Topology as Central Information in Building Models

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Overview

- What is topology?
- Why topology is needed for process modeling?
- How can topologic objects associated with geometric properties?
- How can adjustment techniques applied…
  - …in the reverse engineering?
  - …in the construction?

Topology – Topological Space

System of subsets defined on a basic set *X*

Example: Graph

Basic set X of *vertices*

$X = \{v_1, v_2, v_3, v_4\}$

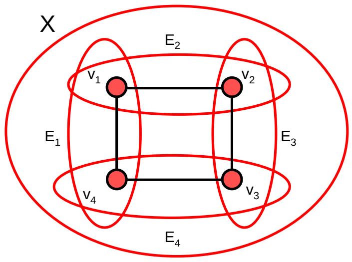
System of two-valued subsets - *edges*

$E_1 \subseteq X = \{v_1, v_2\}$

$E_2 \subseteq X = \{v_2, v_3\}$

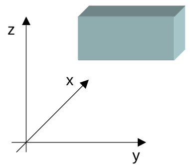
$E_3 \subseteq X = \{v_3, v_4\}$

$E_4 \subseteq X = \{v_4, v_1\}$



Basic Set

All points of a metric space



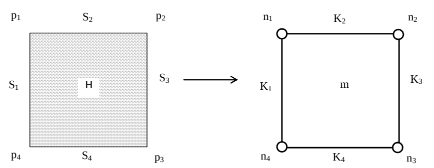
Properties:

1. The set is **infinite**.
2. The set is **uncountable**.

Problem: It's impossible to save all points to a data medium.

Solution: Mapping of point sets on a finite number of topological objects

Mapping Geometry → Topology

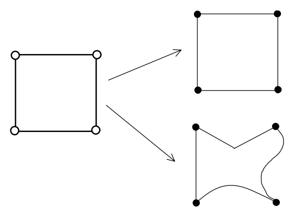


$H \rightarrow m$

$S_1 \rightarrow K_1 = \{n_1, n_4\}$ … $S_4 \rightarrow K_4 = \{n_3, n_4\}$

$p_1 \rightarrow n_1$ … $p_4 \rightarrow n_4$

Mapping Topology → Geometry

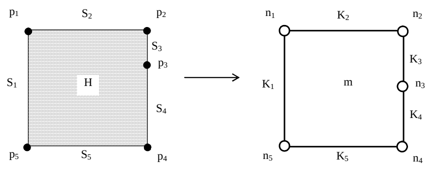


Problem: The mapping topology → geometry is ambiguous.

Solution: Saving of the mapping function.

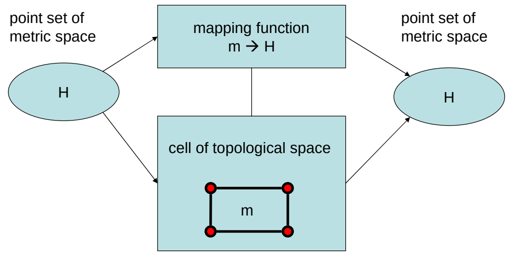
$$f : K_i = \{n_A, n_E\} \rightarrow S_i = \{ \mathbf{x}(t) = \mathbf{x}_A + t \cdot (\mathbf{x}_E - \mathbf{x}_A), \quad t = 0..|\mathbf{x}_E - \mathbf{x}_A| \}$$

Criterion for a Subset



The criterion for defining a point set and map it on a cell is the possibility to describe that set by **one** function.

Saving the Mapping Function

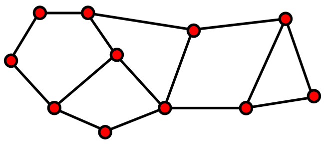


Exception: Vertex → Point

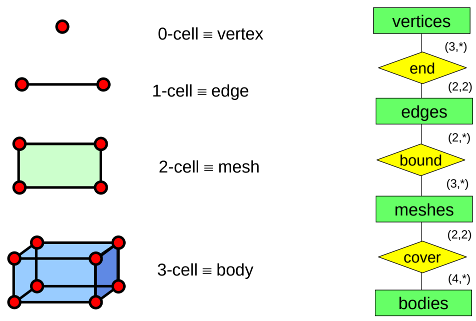
Cell Complex

- Partitioned topological space
- Each point in space belongs to exactly one cell
- Cells of dimension p can be constructed by a framework of cells of dimension (p-1)

