Realising the Foundations of a Higher Dimensional GIS: A Study of Higher Dimensional Spatial Data Models, Data Structures and Operations

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What will I do?

- Realise data models, data structures and operations for higher dimensional (> 3) spatial data.

- Take advantage of the extensive research done in computer science and computer graphics. Apply it to GIS data, which is special.

- The motivation: integration of other (non spatial) dimensions and treat them as spatial (e.g. time, scale, feature spaces)
2D/3D modelling in GIS

• Top-down approach

• Data models are based on standards
  • By standard bodies: ISO 19107, GML, CityGML, ...
  • By developers or the industry: KML, Shapefiles, ...

• Data structures are ad hoc

• Operations are well defined, based on users’ needs
Limitations of models in GIS

- Limited to 2D/3D
- Lack of a formal (mathematical) definition
- Implementations diverge from standards
- Different implementations yield different results
Models in computer science and computer graphics

• Bottom-up approach

• Data models defined mathematically (e.g. point set topology)

• Data structures defined mathematically (e.g. algebraic topology and combinatorics)

• Operations are ad hoc
Data models in CS/CG

- Decomposition models
- Constructive models
- Boundary models
Decomposition models

rasters  

space subdivision  

cell decomposition
Constructive models

half-space

CSG
incidence models

ordered topological models

Boundary models
Boundary based models are best

- No need to make data conform to a particular shape (decomposition models)
- Easy to append information to vertices, edges, faces, ...
- Efficient storage
- Good for visualisation
- Options for $n$-D: simplices, polytopes, intermediate
An intuitive representation
Data structures in CS/CG

• Fit for $n$-D:
  
  • Simplex based (incidence model)
  
  • Quad-edge, facet-edge and cell-tuple (and half-edge)
  
  • G-maps: from combinatorial maps and $v$-maps
Quad-edge, facet-edge and cell-tuple
Quad-edge, facet-edge and cell-tuple
Quad-edge, facet-edge and cell-tuple
G-maps | Combinatorial maps
G-maps | V-maps

\[ \alpha, \sigma, \gamma \]
G-maps | V-maps
G-maps

\[ \phi_0 = \langle \alpha_1, \alpha_2 \rangle \]

\[ \phi_2 = \langle \alpha_0, \alpha_1 \rangle \]

\[ \phi_1 = \langle \alpha_0, \alpha_2 \rangle \]

3D
What I’ll do

“The realisation of a data model, data structure and the basic algorithms required for the operations in a higher dimensional Geographic Information System”

• Study data models and data structures available
• Find out the specific needs of GIS (operations)
• Realisation: creation, implementation, testing
• Visualisation
<table>
<thead>
<tr>
<th>Phase</th>
<th>Time period</th>
<th>Activities</th>
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| 1     | June-October 2011| Initial (broad) literature review  
Basic implementation of G-maps for GIS data  
Initial work on a 3D visualiser  
Research proposal |
| 2     | November 2011-February 2012 | Continued literature review  
Define the needed $n$-d operations  
Article about bridging computer science/GIS  
Implement more high-level operations on G-maps  
Obtain $n$-d data sets  
Loading and viewing 3D data in visualiser |
| 3     | 2012             | Focused literature review  
Test other data structures  
Comparison of $n$-d data structures  
Article about $n$-d data structures  
Connect $n$-d data structure and visualiser  
Loading and storing $n$-d data |
| 4     | 2013             | $n$-d operations for GIS data  
Investigate database implementation  
Definition of the data structure to use  
Visualisation of $n$-d data |
| 5     | 2014             | Formalisation of the developed ideas |
| 6     | 2015             | Work on dissertation  
Prepare for PhD defence |
What I’ve done

- Literature study
- Implementation of G-maps in arbitrary dimensions
- Visualiser