#### MSc Geomatics thesis presentation

Validation and automatic repair of planar partitions using a constrained triangulation

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Friday, 27 August 2010 at 10:00

Grote Vergaderzaal OTB Research Institute

Jaffalaan 9, Delft



# Representing thematic information

- Pierre Charles Dupin's 1819 map
  - Subdividing the feature space of that theme
  - Distinct visual representation for each class



# Digital thematic maps

- CGIS, SYMAP (Late '60s)
  - Polygons to represent boundaries
  - Well suited for a computer





CORINE E39N32

# Planar partitions | CORINE 2000

### Why planar partitions?

- Simple constraints: no gaps, no overlaps, (no disjoint regions)
- Easy to answer questions:
  - (Aggregation) What is the total area of the features of type A and B?
  - (Topology) Are features A and B adjacent?



### The problem

- Validate a planar partition
- If it's invalid, **automatically** repair it.



Spain - Portugal border

### The problem

- Validate a planar partition
- If it's invalid, **automatically** repair it.





### Why is it hard?

Discrete and approximate representations



(24.0000000000005, 24.0000000000000517765)

Errors in computer operations

Orientation test



ESRI

### Polygons with holes

Valid polygons





### Validation process

- Rings:
  - Closed, not self-intersecting, not zero area, correct winding, ...
- Polygons:
  - Nested rings, connected interior, not zero area, ...
- Planar Partitions:
  - No gaps, no overlaps, no disjoint regions... CORINE E30N33



### Polygon validation constraints

- ArcGIS: too short line segments, unclosed rings, self-intersections, incorrect ring ordering.
- JTS/GEOS: self-touching rings, zero area rings, zero area polygons, improperly nested rings, duplicate vertices, spikes and gores, touching parts, crossing rings.
- Oracle Spatial: polygon with fewer than 4 vertices, unclosed rings, selfintersections, touching rings, overlapping rings, points too close together, wrong orientation.

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Problems are unavoidable

ArcGIS and the zero area polygon

# Validation of planar partitions

- Nearly impossible without topology: finding gaps
- Creation of a planar graph based representation
- Plümer and Groger: no dangling edges, no zero-length edges, planarity, no holes, no self-intersections, no overlaps, connectivity.



Andorra in CORINE



# Repair of planar partitions using snapping

Thresholds

# Repair using snapping

- Extensively available: ArcGIS, FME, GRASS, Radius Topology
- Possibilities: point to point, point to line, line to line











### Repair using snapping

Not a complete solution



### Repair using snapping

Clean-up required

# After snapping: constraints for planar partition repair

- Radius Topology: share node, node-split-edge, edge-split-edge
- GRASS: break at intersections, remove duplicate line segments, remove dangling edges, remove bridges, remove vertices within a threshold of a line segment, remove too small areas, remove too small angles

• But still, no guarantees

#### - 0 ×

# Topological planar partition repair

- Use topological constraints instead
- Snapping can still be performed
- Available in ArcGIS: must not overlap, must not have gaps, must not overlap with, must not have dangles, must not have pseudonodes, must not self intersect

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# Topological repair in ArcGIS

Manual editing of topology

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# Topological repair in ArcGIS

Manual editing of topology

## The solution

- Repair individual polygons.
- Create a triangulation containing every edge of every polygon.
- Tag every triangle with the polygons it belongs to.
- Re-tag areas with multiple or no tags, according to predefined criteria.
- Reconstruct the polygons in the triangulation.







# Triangulations

Polygons

# The constrained Delaunay triangulation

- Delaunay triangulation: empty circle property, uniqueness
- Constrained edges

![](_page_27_Picture_3.jpeg)

# Repair an individual polygon

- Use the same techniques devised to repair planar partitions.
- Create a triangulation from the polygon.
- Iteratively define exterior and interior when passing a constrained edge.
- Reconstruct polygon.

![](_page_28_Figure_5.jpeg)

# Create triangulation

- Add every edge of every (now valid) polygon to the triangulation as a constrained edge.
- Track whenever constrained edges are split.

![](_page_29_Picture_3.jpeg)

CORINE E39N32

# Tag triangulation

- Mark each triangle with the polygons that it belongs to.
- No tags = gap
- Multiple tags = overlap

![](_page_30_Picture_4.jpeg)

#### Repair operations

- At the end, ensure that each triangle has exactly one tag.
- Some possible options:
  - Assign triangle or region to the neighbour present on most sides.
  - Assign triangle or region to the neighbour with the longest boundary.
  - Assign region to the class with the highest priority.

![](_page_32_Picture_0.jpeg)

### Repair operations

Spain - Portugal border

![](_page_33_Picture_0.jpeg)

![](_page_33_Picture_1.jpeg)

![](_page_33_Picture_2.jpeg)

Triangle with longest boundary

Random region

Region with longest boundary

# Polygon reconstruction

- Recursively create a chain of edges representing all boundaries (and some connecting segments).
- Cut where more than two edges join.
- Join small chains in the correct order to form rings.

![](_page_34_Picture_4.jpeg)

CORINE E40N31 pol. 1752

### The prototype

- C++ with CGAL and OGR
- Open source and freely available

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![](_page_35_Picture_4.jpeg)

# Comparisons with other software

- Test polygons with specific problems (ArcGIS)
  - Significant differences in interpretation
  - Standards specify how to define a certain polygon, not how to interpret an existing one

#### Comparisons with other software

• Large "normal" data sets (ArcGIS, FME, GRASS)

Test	СТ		ArcGIS		FME		GRASS	
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4tiles	100 MB	3m25s	113 MB	37s	105 MB	31s	49 MB	53s
16tiles	1.51 GB	1h20m	crashes	_	636 MB	15m48s	crashes	_
Mexico	983 MB	18m53s	216 MB	>1d	264 MB	2m45s	408 MB	11m38s

• Good performance, considering that it does much more

### Conclusions

- Planar partition validation and automatic repair with a constrained triangulation is theoretically simple, yet powerful.
- It keeps a valid topology throughout, without a complex set of rules to check every step of the way.
- Changes that are made to the triangulation have only a local effect.
- New repair operations, based on different criteria, can be easily implemented without breaking the validity of the planar partition.
- Snapping is possible, but not required.

### Future work

- Optimisations for simpler polygons
- Improved algorithms for extracting polygons from a triangulation
- Eliminating memory limitations
- Improving the order of point insertions
- Extension to 3D
- Implementation in a database

### Questions?

http://www.gdmc.nl/~ken/thesis.pdf

#### MSc thesis in Geomatics

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August 2010

![](_page_40_Picture_5.jpeg)