Presentation Overview

• This presentation reports on four projects related to 2D and 3D spatial data models, all emphasize linked primal & dual relationships
• 1: A Unified Spatial Model for 2D GIS (the published paper)
• 2: A Kinetic 2D Marine Navigation System
• 3: 3D Kinetic Voronoi (Proximal) Models
• 4: 3D Building Interior Modelling
1:
A Unified Spatial Model for GIS

Maciej Dakowicz and Chris Gold
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“Context” and “Embedding”

• “Spatial Context”: what is “near” some spatial entity, and how these neighbours are arranged
• “Spatial Embedding”: non-overlapping within the 2D or 3D space
• The context (often Voronoi) network is the dual of the connectivity (often Delaunay) graph
• Every object has a ‘bubble’, and a set of neighbours
• EACH MAIN EDGE HAS A MATCHED DUAL EDGE
2D Spatial Entities in GIS

Discrete Objects  Networks  Polygons  Surfaces

VD/DT/CDT/LSVD

Layers of Voronoi diagrams
Discrete Objects: Points
- matching edges: Voronoi + Delaunay
Discrete Objects: Polygons
- half-edges form ‘bubbles’
Mobile Point Model
-maintains bubbles and relationships
Networks: Roads and Polygons
- space-filling connectivity
Surfaces: Sibson Interpolation
- new value found from neighbours

\[ Z = \frac{\sum_{i=1}^{5} a_i z_i}{\sum_{i=1}^{5} z_i} \]
Surface Modelling: interpolation & connectivity/slope between points
Runoff Modelling: cells + dual edges
=> containers and flow
Modified Context
- things you can do with cells

• Labelled Skeleton: grouped context
• Geometric Skeleton and Crust
• Buildings: grouped contexts
• Buffer Zone: clipped context
Labelled Skeleton
- group by label
Geometric Skeleton and Crust - group cells by proximity
Rivers: Adjacency AND Context
- ‘reach’ adjacency & micro-catchment
Height Transform for Skeleton
- height model from river alone
Static Simulation
- cumulative catchment area
Skeleton: Grouped Contexts
- grouped building parts, neighbours
Buffer: Clipped Contexts
- only part of cell needed
Conclusion: A Unified Model for Overlays

• The objective was to provide a single model for typical GIS data. This has been achieved.
• There is a single data structure and set of algorithms for many of the major data types: every primal edge has a dual edge.
• The following example combines a building layer and the previous road layer.
The Final Unified 2D Spatial Model

**Discrete objects**
- Points: mailboxes
- Polygons: buildings
- Voronoi Diagram

**Networks**
- Networks: roads
- Networks: rivers
- Line Segment VD
- LSVD network
- Coast and Skeleton

**Surfaces**
- Proximal fields
- TIN
- Voronoi Diagram
- Surface: elevation data
- Surface: contours
- Grid
2: Mobile Context: 2D Kinetic Models

• We may combine the (2D) context model with real-time local updating to provide a kinetic decision support system, e.g. for navigation.

• This is integrated with fully interactive 3D graphics to produce a geo-visualisation system for land, sea and sub-sea applications.

• This has been commercialised as a UK start-up company, with funding support.
The company

- Created to commercialize over a decade of academic research
- Spin-out of the University of Glamorgan
- Received Welsh Assembly Government (WAG) funding in March 2010
- Finance Wales (a WAG subsidiary) holds 33% of its shares
Screenshot 1
Screenshot 2
Screenshot 4
3: 3D Kinetic Voronoi Models

- This work by Hugo Ledoux developed proximal models and data structures for moving points in 3D space.
- A wide variety of queries can be posed concerning adjacency and volumetric conditions at any moment in time.
- The software has been used for a variety of applications, including geology and oceanography.
4: 3D Building Interior Modelling

- For a 3D graph, e.g. a cellular complex, the dual graph is well defined:
  - Vertices $\leftrightarrow$ volumes
  - Edges $\leftrightarrow$ faces
- This does not necessarily need the Voronoi geometric support.
- We define the “Dual Half-Edge” structure: each primal half-edge has a dual equivalent.
Dual Half-Edge (DHE)
- primal edge ‘he’ and dual ‘he.D’
Multiple Shell Management
- dual, and volumes, always preserved
Applications of our Building Simulation System (B-Sim)

• On this basis we may implement a CAD –type system for ‘joined-up’ structures.

• Applications include our original escape-route planning, virtual museums, sound, noise, RFI and pollution propagation simulation.

• Model construction is based on a primal-dual version of incremental Euler operators.

• The model below took just two weeks to build, and a demo is available.
Glamorgan Campus
(1300 cells, including rooms, corridors, doors and exterior)
Escape Routes
Conclusions

• Our recent research on spatial context has borne fruit, and created new products, in 2D and 3D GIS and visualisation.

• All are based on linked primal and dual graphs

• Hopefully others will continue to work in this field, which has obvious value in future software development and applications.

• Thank you.
ISPRS WG II/5
3D and Mobile Modelling:
Main Contributors

• Pawel Boguslawski and Chris Gold
• - 3D building interior modelling
• Hugo Ledoux
• - 3D City models, CityGML
• Zaffir Sadiq Mohamed Ghouse
• - 3D cadastre, mobile applications
• Thomas Becker, Thomas Kolbe
• - Indoor navigation
• Alias Abdul-Rahman
• - 3D cadastre, flood modelling, 3D indexing
• Francois Anton
• - 3D topological models
Pawel Boguslawski and Chris Gold
- 3D building interior modelling

• Relevant activities: six papers, one keynote
• “Dual Half-Edge” data structure and “B-Sim” software system for building interior modelling, navigation and simulation
Hugo Ledoux
- 3D City models, CityGML

• Relevant activities: Four papers
• Four Programme Committees on 3D models
• Invited speaker, Swedish 3D GIS conference
• Programme Chair, “3D City Modelling”, GeoWeb 2010, Canada
Zaffir Sadiq Mohamed Ghouse
- 3D cadastre, mobile applications

• Relevant activities: one paper
• Co-chair of WG II/5
Thomas Becker, Thomas Kolbe
- Indoor navigation

• Relevant activities: two papers
• Active in Open Geospatial Consortium committees on 3D data structures
Alias Abdul-Rahman
- 3D cadastre, flood modelling and 3D indexing

• October 2009: Organised the International Workshop on Dynamic and Multidimensional GIS, Malaysia
• WG II/5 Chairman
• 12 papers with students
• Two presentations
Francois Anton
- 3D topological models

• July 2009: Organised the International Symposium on Voronoi Diagrams, Denmark
• Collaboration on 3D topological structures
ISPRS WG II/5
3D and Mobile Modelling:
Main Activities

• October 2009: International Workshop on Dynamic and Multidimensional GIS, Malaysia

• July 2009: International Symposium on Voronoi Diagrams, Denmark

• Ongoing collaborative group on “3D Topology” formed, to exchange working papers