MSc Geomatics thesis presentation

Validation and automatic repair of planar partitions using a constrained triangulation

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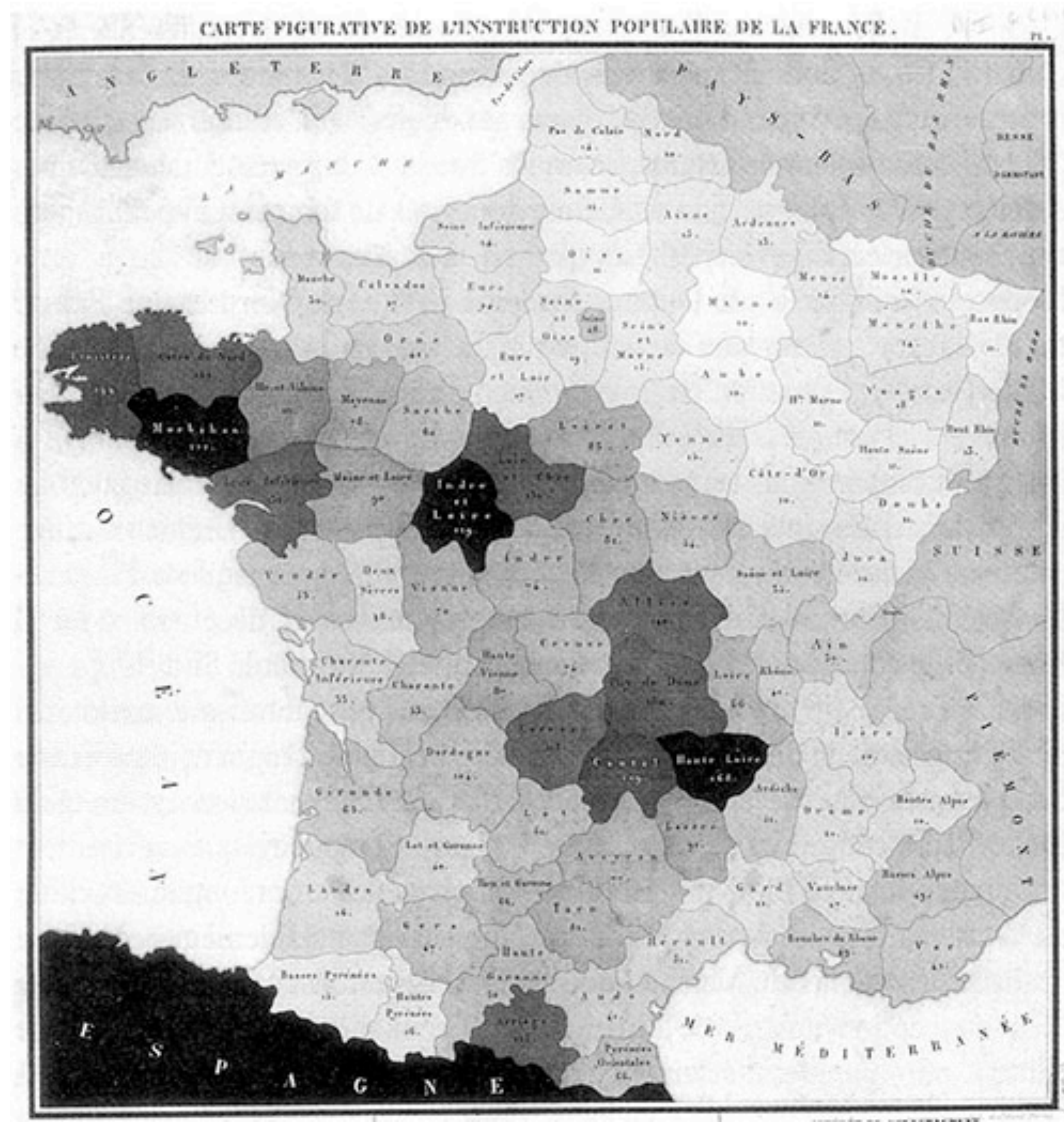
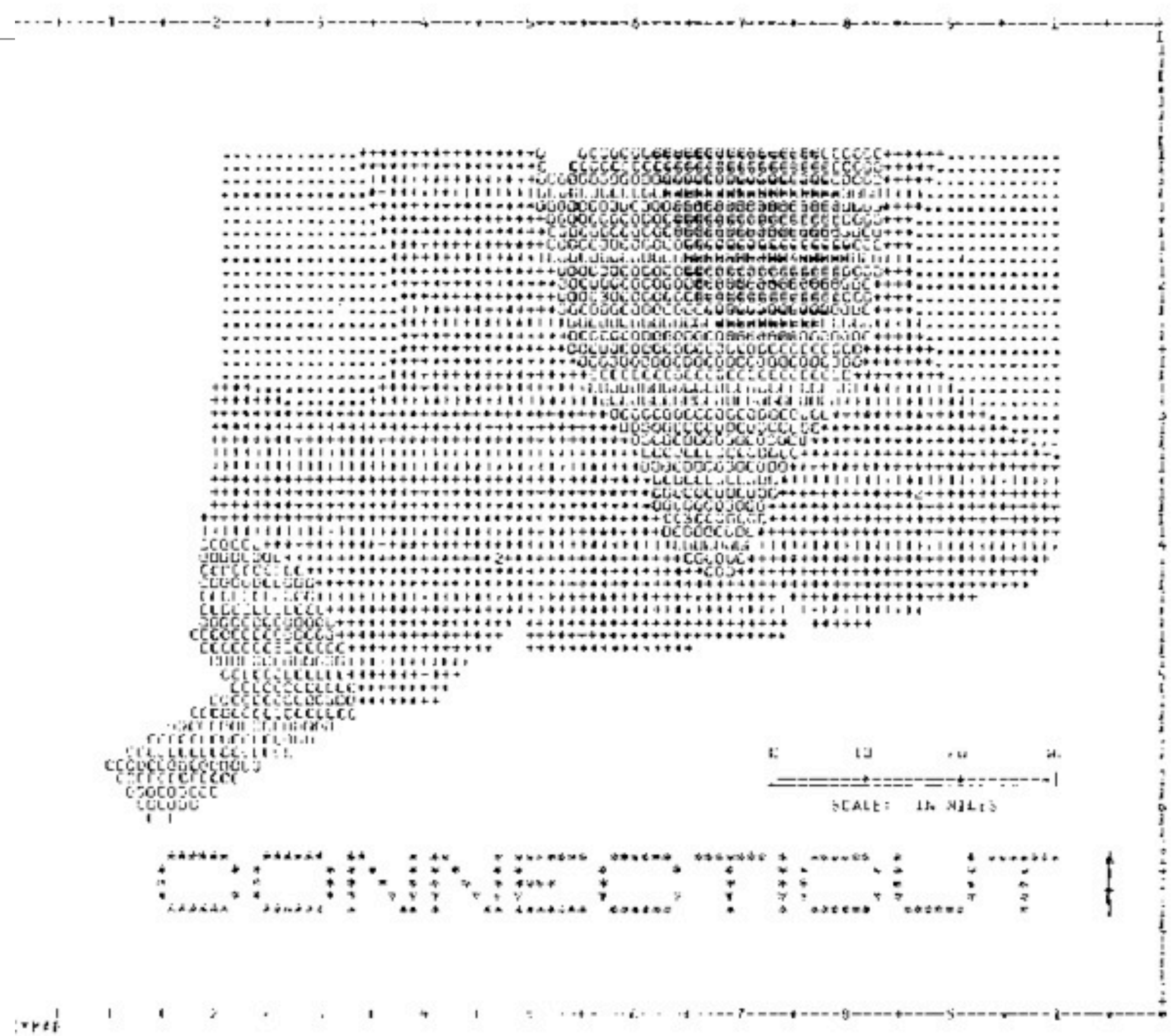
Representing thematic information

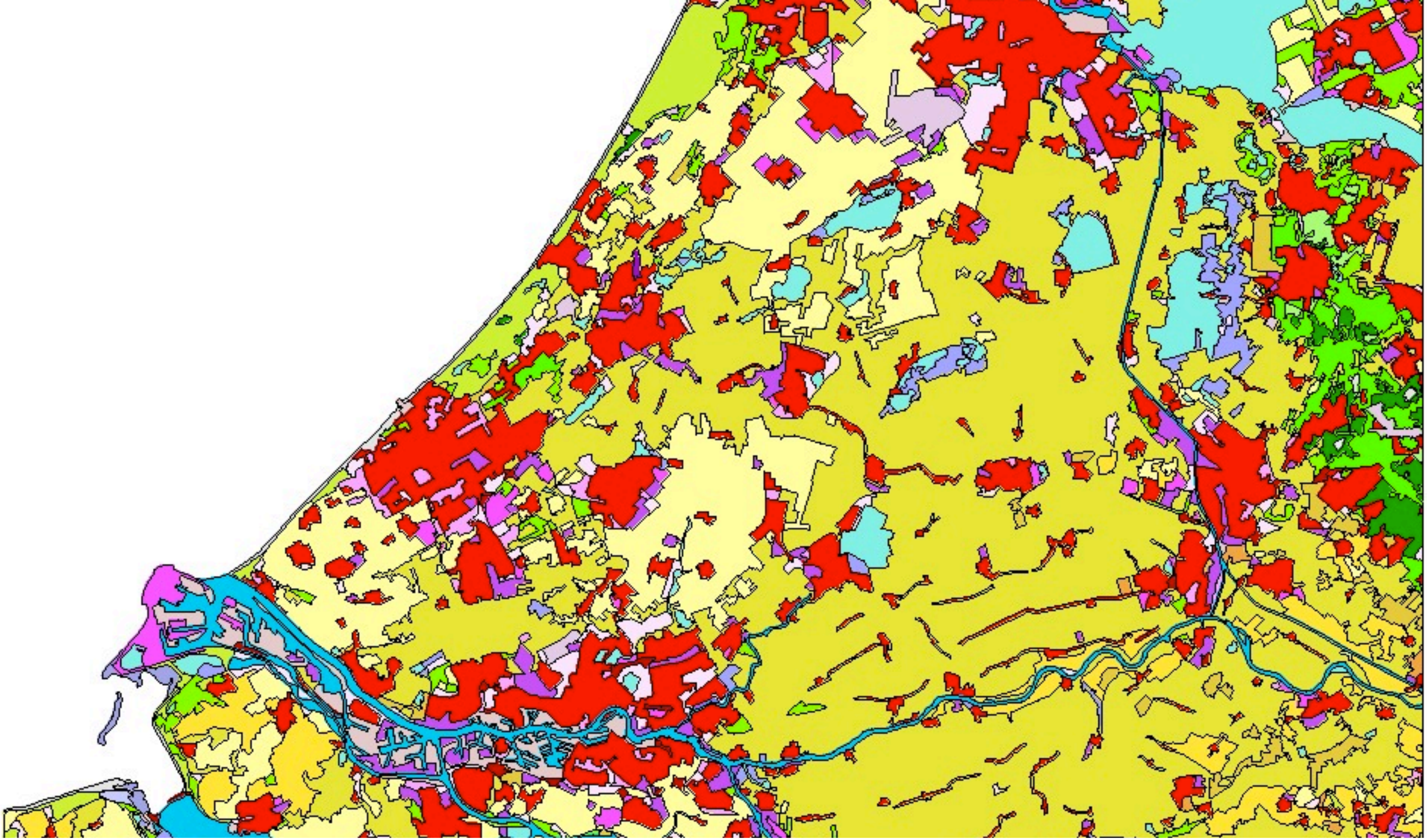
- Pierre Charles Dupin's 1819 map
  - Subdividing the feature space of that theme
  - Distinct visual representation for each class



Digital thematic maps

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



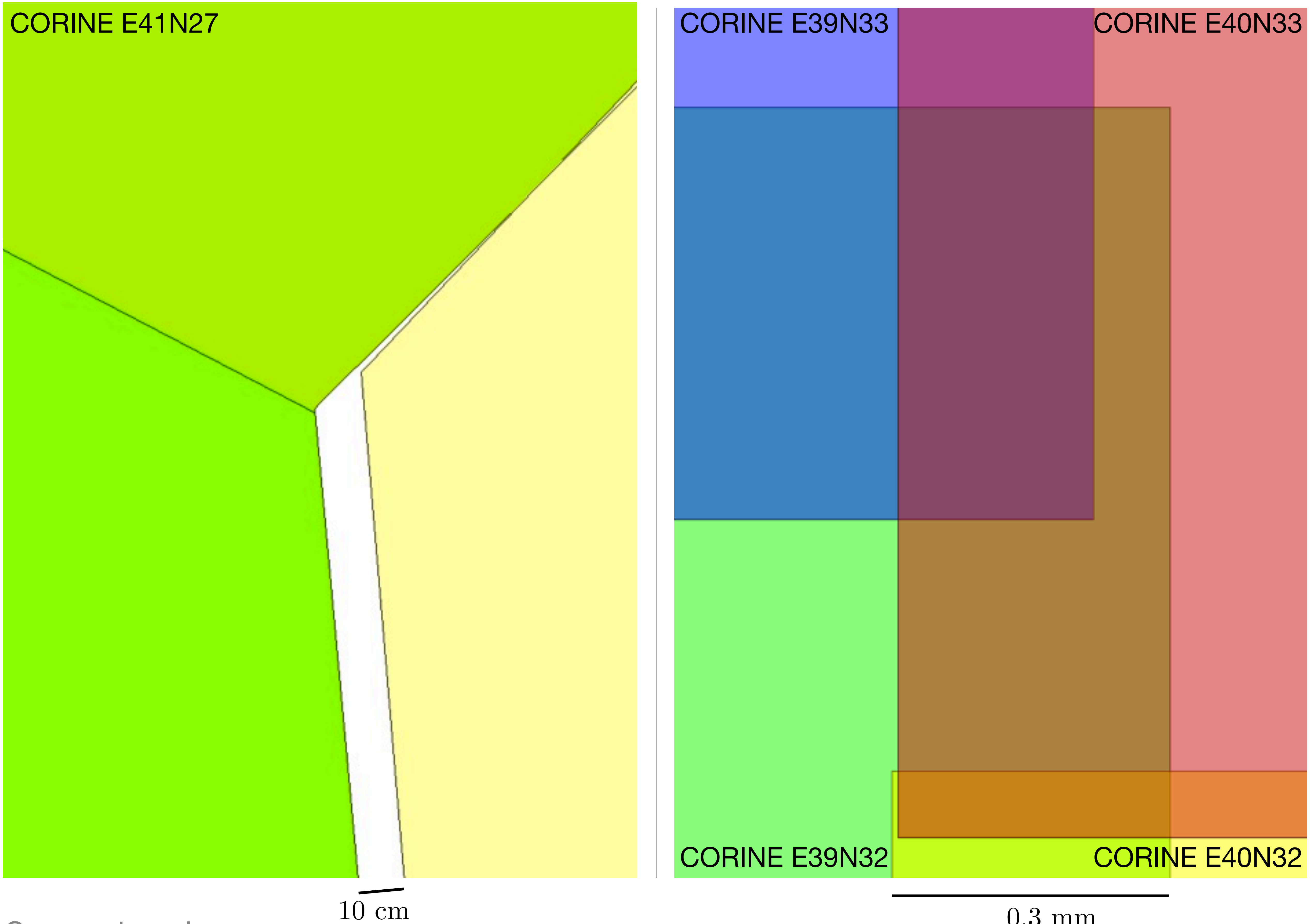

CORINE E39N32

Planar partitions

CORINE 2000

Why planar partitions?

