

Topology as Central Information in Building Models

Frank Gielsdorf technet GmbH Berlin
 Wolfgang Huhnt Technical University Berlin

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?

F. Gielsdorf, W. Huhnt: Topology as Central Information in Building Models

Topology – Topological Space

System of subsets defined on a basic set X

Example: Graph

Basic set X of vertices

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

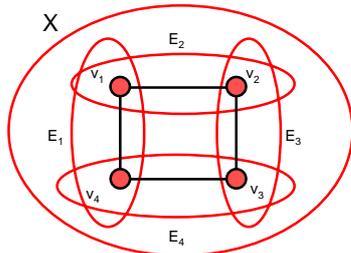
System of two-valued subsets - edges

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

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

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

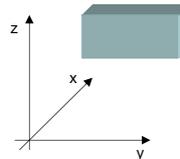
$$E_4 \subseteq X = \{v_4, v_1\}$$



F. Gielsdorf, W. Huhnt: Topology as Central Information in Building Models

Basic Set

All points of a metric space



Properties:

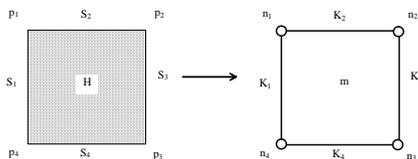
1. The set is **infinite**.
2. The set is **uncountable**.

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

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

F. Gielsdorf, W. Huhnt: Topology as Central Information in Building Models

Mapping Geometry → Topology



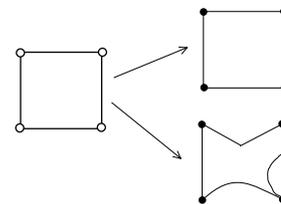
$$H \rightarrow m$$

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

$$p_1 \rightarrow n_1 \quad \dots \quad p_4 \rightarrow n_4$$

F. Gielsdorf, W. Huhnt: Topology as Central Information in Building Models

Mapping Topology → Geometry



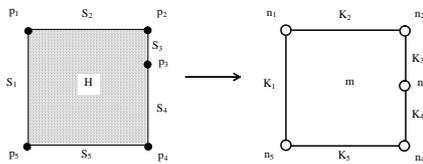
Problem: The mapping topology → geometry is ambiguous.

Solution: Saving of the mapping function.

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

F. Gielsdorf, W. Huhnt: Topology as Central Information in Building Models

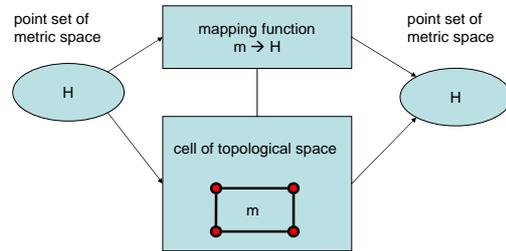
Criterion for a Subset



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

F. Gietsdorf, W. Huhnt: Topology as Central Information in Building Models

Saving the Mapping Function



Exception: Vertex \rightarrow Point

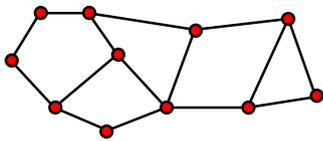
F. Gietsdorf, W. Huhnt: Topology as Central Information in Building Models

Cell Complex



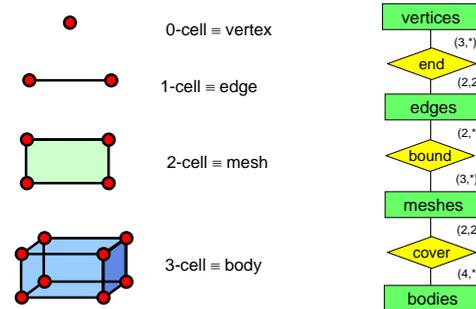
- Partitioned topological space
- Each point in space belongs to exactly one cell
- Cells of dimension p can be constructed by a framework of cells of dimension $(p-1)$

Example: Cell complex of dimension 2



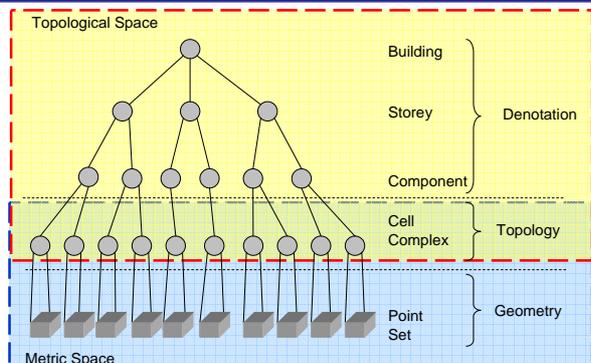
F. Gietsdorf, W. Huhnt: Topology as Central Information in Building Models