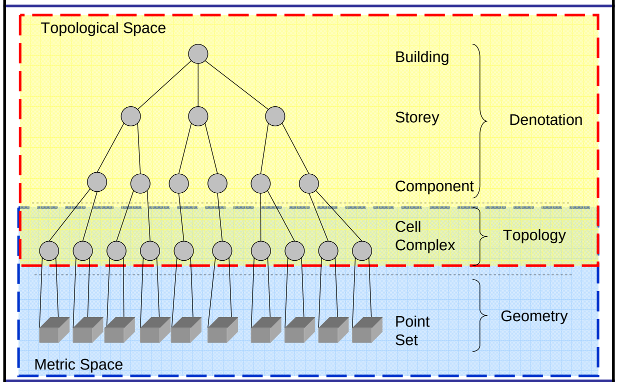
Example: Cell complex of dimension 2



3D Cell Complex

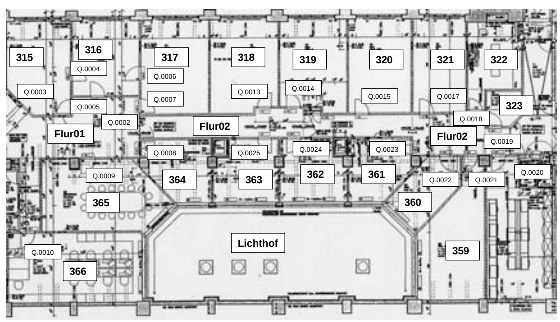


Topology

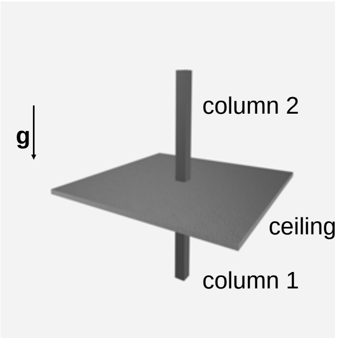


Denotation

Example: Civil Engineering at TU Berlin (extract): zones and doors



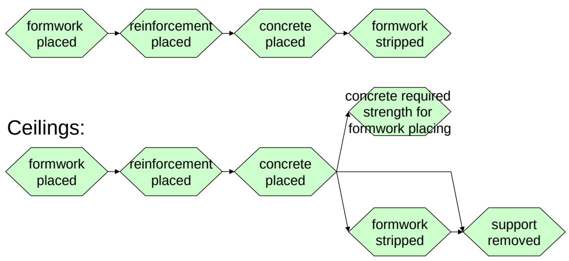
Construction Processes



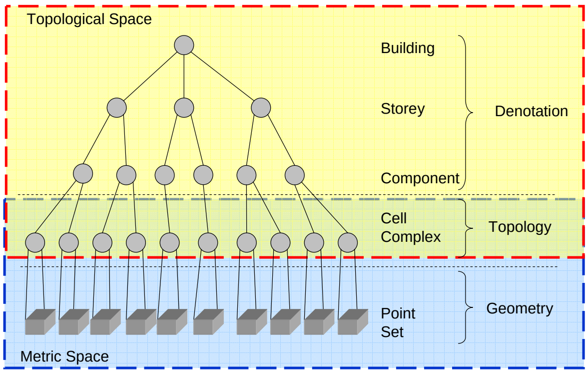
- Several activities are necessary to manufacture components.
- Status graphs are suitable to describe the manufacturing process of each component.

Construction Processes

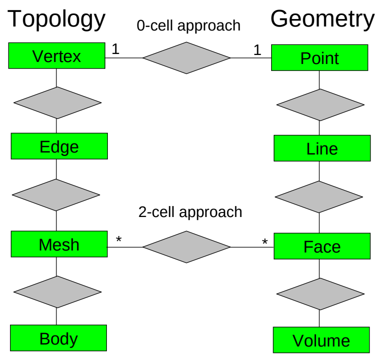
Status graphs



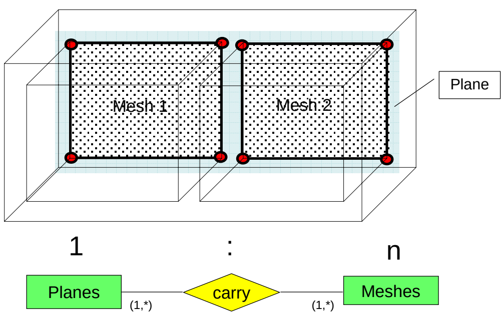
Topology



Geometry



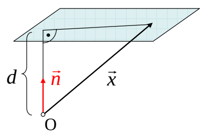
Geometry and Topology



Parameterization of Planes

Plane
persistent

$$\vec{n} \cdot \vec{x} - d = 0$$

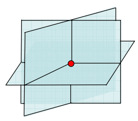


Point
View

$$\vec{n}_1 \cdot \vec{x} = d_1$$
$$\vec{n}_2 \cdot \vec{x} = d_2$$
$$\vec{n}_3 \cdot \vec{x} = d_3$$