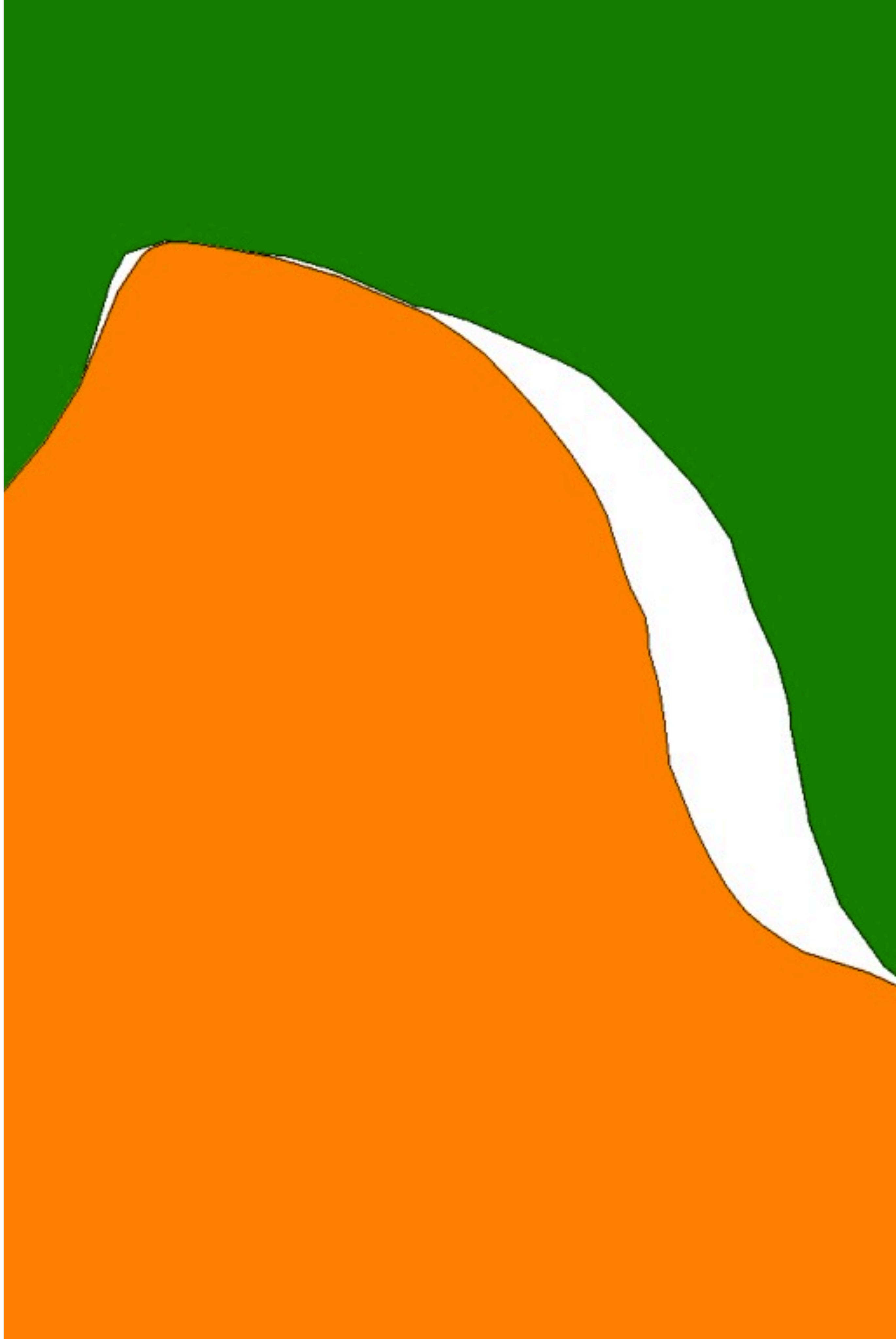
- Simple constraints: no gaps, no overlaps, (no disjoint regions)
- Easy to answer questions:
  - (Aggregation) What is the total area of the features of type A and B?
  - (Topology) Are features A and B adjacent?



Gaps and overlaps

The problem

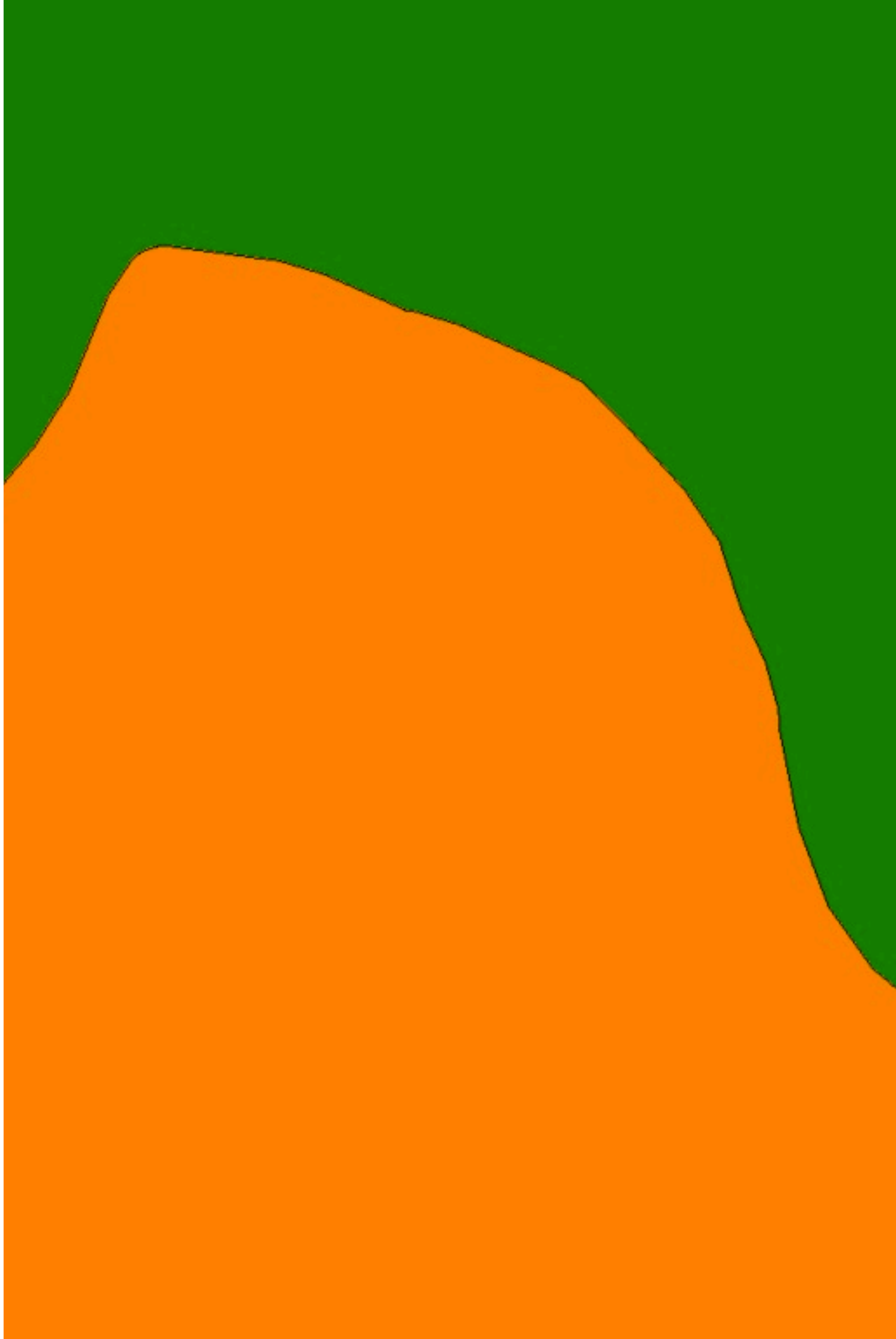
- Validate a planar partition
- If it's invalid, **automatically** repair it.



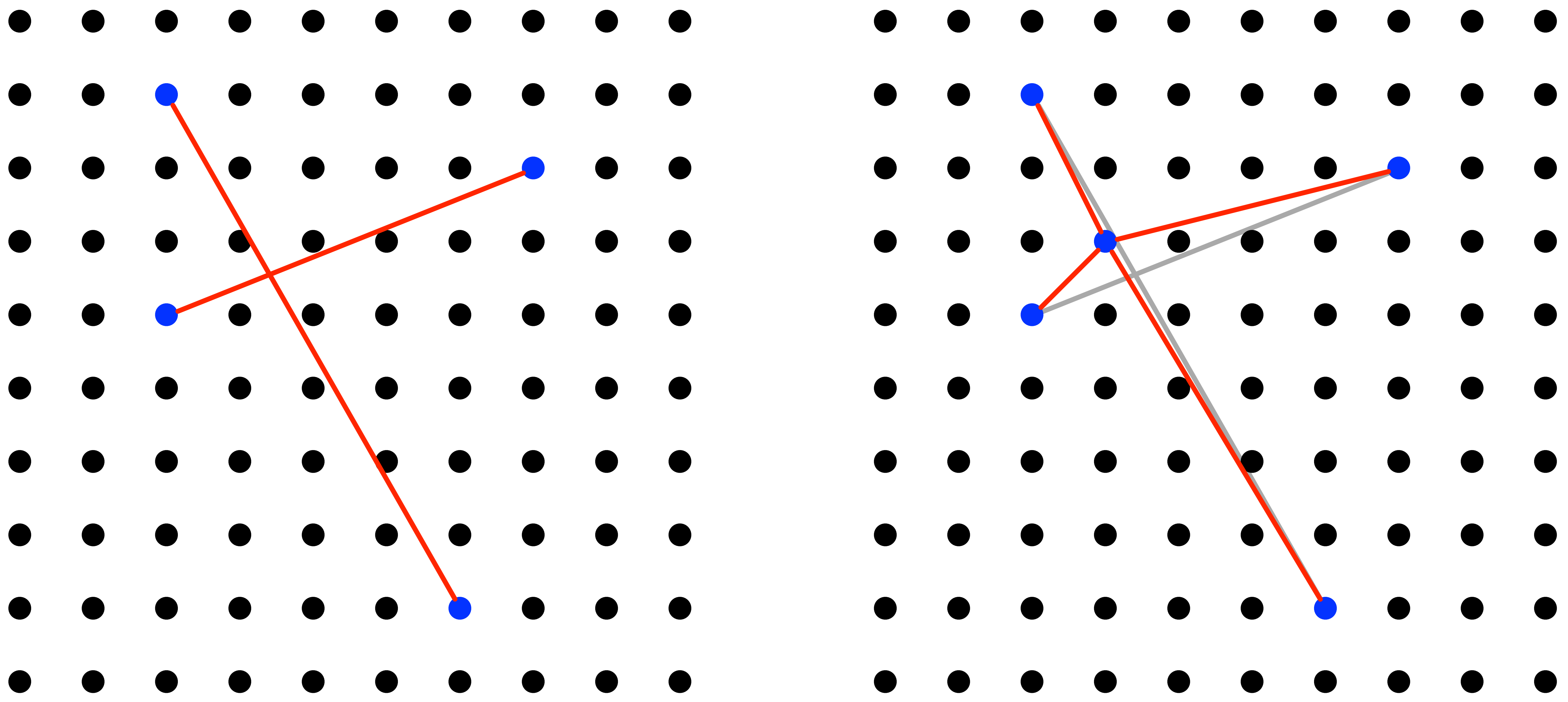
Spain - Portugal border

The problem

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

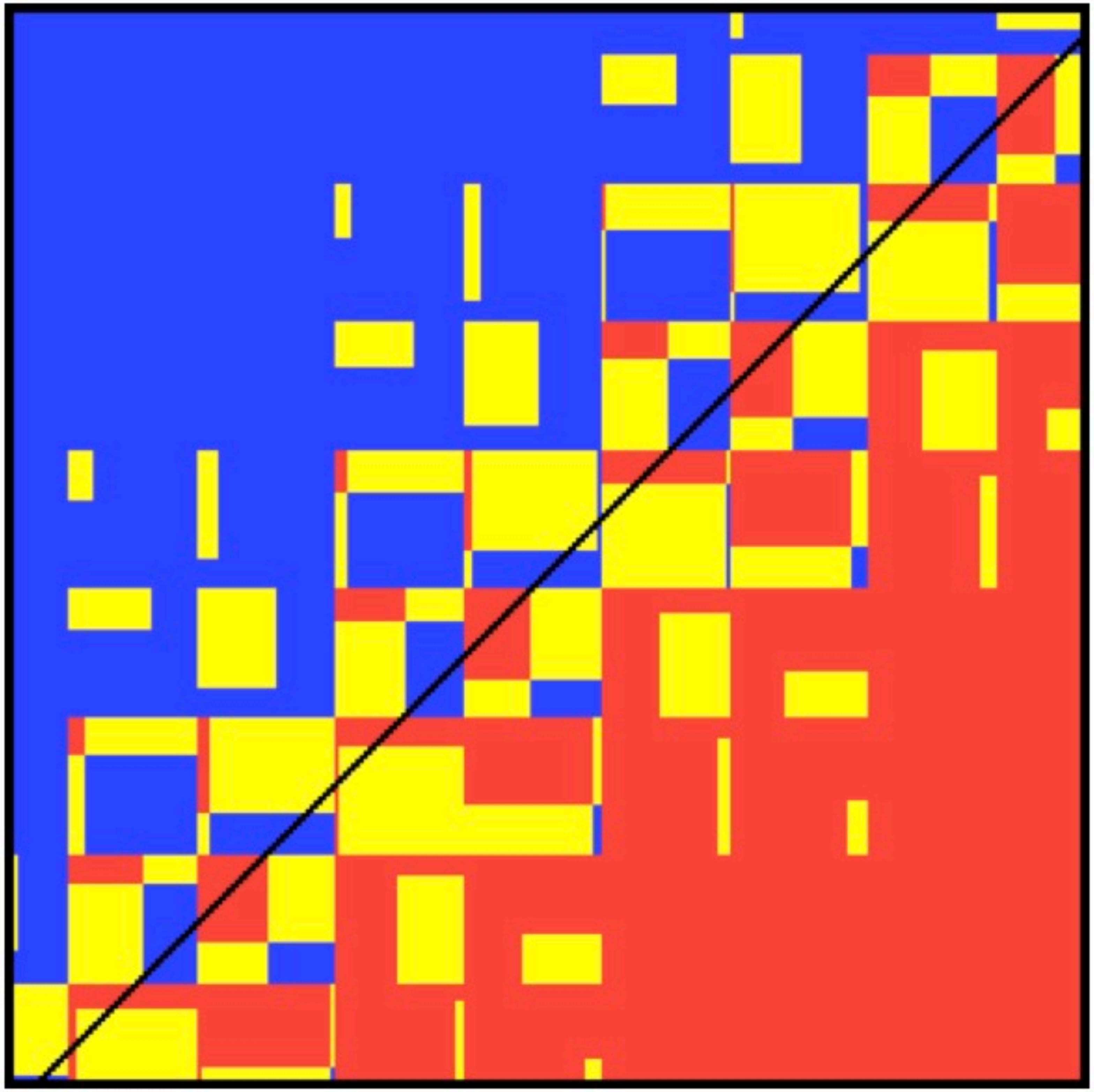


Spain - Portugal border



Why is it hard?