3D Cell Complex



F. Gietsdorf, W. Huhnt: Topology as Central Information in Building Models

Topology

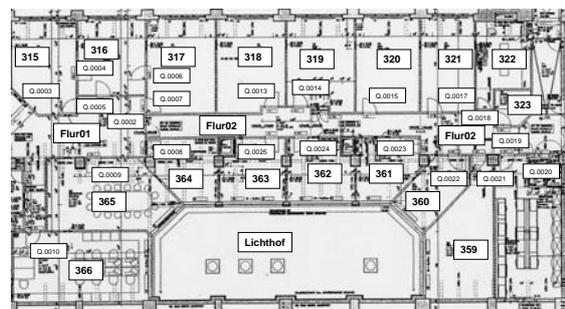


F. Gietsdorf, W. Huhnt: Topology as Central Information in Building Models

Denotation



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



F. Gietsdorf, W. Huhnt: Topology as Central Information in Building Models

Construction Processes

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

F. Gielsdorf, W. Huhnt: Topology as Central Information in Building Models

Construction Processes

Status graphs

Columns:

```

    graph LR
      A[formwork placed] --> B[reinforcement placed]
      B --> C[concrete placed]
      C --> D[formwork stripped]
  
```

Ceilings:

```

    graph LR
      A[formwork placed] --> B[reinforcement placed]
      B --> C[concrete placed]
      C --> D[formwork stripped]
      C --> E[concrete required strength for formwork plating]
      E --> D
      D --> F[support removed]
  
```

F. Gielsdorf, W. Huhnt: Topology as Central Information in Building Models

Topology

Building
Storey
Component
Cell Complex
Point Set
Metric Space

Denotation
Topology
Geometry

F. Gielsdorf, W. Huhnt: Topology as Central Information in Building Models

Geometry

Topology: Vertex, Edge, Mesh, Body

Geometry: Point, Line, Face, Volume

0-cell approach: Vertex \leftrightarrow Point

2-cell approach: Mesh \leftrightarrow Face

F. Gielsdorf, W. Huhnt: Topology as Central Information in Building Models

Geometry and Topology

Mesh 1, Mesh 2, Plane

1 : n

Planes (1,*) carry (1,*) Meshes

F. Gielsdorf, W. Huhnt: Topology as Central Information in Building Models

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 $\rightarrow \vec{x}$

F. Gielsdorf, W. Huhnt: Topology as Central Information in Building Models

Geometrical Constraints

Coplanarity → implicit

Parallelism identical normal vectors

Orthogonality (in x,y-plane)

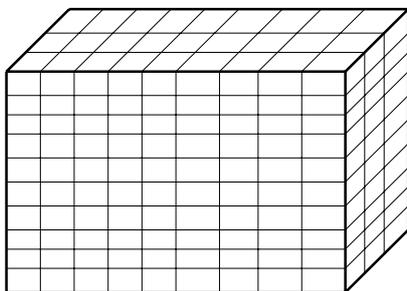
$$\vec{n}_1 = \begin{pmatrix} a \\ b \\ 0 \end{pmatrix}$$

$\begin{matrix} \rightarrow a \\ \rightarrow b \end{matrix}$

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

F. Gielsdorf, W. Huhnt: Topology as Central Information in Building Models

Example: Theoretical Building

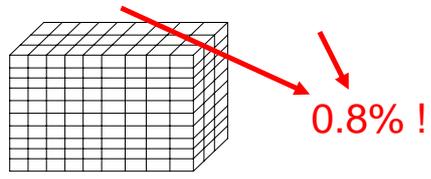


10 floors
4 longitudinal walls
11 transversal walls

F. Gielsdorf, W. Huhnt: Topology as Central Information in Building Models

Number of Geometry Parameters

<p>0-Cell Approach: parameterization by coordinates x, y, z 10 * 10 * 3 + 1 = 301 rooms 301 * 8 = 2408 points 2408 * 3 = 7224 coordinates</p>	<p>2-Cell-Approach: parameterization by plane parameters $n \cdot x - d = 0 \rightarrow n_x, n_y, n_z, d$ 10*2 + 4*2 + 11*2 = 50 planes 3 normal vectors * 3 components + 50 translations d = 59 plane parameters</p>
--	---



F. Gielsdorf, W. Huhnt: Topology as Central Information in Building Models

Adjustment Techniques

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

observations
 I, C_{II}
(redundant,
uncorrelated)

adjustment
calculation

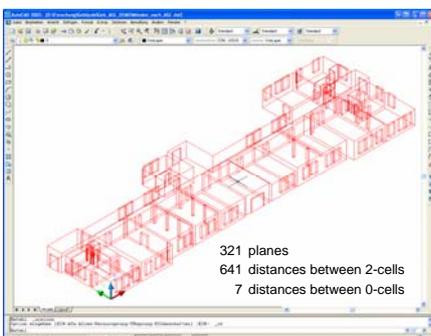
geometrical
parameters
 x, C_{xx}
(unique,
correlated)

F. Gielsdorf, W. Huhnt: Topology as Central Information in Building Models

Reverse Engineering

Example:
Architectural Survey

University Bielefeld
Department of
Architecture
and
Civil Engineering,
Minden,
ground floor



321 planes
641 distances between 2-cells
7 distances between 0-cells

F. Gielsdorf, W. Huhnt: Topology as Central Information in Building Models

Construction

Classic

Absolute Geometry

Denotation

Process Planning

Implementation

Topologic

Topology

Relative Geometry

Adjustment Calculation

Absolute Geometry

Denotation

Process Planning

Implementation

F. Gielsdorf, W. Huhnt: Topology as Central Information in Building Models

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.

F. Gielsdorf, W. Huhnt: Topology as Central Information in Building Models



Thank you for your attention!

frank.gielsdorf@technet-gmbh.com

huhnt@tu-berlin.de