SQL-Statement

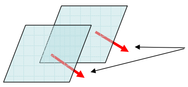
$\vec{x}$



Geometrical Constraints

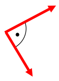
Coplanarity → implicit

Parallelism



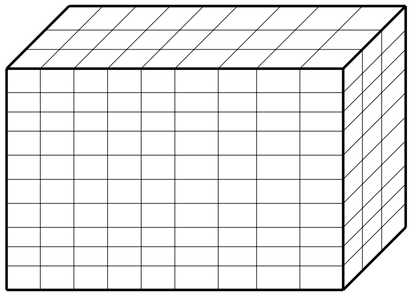
identical normal vectors

Orthogonality (in x,y-plane)



$$\vec{n}_1 = \begin{pmatrix} a \\ b \\ 0 \end{pmatrix} \quad \begin{matrix} a \\ b \end{matrix} \quad \vec{n}_2 = \begin{pmatrix} -b \\ a \\ 0 \end{pmatrix}$$

Example: Theoretical Building



10 floors

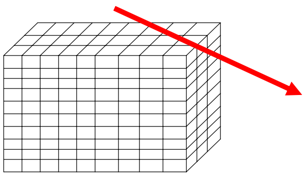
4 longitudinal walls

11 transversal walls

Number of Geometry Parameters

0-Cell Approach:
parameterization by coordinates
x, y, z
10 * 10 * 3 + 1 = 301 rooms
301 * 8 = 2408 points
2408 * 3 = 7224 coordinates

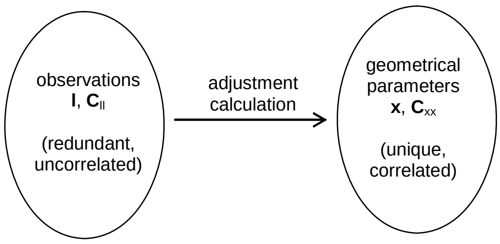
2-Cell-Approach:
parameterization by plane parameters
$\boldsymbol{n} \cdot \boldsymbol{x} - d = 0$ → n_x, n_y, n_z, d
10*2 + 4*2 + 11*2 = 50 planes
3 normal vectors * 3 components
+ 50 translations d
= 59 plane parameters



0.8% !

Adjustment Techniques

- Redundant relative measures can be processed
- Unique result with accuracy and reliability values

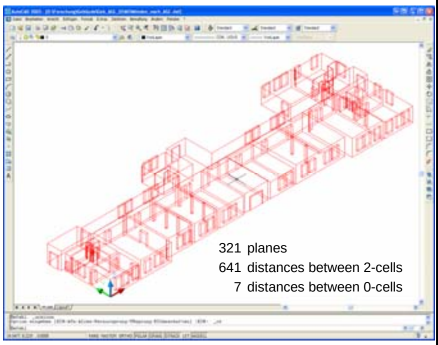


Reverse Engineering

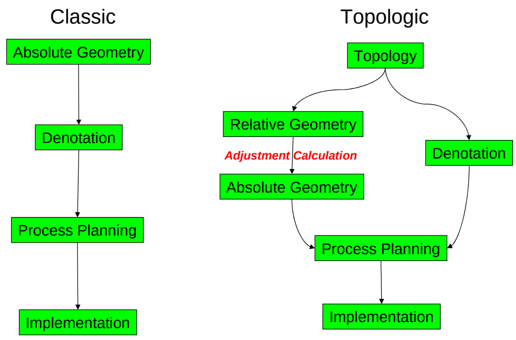
Example:
Architectural Survey

University Bielefeld
Department of Architecture
and
Civil Engineering, Minden,

ground floor



Construction



Conclusions

- A topological data model is the prerequisite for the denotation and the building process planning.
- A direct parameterization of surfaces needs considerably fewer parameters and allows the application of adjustment techniques.
- Adjustment techniques:
  - Allow a very efficient reverse engineering of geometry.
  - Provide new ways for the building construction.

Thank you for your attention!

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