Discrete and approximate representations

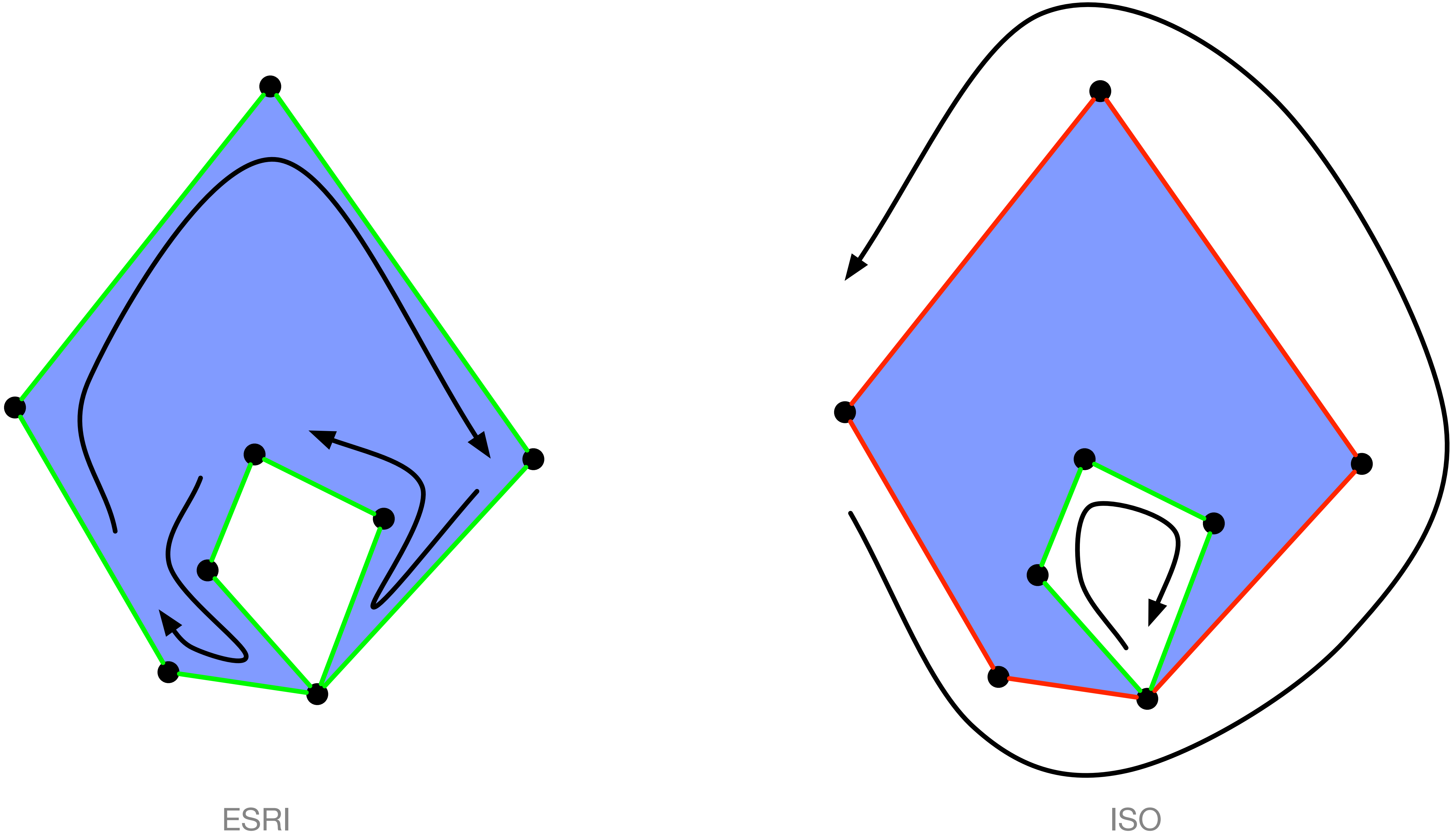


(17.300000000000001,
17.300000000000001)

(24.00000000000005,
24.0000000000000517765)

Errors in computer operations

Orientation test



Polygons with holes

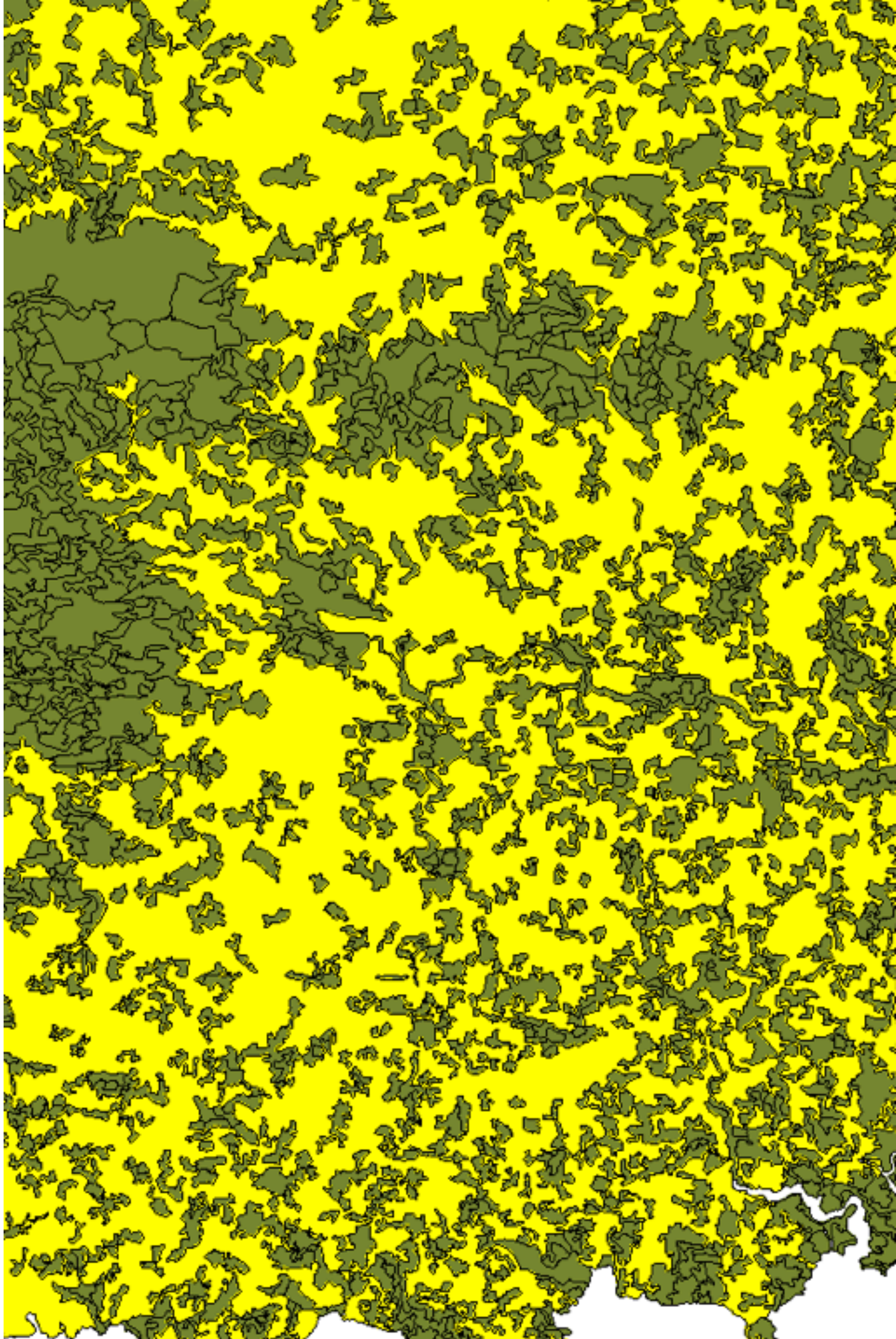
Valid polygons

Spain - Portugal border

Different sources | More ambiguity

Validation process

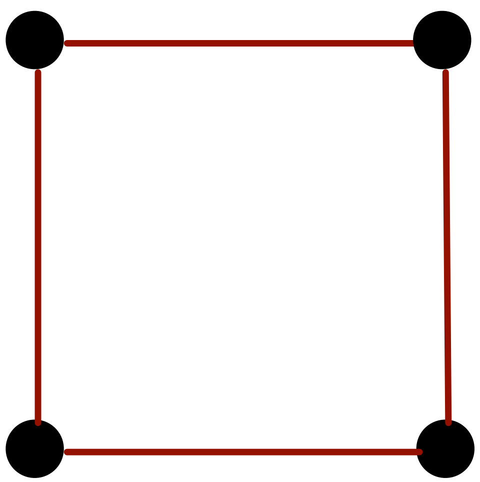
- Rings:
  - Closed, not self-intersecting, not zero area, correct winding, ...
- Polygons:
  - Nested rings, connected interior, not zero area, ...
- Planar Partitions:
  - No gaps, no overlaps, no disjoint regions...

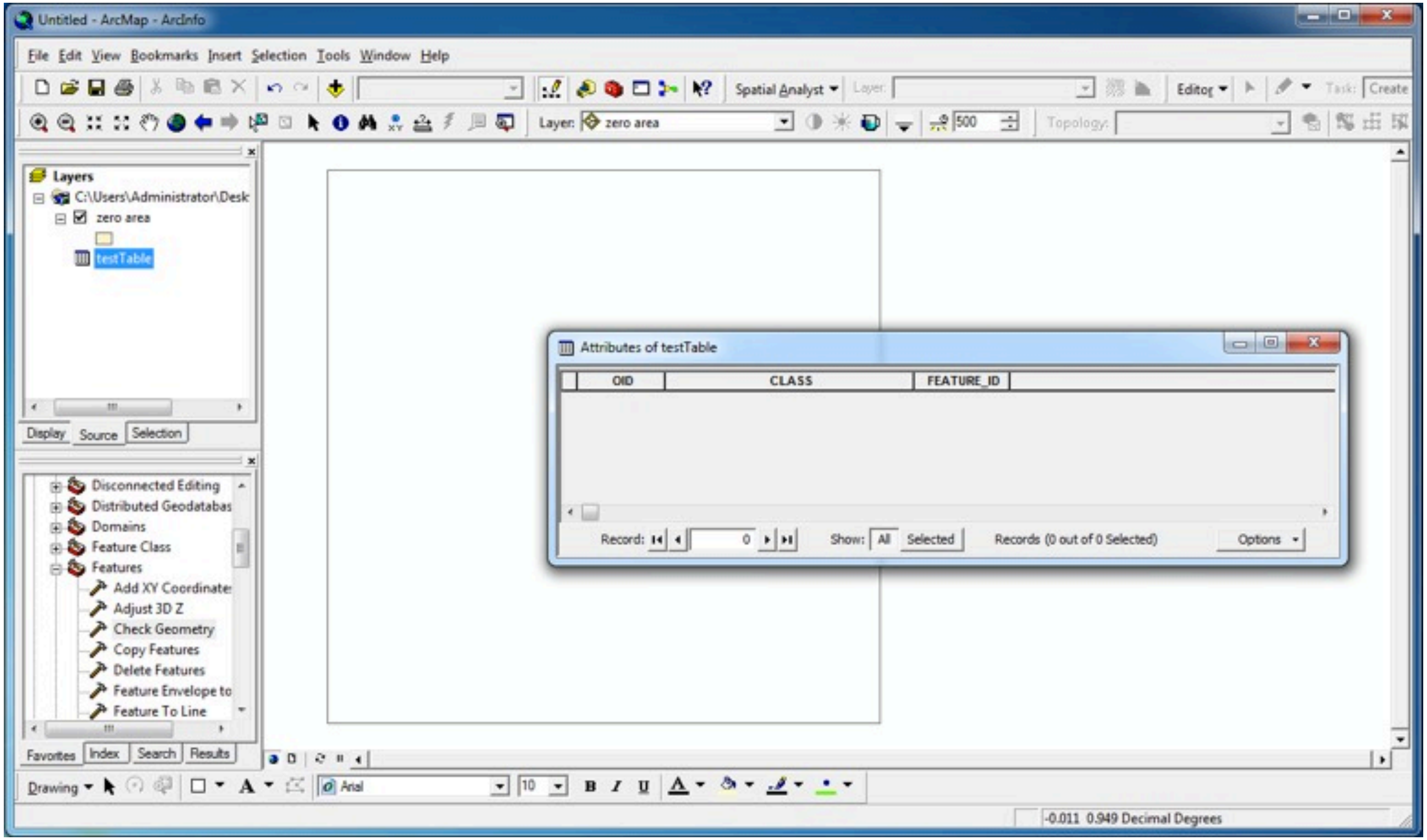


CORINE E30N33

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, self-intersections, touching rings, overlapping rings, points too close together, wrong orientation.



