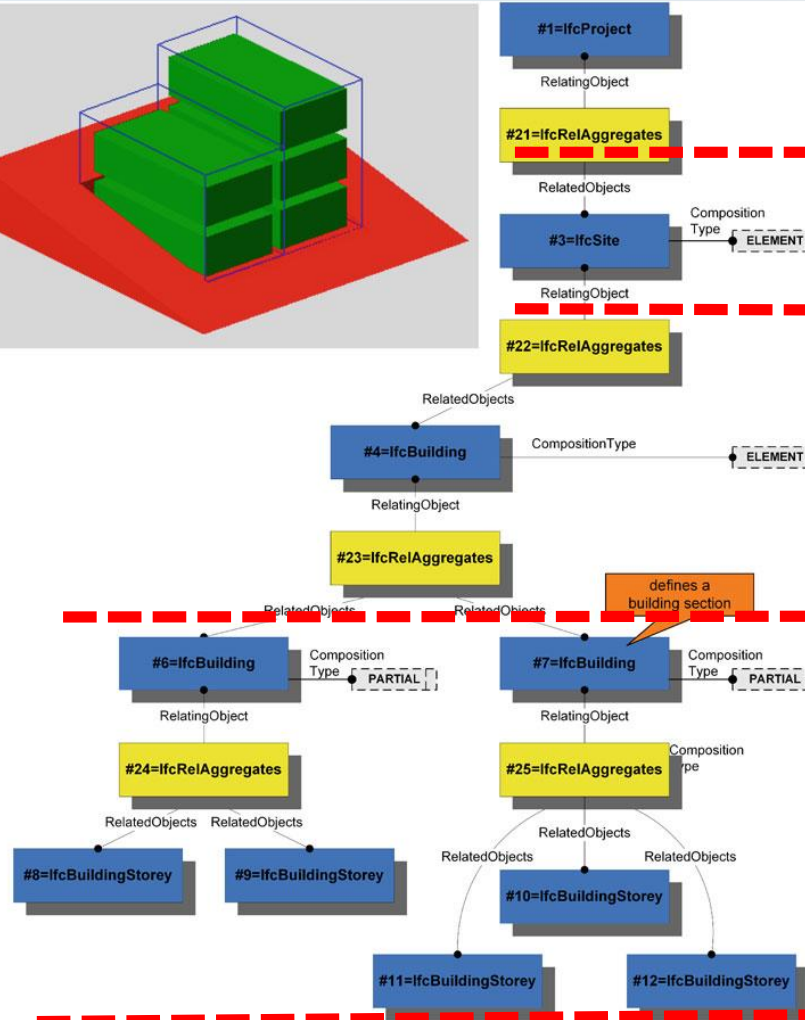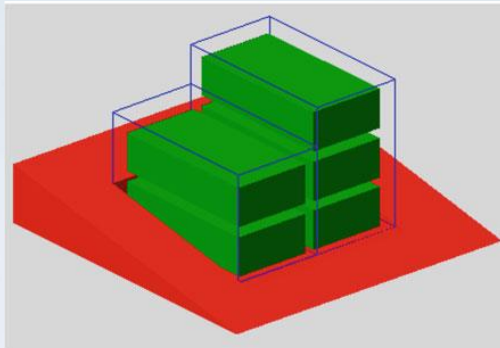**Topology as space decomposition?**

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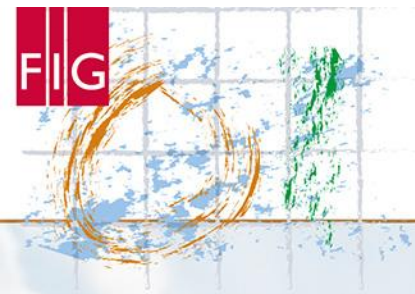
BIM != BIM

Semantics: Feel the power of the light side!

In CAD drawing-elements are grouped in **layers** to classify points, lines, surfaces and solids**.** In object oriented BIMs objects belong to classes and have properties (attributes).
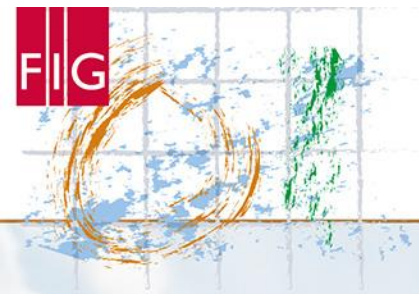
Simple definition of semantic for BIM:

Semantic Information == nongraphical data in the model

The "tools" for **semantic modelling** are

> **classification** (a hierarchy of classes from general to specific)
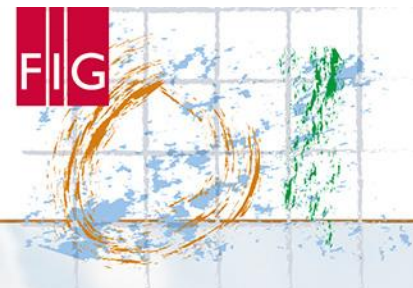> **attributation** (atomar propety-value pairs)

Semantics: Feel the power of the light side!

