3D TOPOLOGY FOR MODELLING OF URBAN STRUCTURES

Tarun Ghawana & Sisi Zlatanovoa
Increased awareness of underground information

Ludvig Emgard

Jakob Beetz
Infrastructure Projects
Maasvlakte 2, Port Rotterdam

http://maasvlakte2-3dsdi.ddss.nl/
Physical models!
The integrated 3D information model (3DIM)

Integrated 3D model (above, below surface)
The integrated 3D information model (3DIM)
Spoorzone Delft

Renovation of the area of the railway station

- Drawings, images
- 2D plans and sections
- Vertical sections
- 3D physical models
- Lots of documents
Creating the 3D model

- **Above surface**
  - Buildings (extrusion)
  - Terrain (with integrated surfaces objects as streets, bicycle paths, pavements)
  - Boreholes, soundings (given as points on the surfaces)

- **Below surface**
  - Loading measurements in the tables
  - Interpretation of boreholes and soundings
  - Modelling of the surfaces in RockWorks and export of shape files to get the geometry
Integration of all data in ArcGIS

Wiebke Tegtmeier
The result ...

- We had geometries:
  - Self-intersecting objects
  - Intersecting objects
  - Overlaps
  - Gaps between objects
  - ...
... Many issues familiar from 2D cases...

- Complex constructions
- Vertical and horizontal dimensions
- Correct geometries (wind should not blow through the buildings)
- Geometric analysis (compute volumes)

....Can we have an integrated topological model?
Where topology can be useful?

- Data modelling (construction and validation)
- Analysis (after structuring in a topological model)
Models in CG

V- vertices, E - edges, F- faces

Only few relations are constant:
- Edge-vertex (1 edge has 2 adjacent vertices)
- Edge-face (1 edge has 2 adjacent faces)

Example GIS: 3D Formal Data Structure (3D FDS)

3D (spatial) models

- Semantic (thematic)
- Geometry (coordinates, derive relationships)
- Appearance
- Topology (relationships, derive coordinates)

- explicit primitives
- explicit relationships
Models in GIS

- Topology
- Topology/Geometry
- Geometry/Topology
- Geometry
- Geometry/Semantics, Semantics/Geometry
- Semantics/Geometry/Topology

- Very rare
- Very rare
- Possible
- Most often
- Very often
- Possible
Above surface

<table>
<thead>
<tr>
<th>3D Model</th>
<th>Supported Primitives</th>
<th>Constraints on primitives</th>
<th>Relations between primitives</th>
<th>Representation of objects</th>
<th>Subdivision of space</th>
<th>Thematic Semantics (yes, no)</th>
</tr>
</thead>
</table>
| 3D FDS   | Node, Arc, Edge, Face| node has unique coordinates
Arc is straight lines
Face is planar | arc has two nodes
arc has left and right face
ace has left and right body.
Singularities: node-on-face, arc-on-face, node-in-body and arc-in-body. | Point: node
Line: arcs
Surface: faces.
Body: faces (closed volume). | Full | Theme Classes |
| TEN      | Node. Arc, Triangle, Tetrahedron | Node has unique coordinates
Arc is straight lines | Arc has two nodes
Triangle has three arcs
Triangle has left and right tetrahedron
Singularities are not permitted. | Point: nodes
Line: arcs
Surface: triangles
Body: tetrahedrons | Full | Theme classes |
| SSS      | Nodes, Faces,       | Node has unique coordinates
Arc is straight lines
Face is planar and convex | Faces are described by nodes
Singularities: node-in-face and face-in-body | Point: nodes
Line: nodes
Surface: faces
Body: faces (closed volume) | Embedding (single-valued) | Not Discussed |
| CityGML  | Point, Curve, Surface, Solid | Primitive is described by set of coordinates (GML3 compliant geometry). | Xlinks for topology implementation between solids.
Xlinks performs aggregates to components directional topology. | Point: point
Line: curve
Surface: surface.
Body: surface/volume | Embedding (single valued) | Yes |
## Below surface

<table>
<thead>
<tr>
<th>Integral Real 3D Spatial Model</th>
<th>Generalised tri-prism (GTP)</th>
<th>Side-face is planar (subdivision to prism or tetrahedron with diagonals)</th>
<th>GTP has: 6 nodes, 6 TIN-edges, 3 Side-edges, 2 TIN-faces, 3 Side-faces, 3 diagonals</th>
<th>Body: GTP</th>
<th>Full</th>
<th>Not discussed</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D Vector Topological Geological Model</td>
<td>Point, Line, Face, Polyhedron</td>
<td>Polyhedron must be valid.</td>
<td>Face in a multi-hierarchic network. Node connects more than two edges or arris. Face has arris.</td>
<td>Body: polyhedron</td>
<td>Full</td>
<td>Yes</td>
</tr>
<tr>
<td>3D OO-Solid Model</td>
<td>Node, Arc, Polygon, Region, Solid</td>
<td>Node has coordinates (6 types of nodes) Polygon must have orientation</td>
<td>Arc has 2 nodes Polygon is composed of arcs Region has polygons</td>
<td>Line: arc Surface: regions Simple volume: regions (closed) Composed volume: simple volume.</td>
<td>Full</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Comparison

- **Above surface:**
  - Polyhedron (when 3D primitive)
  - Faces (for texturing), arcs, nodes
  - Full subdivision of space

- **Below surface:**
  - Polyhedron/Prism/Tetrahedron
  - Full subdivision of space
Adding topological model

- What kind of primitive for the 3D
  - Tetrahedron based-model
    - (-) Subdivide objects, which might become very complex as the LOD increases
    - (+) Simple and robust model; can be maintained easily
  - Polyhedron-based
    - (-) Require check of many rules (closed, orientable, non-intersecting)
    - (+) Closer to the real outlook of objects.

- What kind of relationships (data structure)
  - Still not uniformity
  - Study CG solutions
Conclusion

- Current software
  - hardly provides valid 3D objects (polyhedrons)
  - does not offer 3D topological structures

- The work on 3D topological model should consider above and below objects.

- Investigate other volumetric data structures
3D Topology?

Maurits Cornelis Escher (1898-1972)