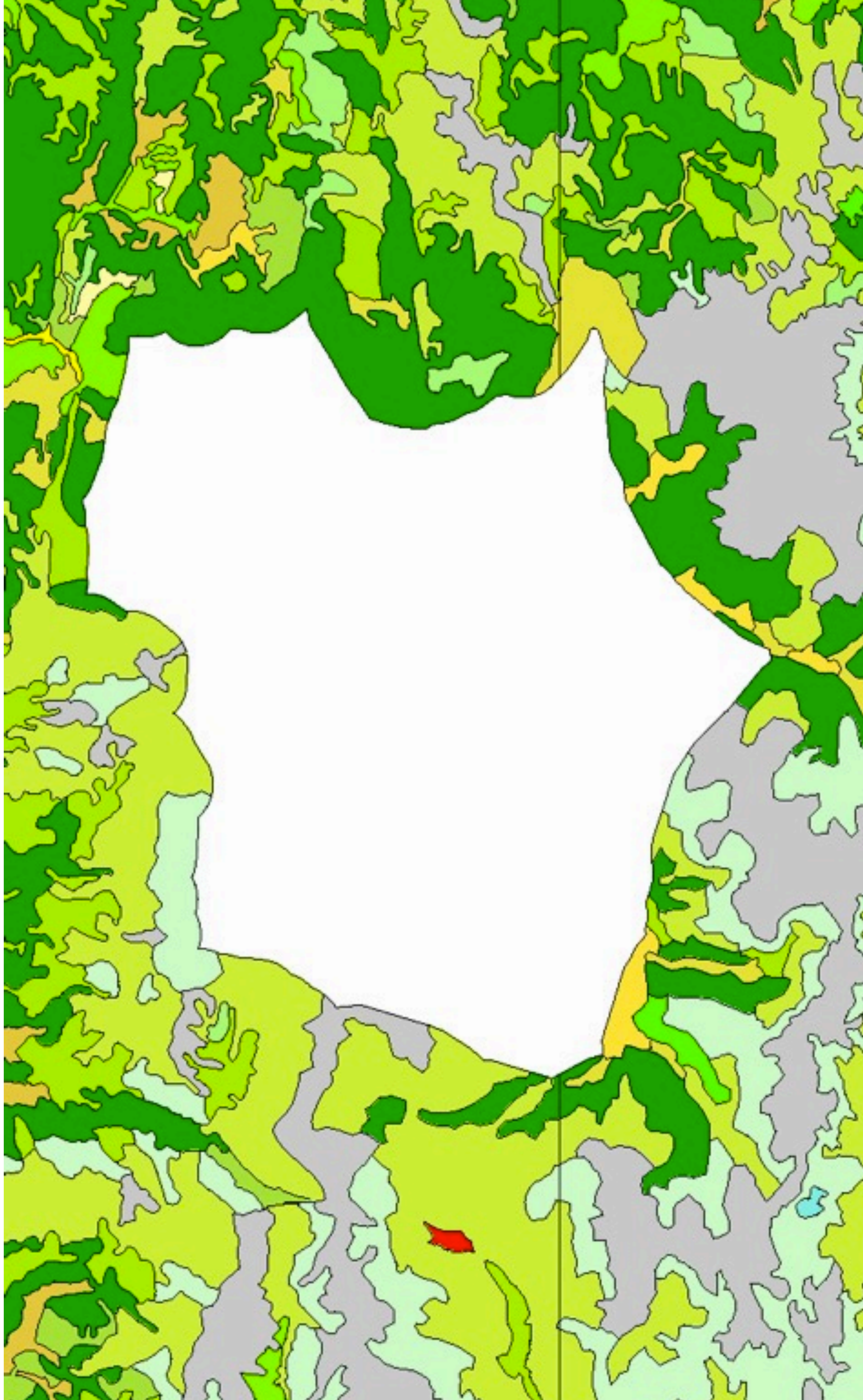


Problems are unavoidable

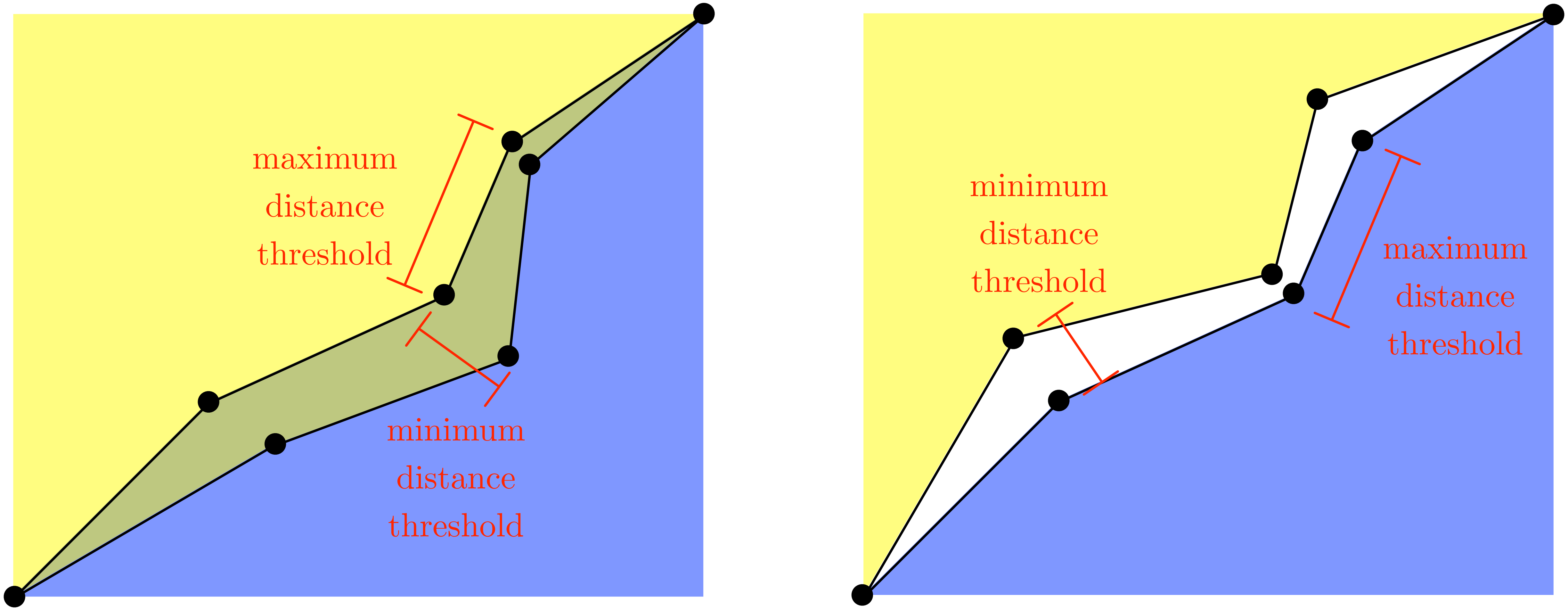
ArcGIS and the zero area polygon

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



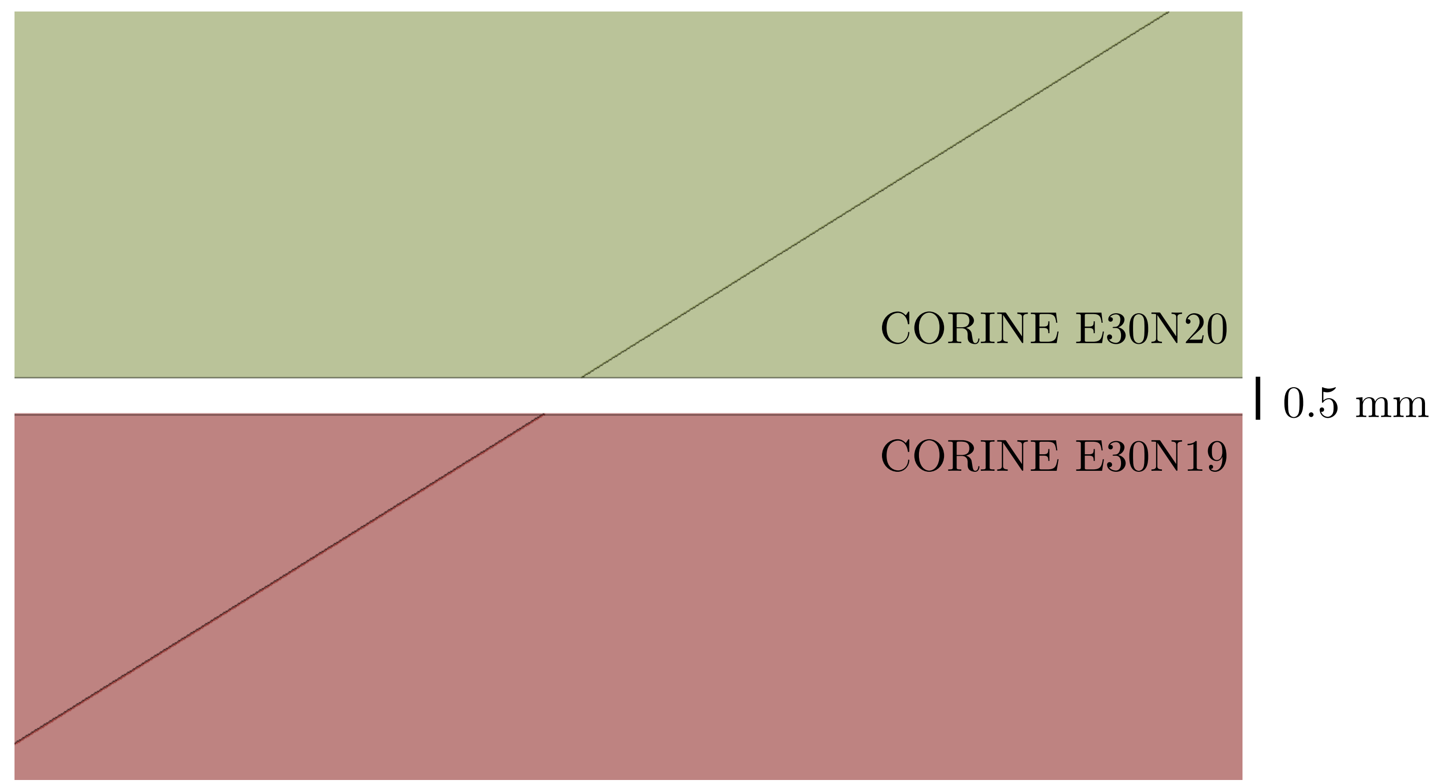
Repair of planar partitions using snapping

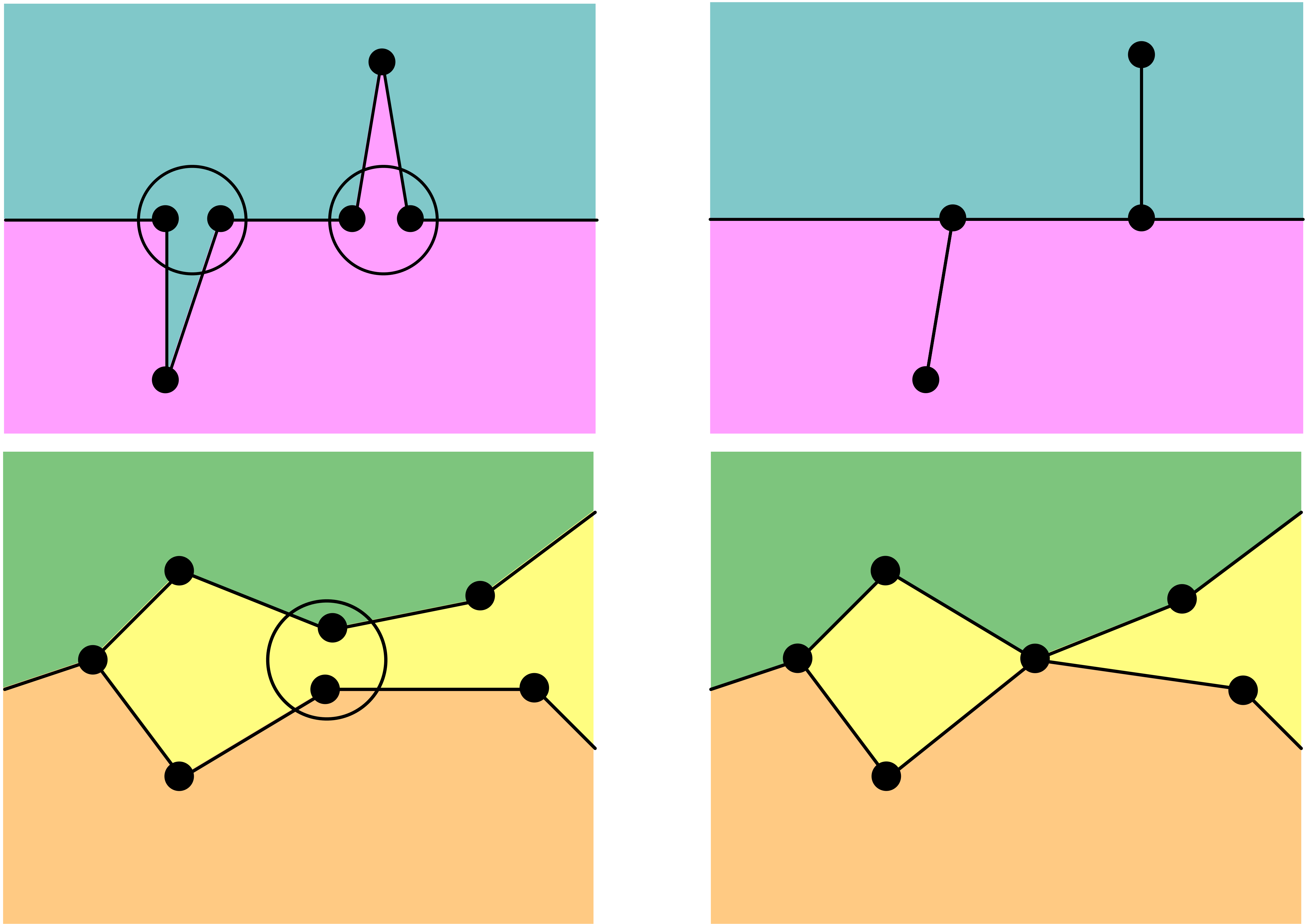
Thresholds

Repair using snapping

- Extensively available: ArcGIS, FME, GRASS, Radius Topology

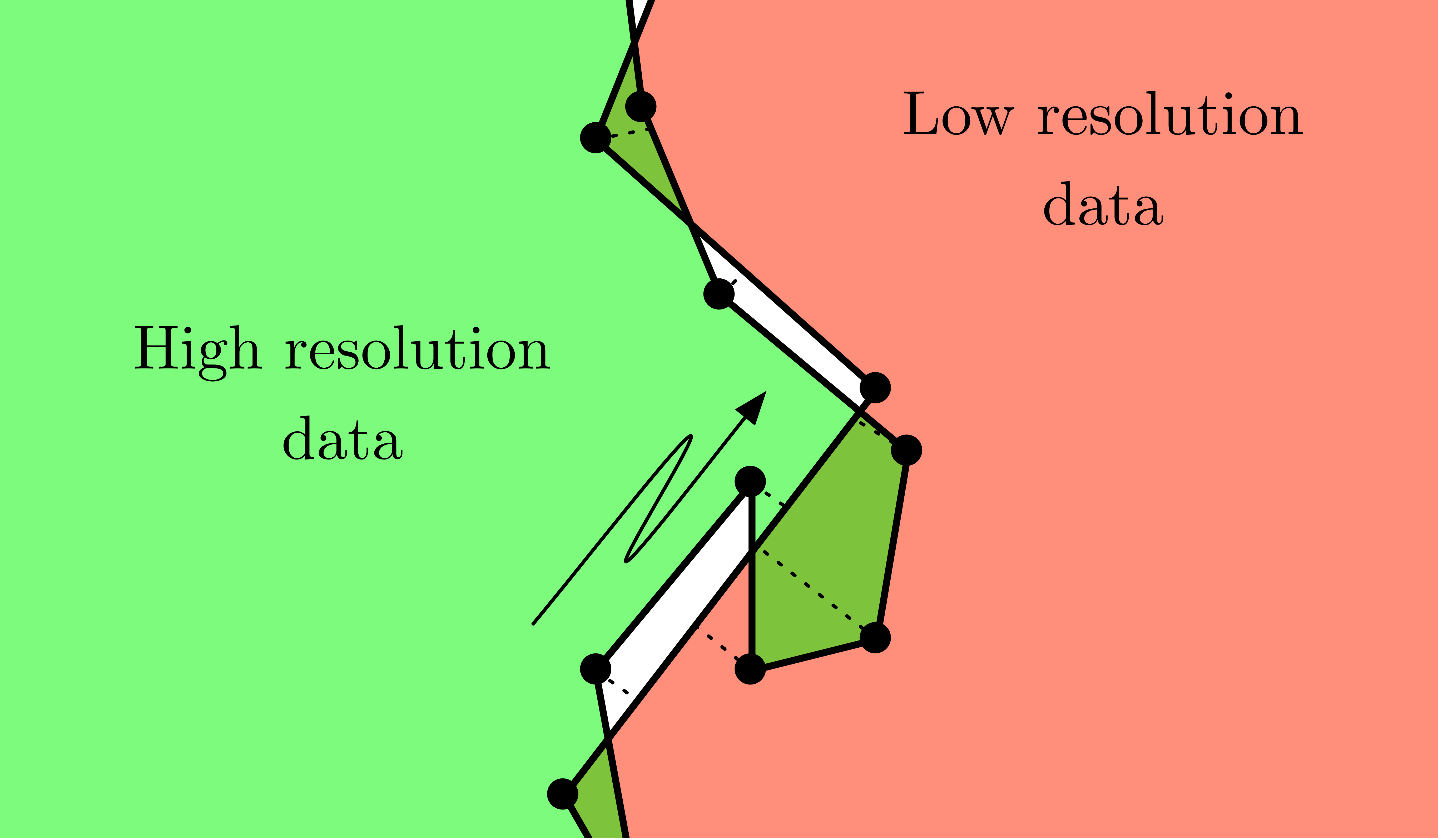
- Possibilities: point to point, point to line, line to line