Challenge 1: How to **classify** (order of classification level: structural function of the component, costs schema, location, material, schedule, vendor,....)
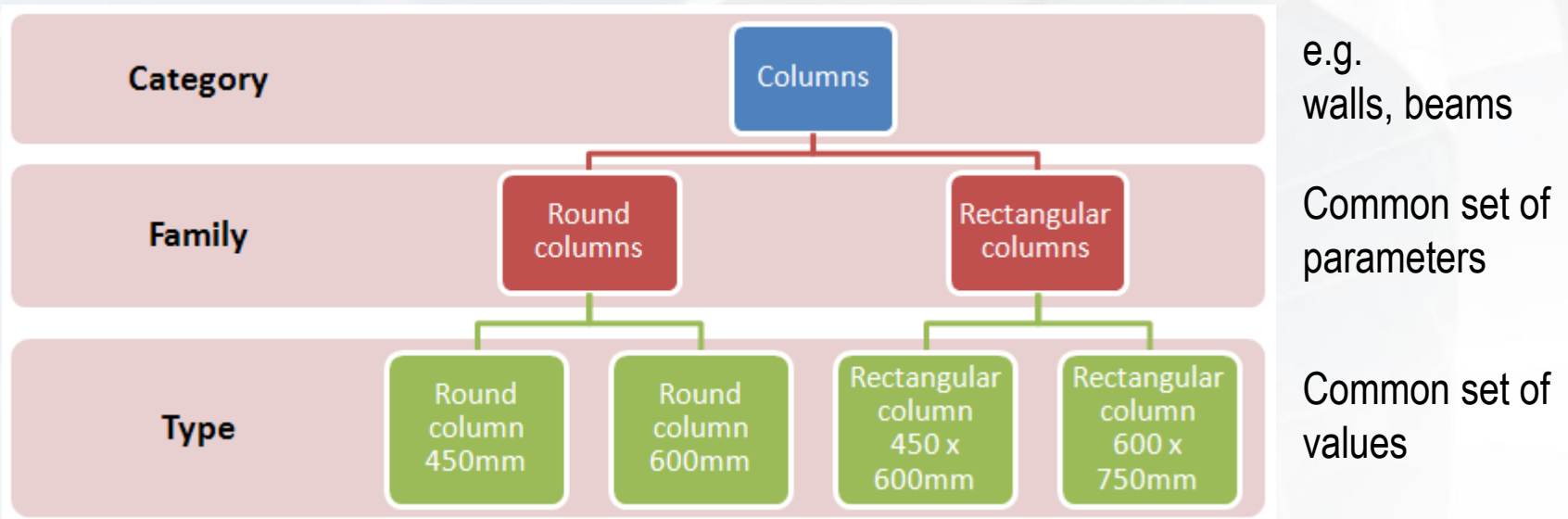
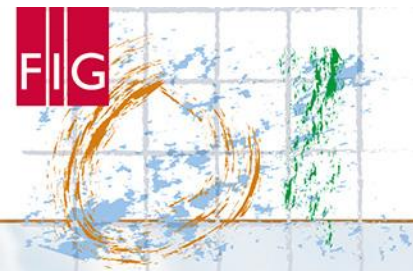**Challenge 2:** How **to share** diverse semantic models (Software vs. Standard, profession vs. profession)

Semantics

A hierarchy of building components might be given by the software itself (e.g. Autodesk Revit)

e.g.
walls, beams

Common set of parameters

Common set of values

https://knowledge.autodesk.com/support/revit-products/learn-explore/

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Semantics

Formally **published classifications** are e.g.

- DIN276: **Building costs**, e.g. Number 338 means "sun protection", related to all tendering processes for designing, planning and construction in Germany

- DIN277: **Types of areas and volumes** of buildings related to letting and profit calculations

- Omniclass: North American architectural, engineering and construction (AEC) industry, Set of 15 hierarchical tables each ~~of which~~ represents a different facet of construction information:

  - **Number** e.g. **11-15 11 39** (Playground)
  - **Levels** for deeper classification
  - **Definition**: Textual description

The **classification number** (code) is an **attribute** for a BIM object (wall, zone, room)
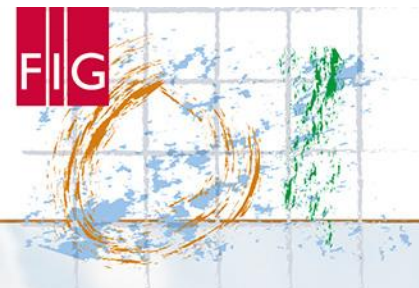
Christian Clemen (Germany): „**3D Geometry, Topology and Semantics**"

Semantics

What does this mean to the surveyor?

Semantic information to be …

- acquired and
- managed

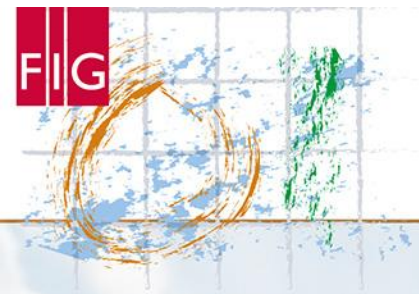Christian Clemen (Germany): „**3D Geometry, Topology and Semantics**"

External Documents -Take care for the sidelined!

Any Information that is not deeply managed in the BIM

- ... Depricated models or CAD Files
- ... Surveying files (raw obeservations)
- ... Datasheets of components
- ... and, and, and

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