Repair using snapping

Not a complete solution



Repair using snapping

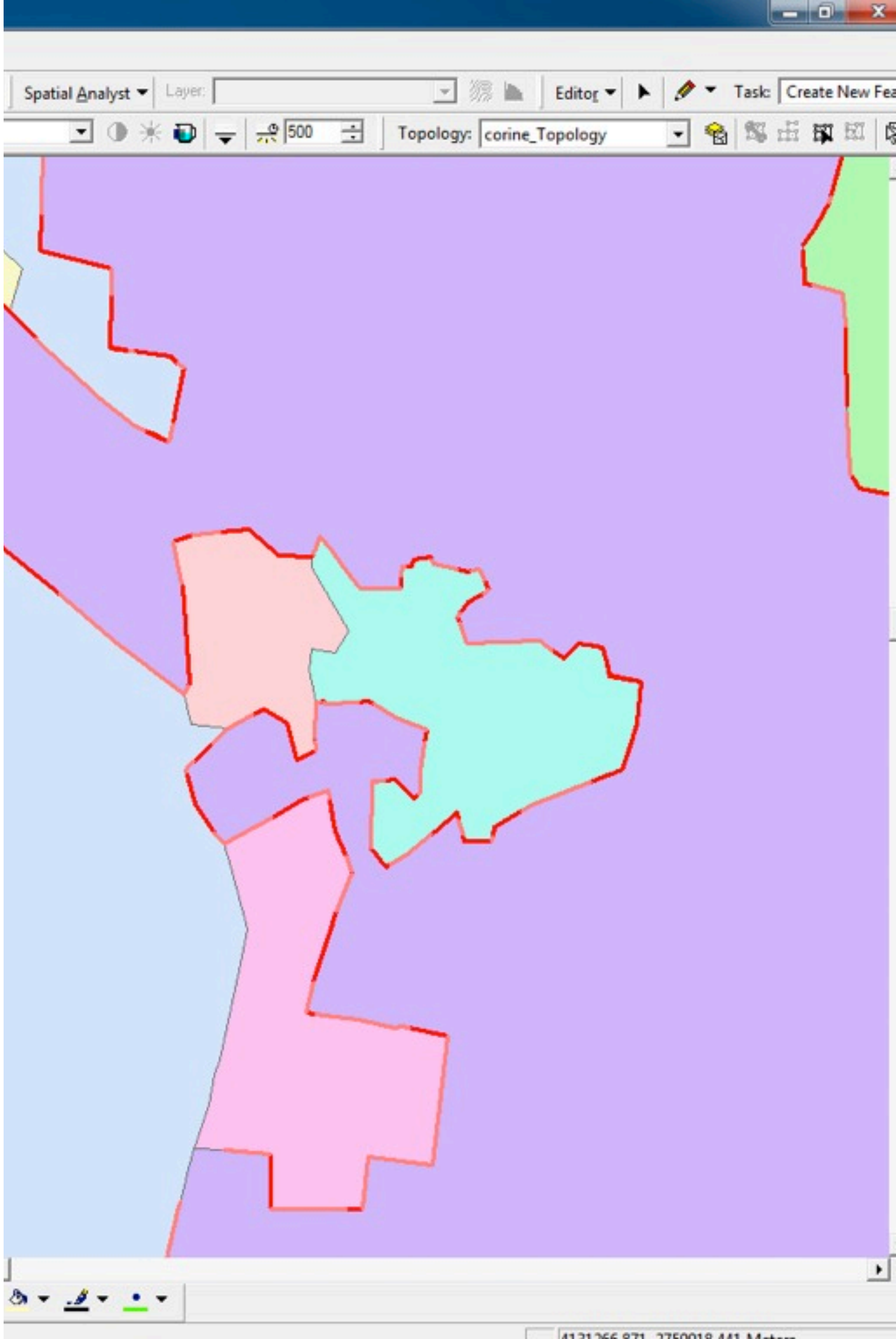
Clean-up required

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

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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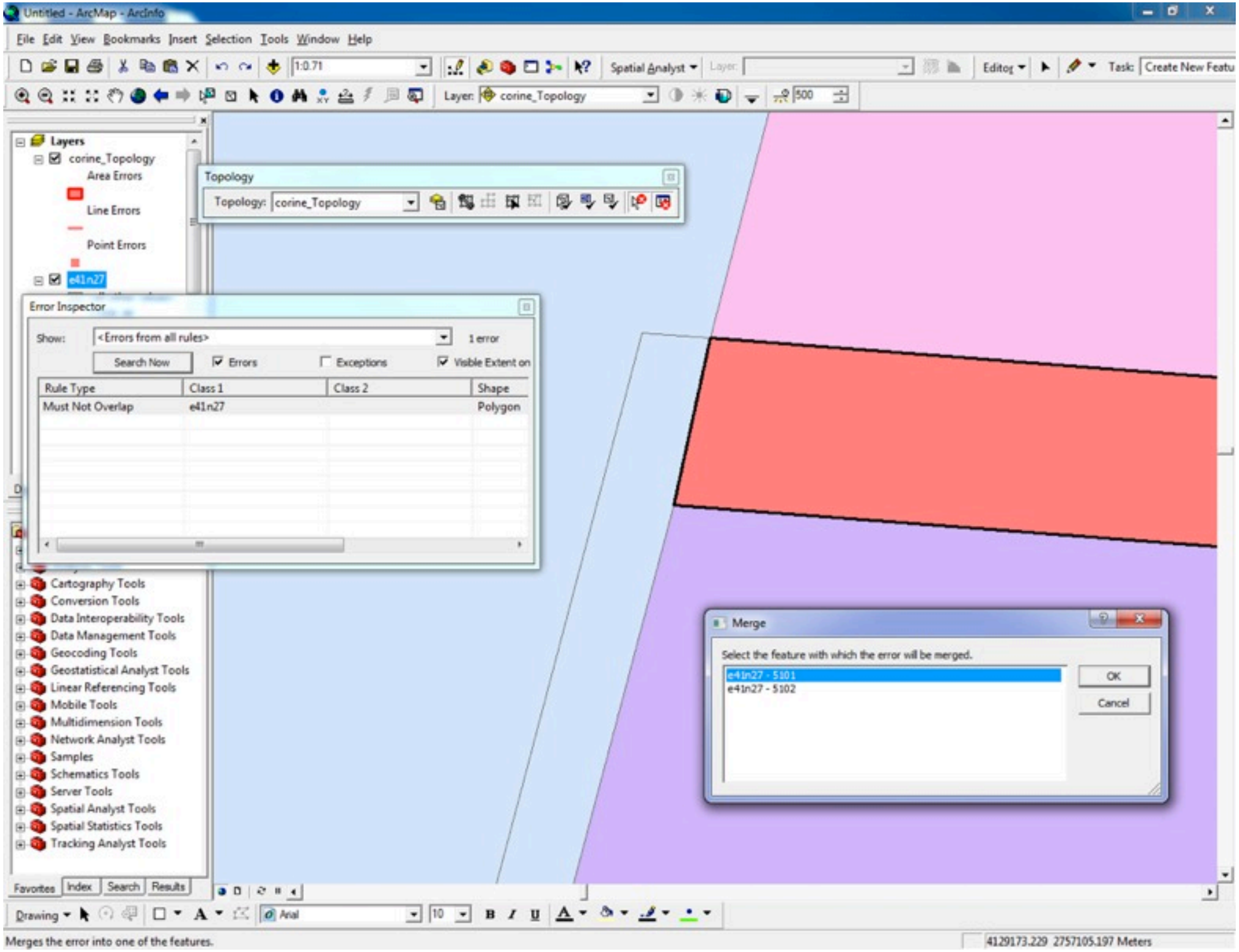
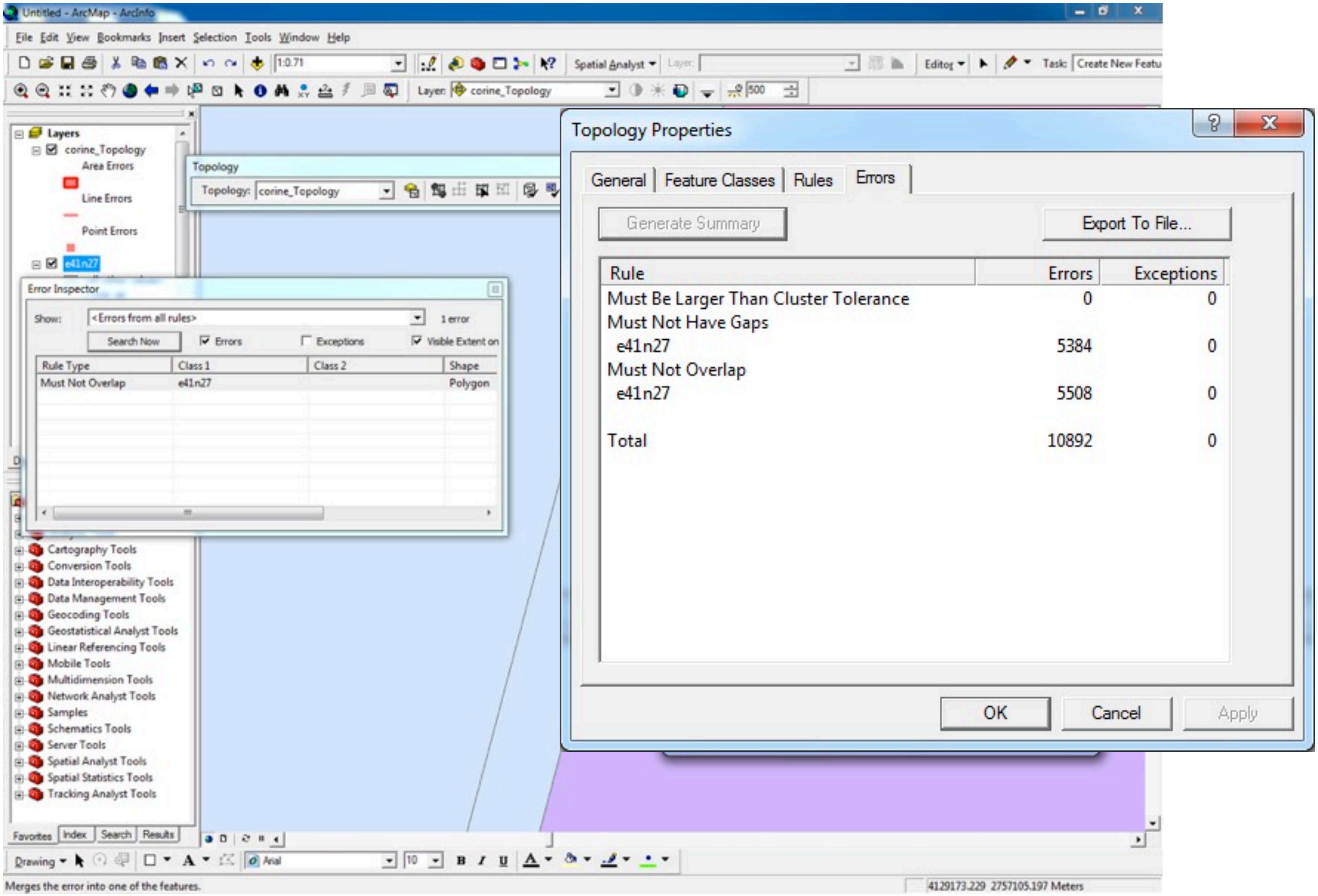


Topological repair in ArcGIS

Manual editing of topology

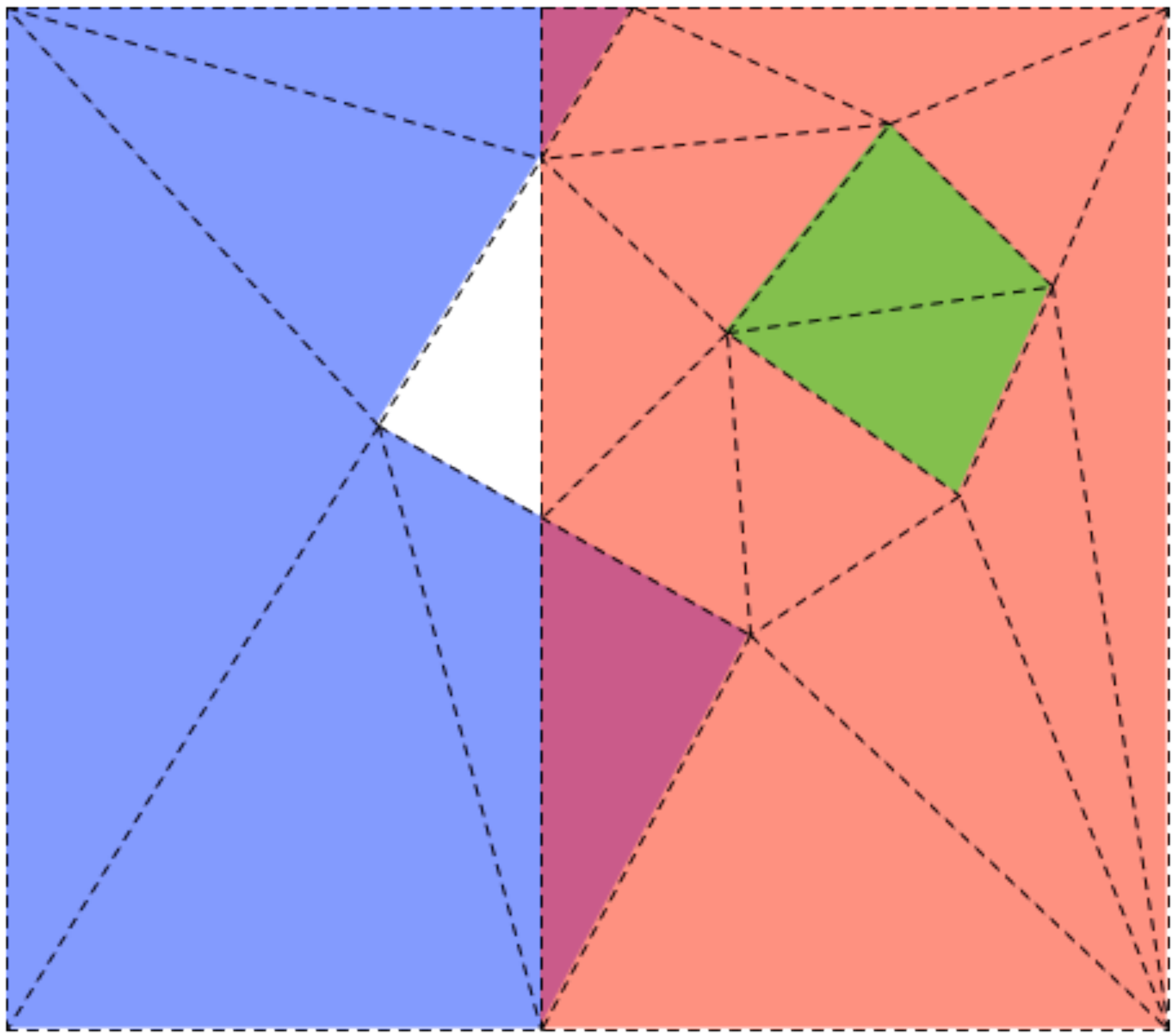


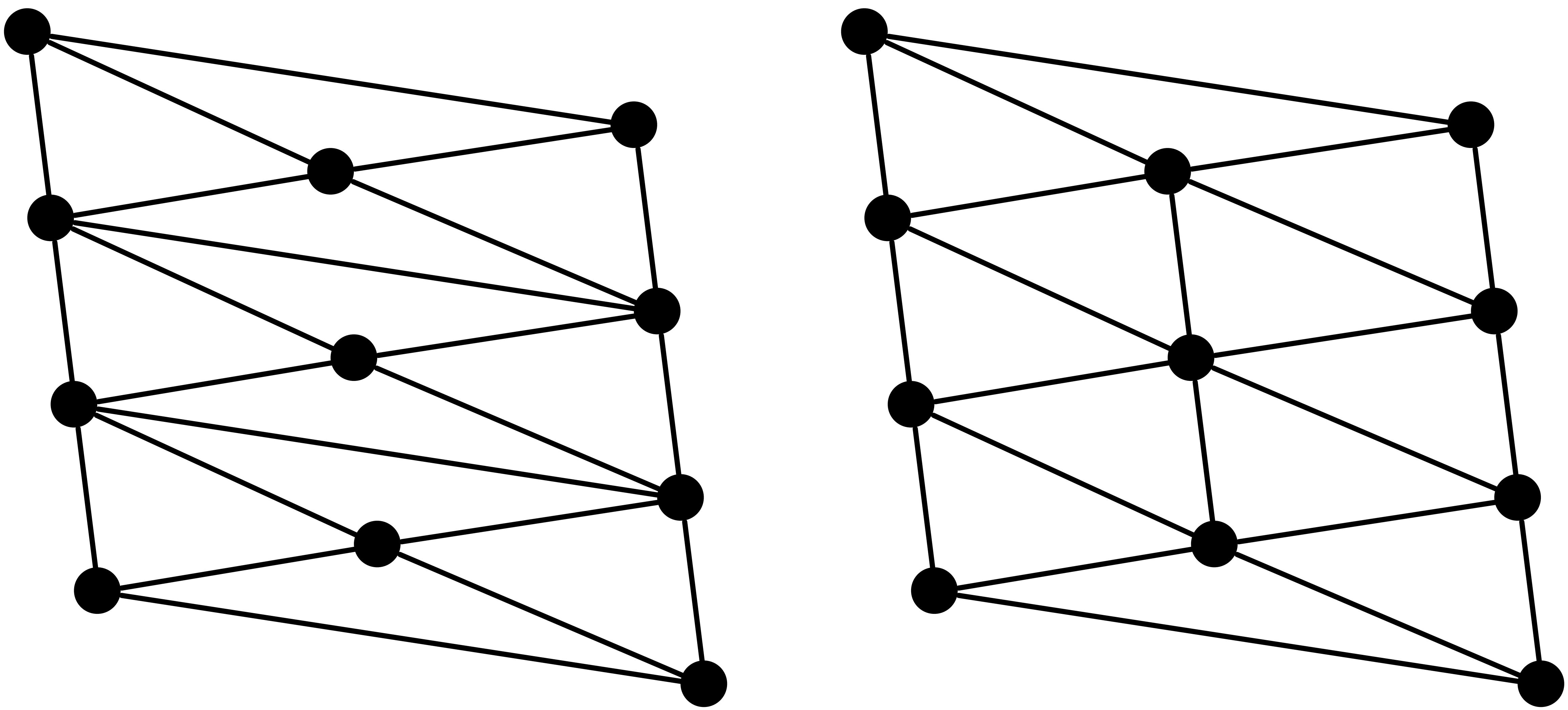
Topological repair in ArcGIS

Manual editing of topology

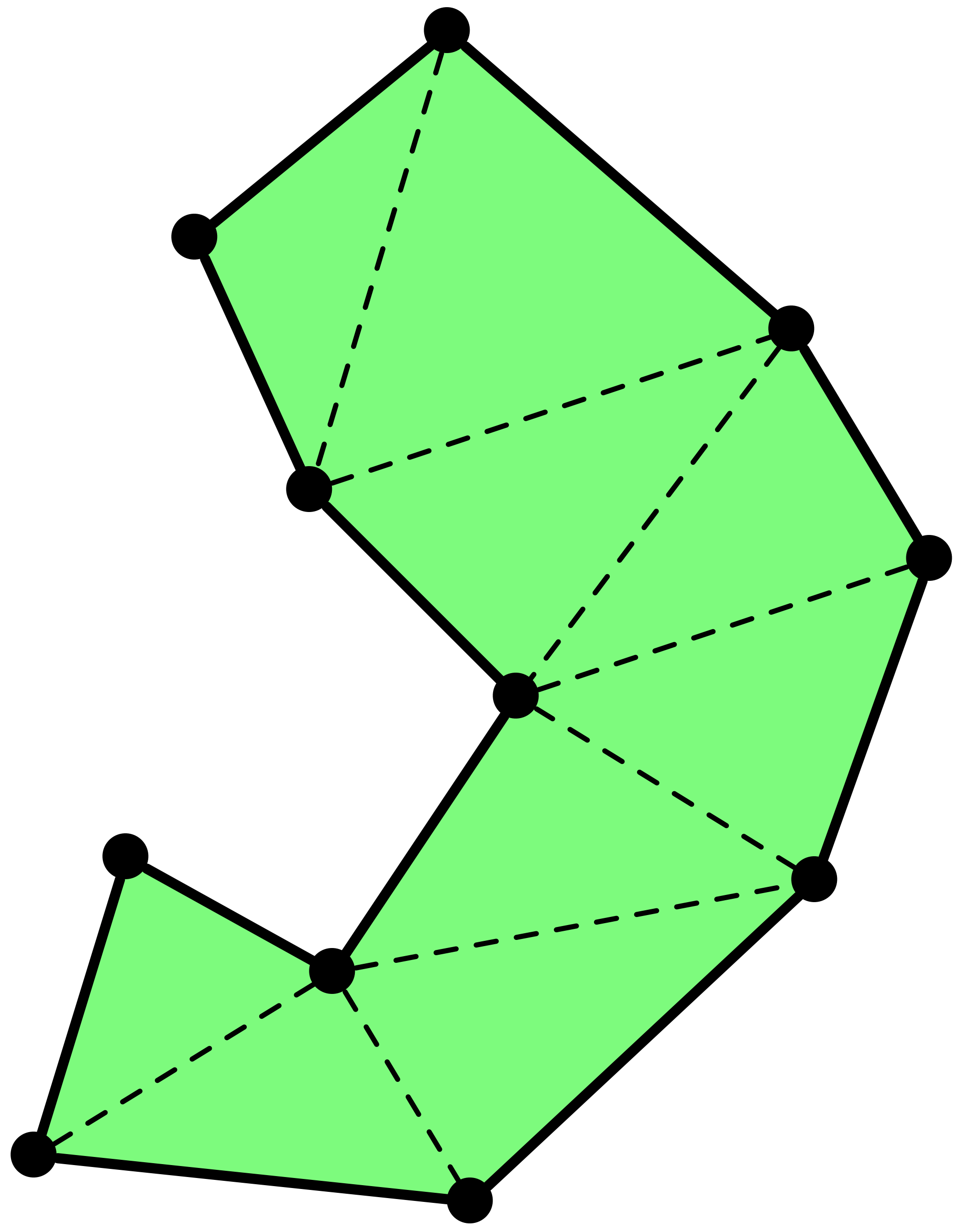
The solution

- 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.





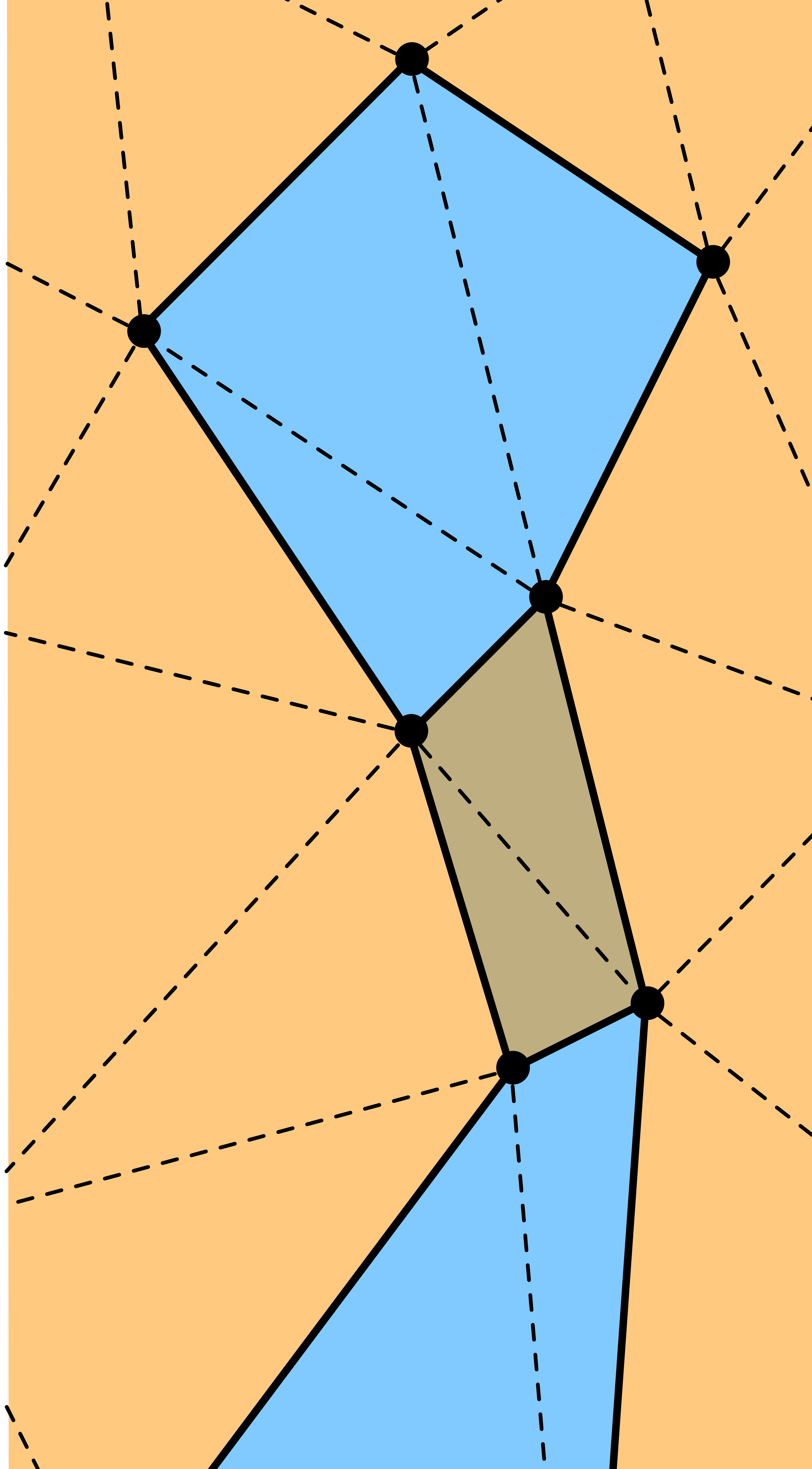
Triangulations | Point sets



Triangulations | Polygons

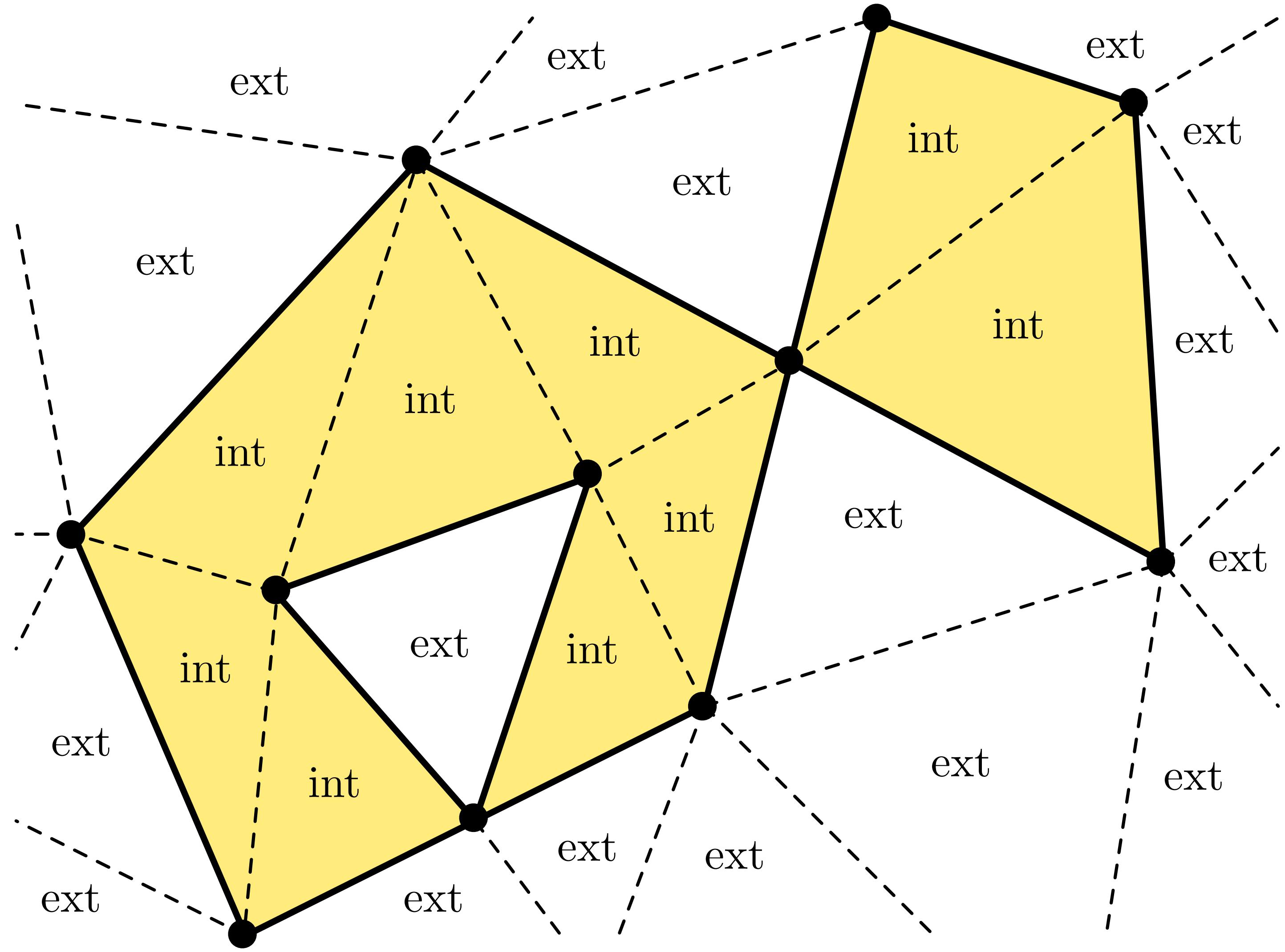
The constrained Delaunay triangulation

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



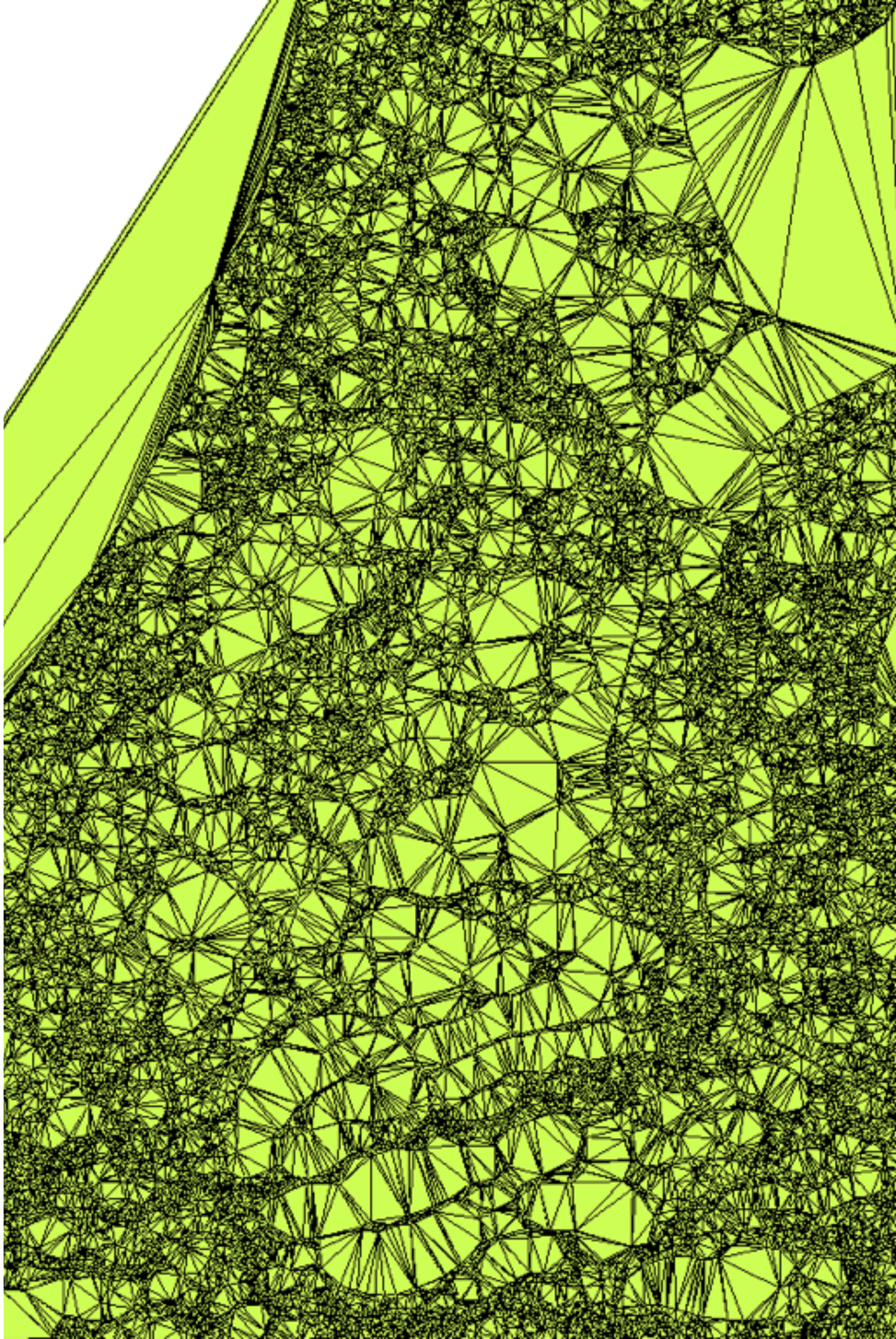
Repair an individual polygon

- 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.



Create triangulation

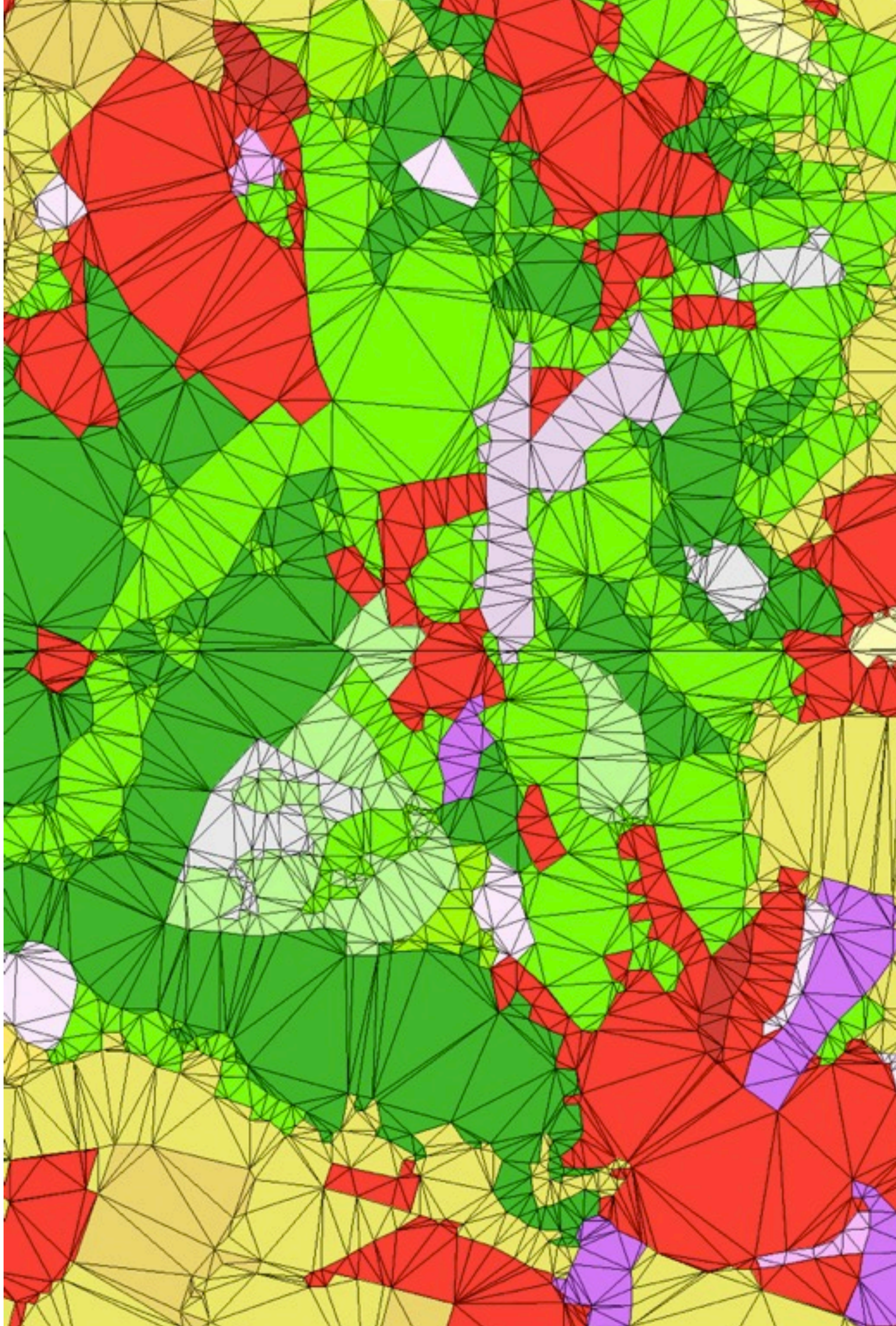
- Add every edge of every (now valid) polygon to the triangulation as a constrained edge.
- Track whenever constrained edges are split.


CORINE E39N32

Tag triangulation

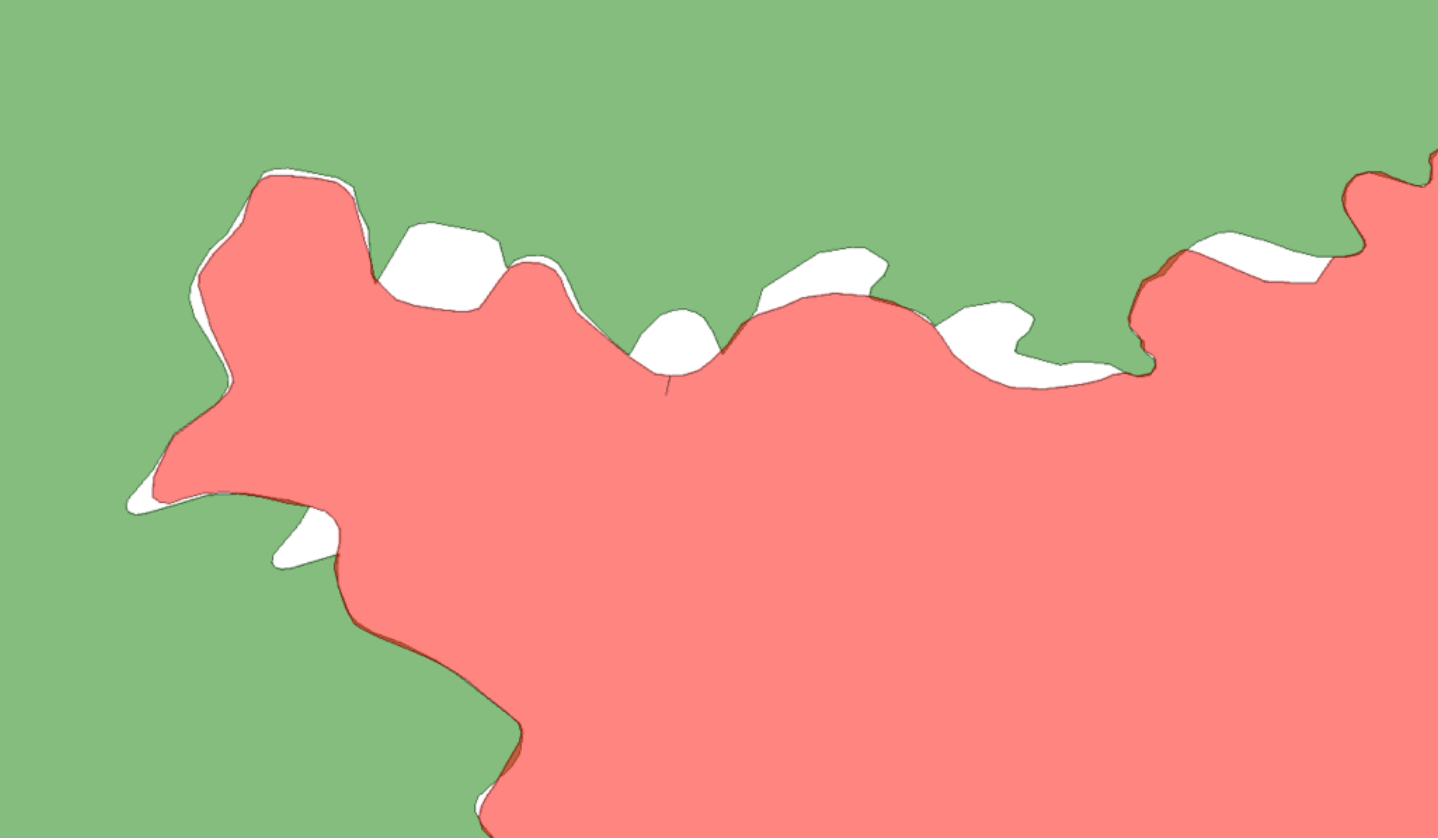
- Mark each triangle with the polygons that it belongs to.
- No tags = gap
- Multiple tags = overlap

CORINE E39N32 & E40N32



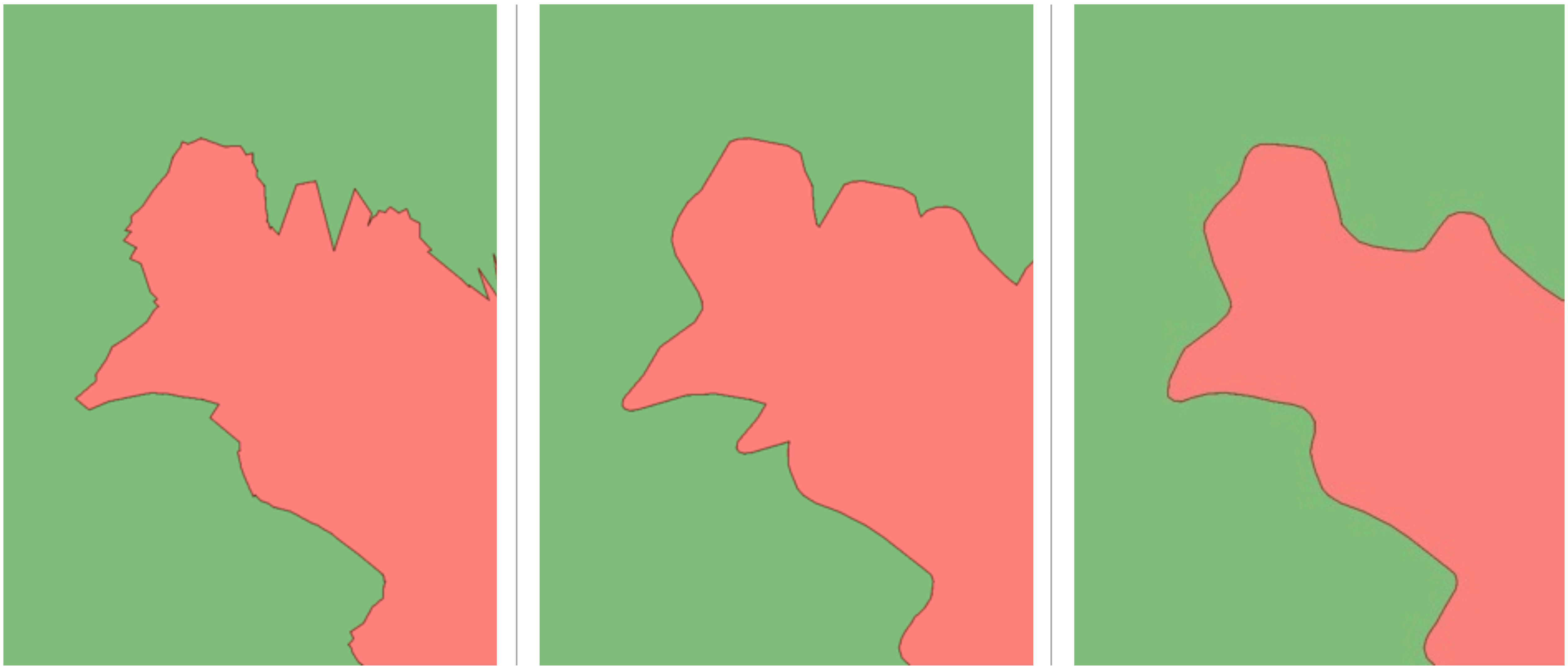
Repair operations

- 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.



Repair operations

Spain - Portugal border



Triangle with longest boundary

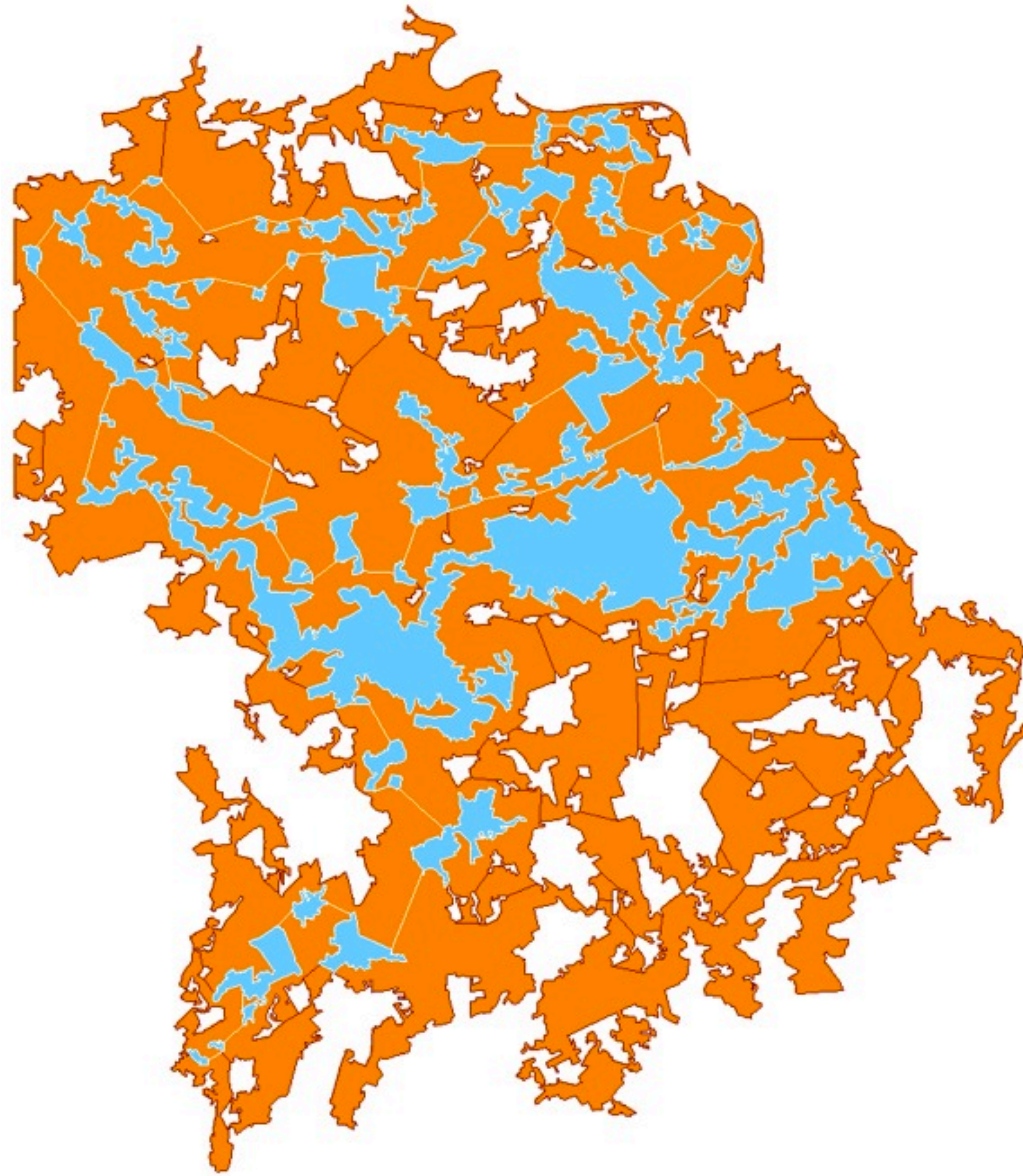
Random region

Region with longest boundary

3 repair operations

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.



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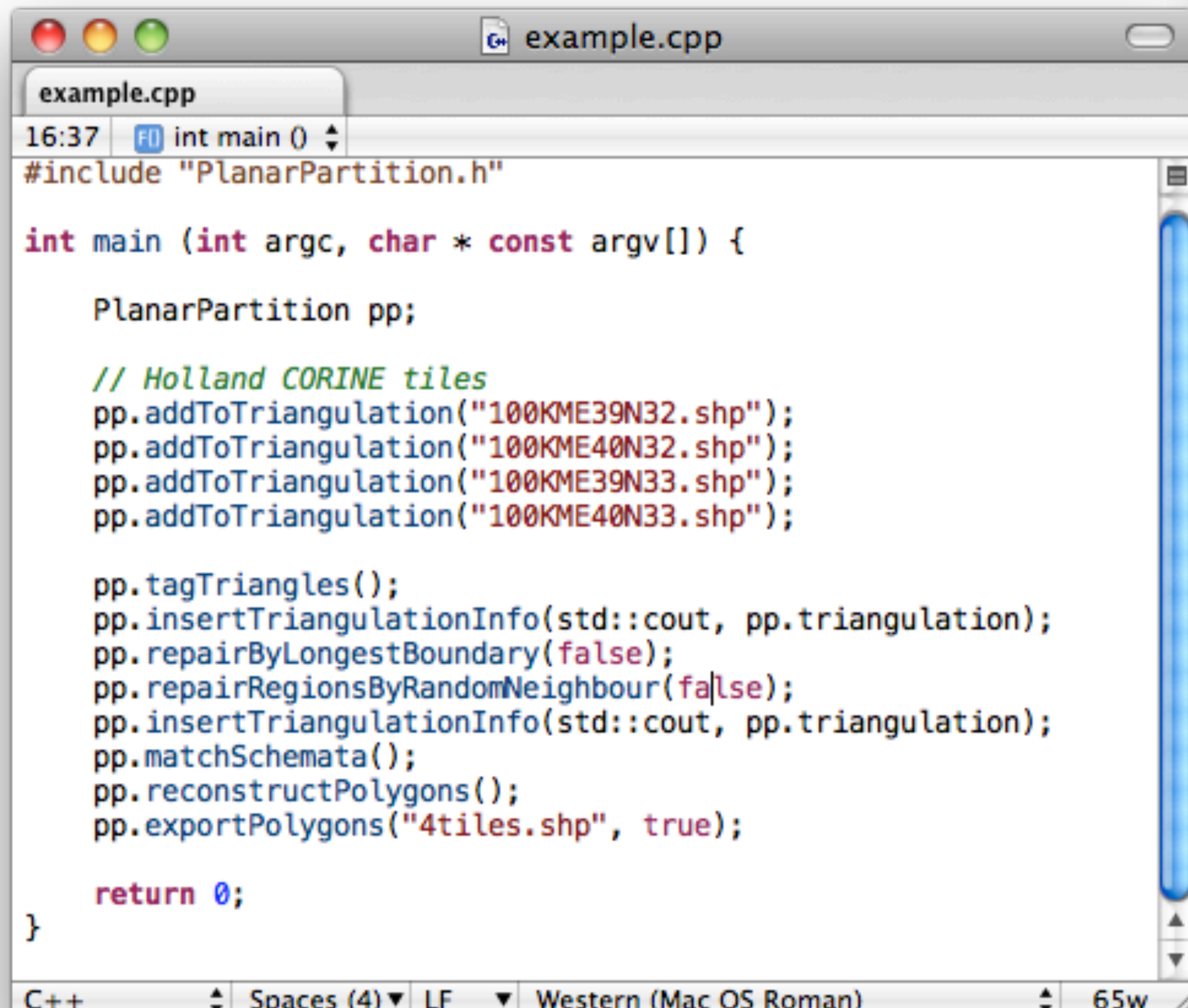
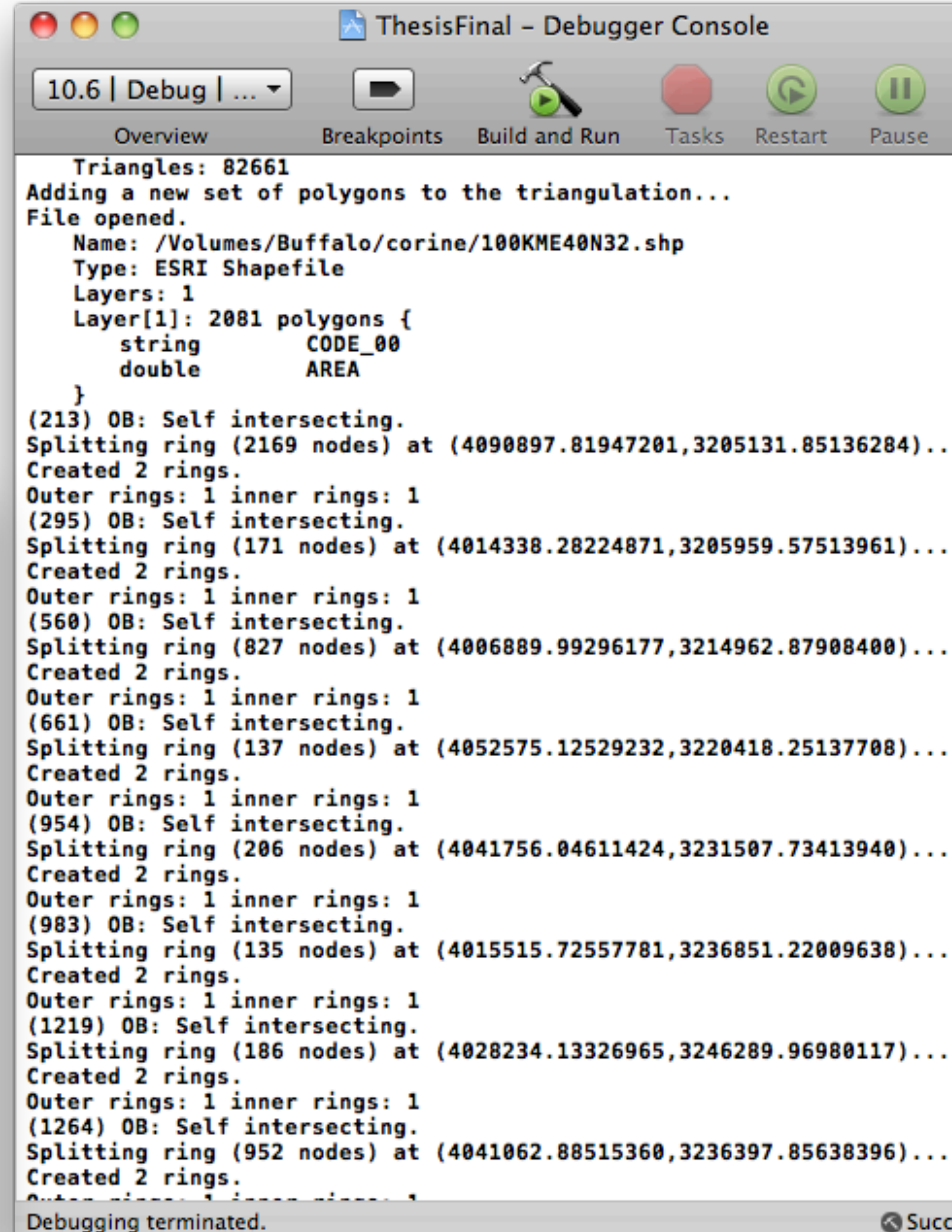
pol. 1752

The prototype

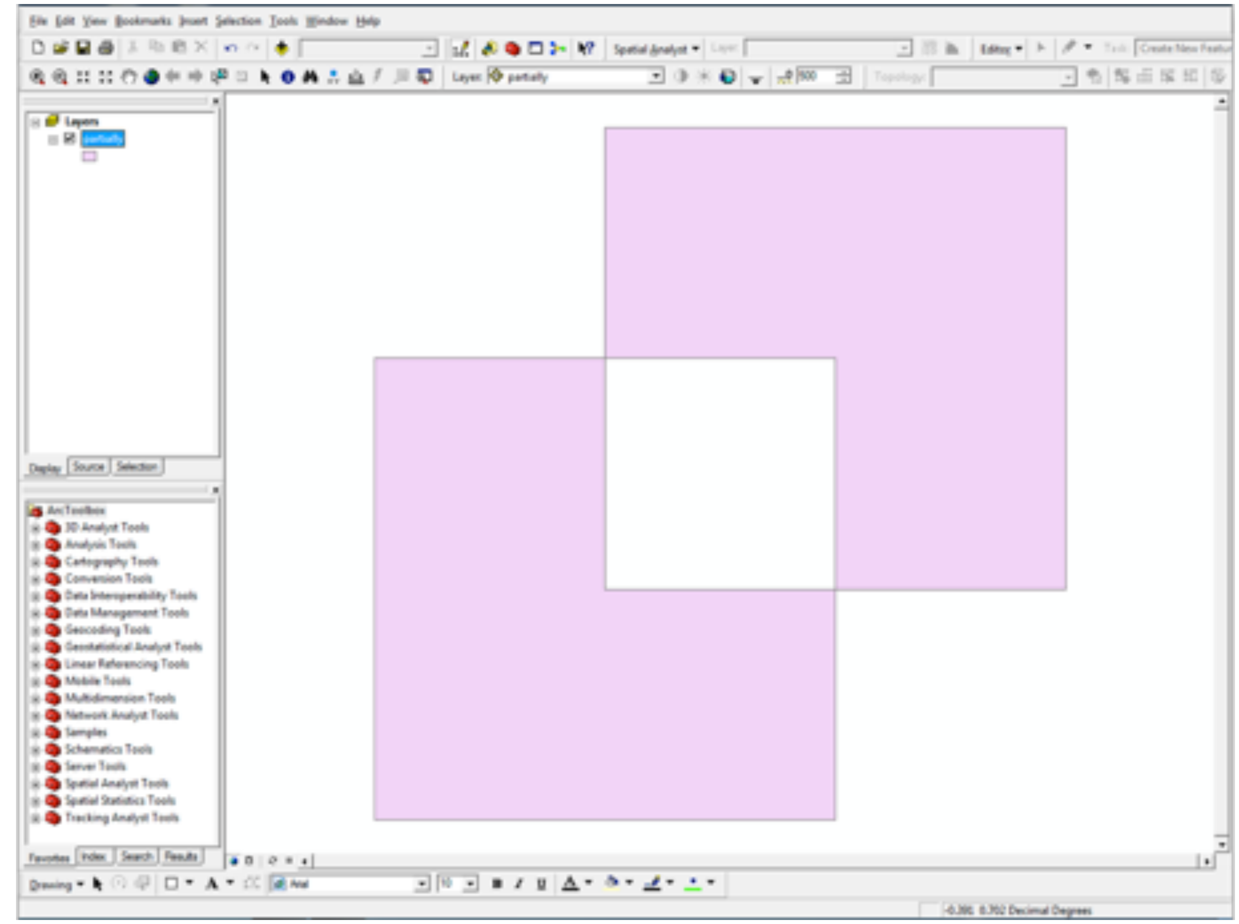
- C++ with CGAL and OGR
- Open source and freely available

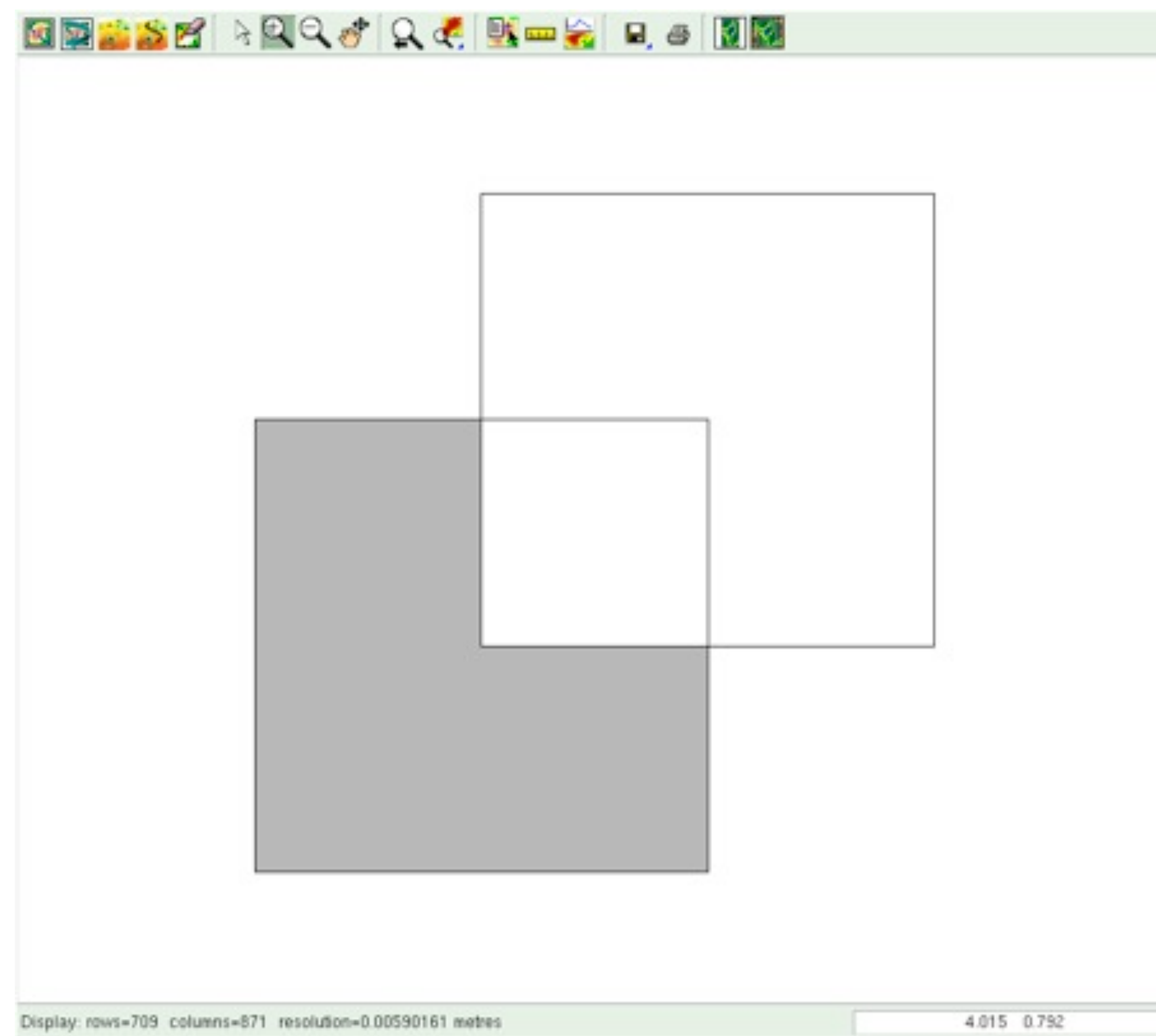




Comparisons with other software

- 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	CT		ArcGIS		FME		GRASS	
	memory	time	memory	time	memory	time	memory	time
E41N27	124 MB	46s	145 MB	1m3s	158 MB	31s	59 MB	3m09s
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