Recent Developments in JTS and GEOS

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- **Geospatial Engineer** at crunchy data
- Developer on:
  - **JTS Topology Suite**
  - **GEOS**
  - **PostGIS**
  - `pg_featureserv`

I ♥ Math & Geometry!

JTS Topology Suite

- Library for representing and processing vector geometry
- Written in Java
- Since 2001; now at version 1.19
- Open source, on GitHub
- License
  - EPL: Eclipse Public License
  - EDL: Eclipse Distribution License (BSD-style)
- Widely used in Java spatial applications

GEOS Geometry Library

- JTS port to C++ with a C API
- Open source, on GitHub
- License: GPL (GNU Public License)
- VERY widely used

GEOS Geometry Engine Open Source

Language Bindings

- Shapely (Python)
- R-sf
- GeoPHP
- GoGEOS
- Node-geos (Javascript)
- rgeos (Rust)

Databases

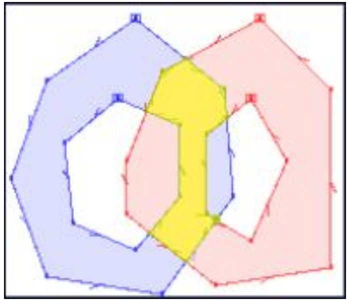
- PostGIS
- SpatialLite
- CockroachDB
- DuckDB
- MonetDB

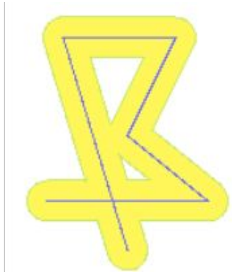
Applications

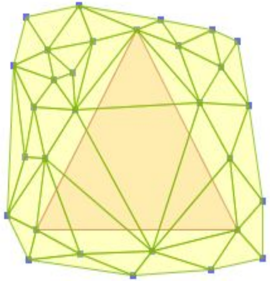
- QGIS
- GDAL
- MapServer
- GRASS

Functionality Overview

- Provides the full OGC **Simple Features for SQL** geometry specification:
  - Points, Linestring, Polygons, collections
  - **Metrics:** Length, Area, Distance
  - **Predicates:** intersects, contains, etc.; relate for DE-9IM
  - **Overlay:** intersection, union, difference, symDifference
  - **Constructions:** Convex Hull, Buffer
- Other functions:
  - Validation, Polygonization, Simplification, Linear Referencing, Delaunay/Voronoi…





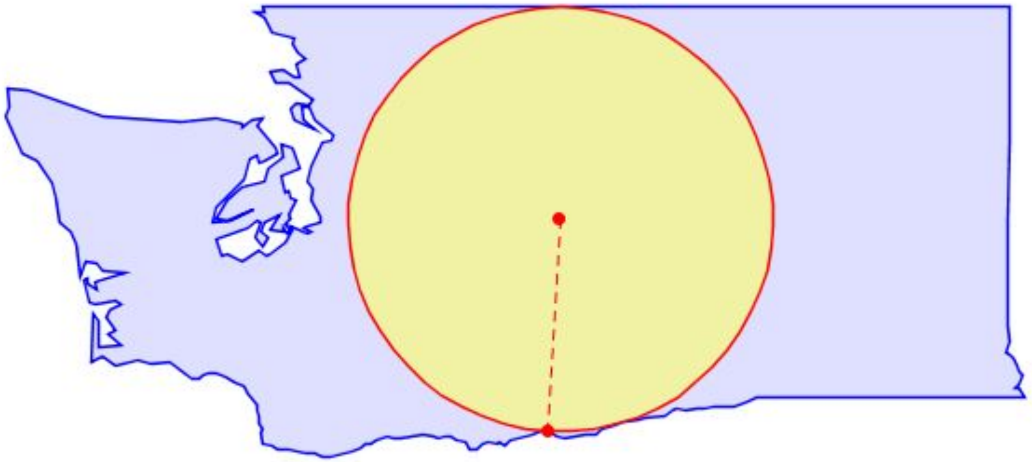


Circles

Maximum Inscribed Circle

- Largest circle inside a polygon
  - Furthest point from polygon boundary
- Iterative approximation - uses an accuracy distance tolerance

```
MaximumInscribedCircle( geom, accuracy );
```



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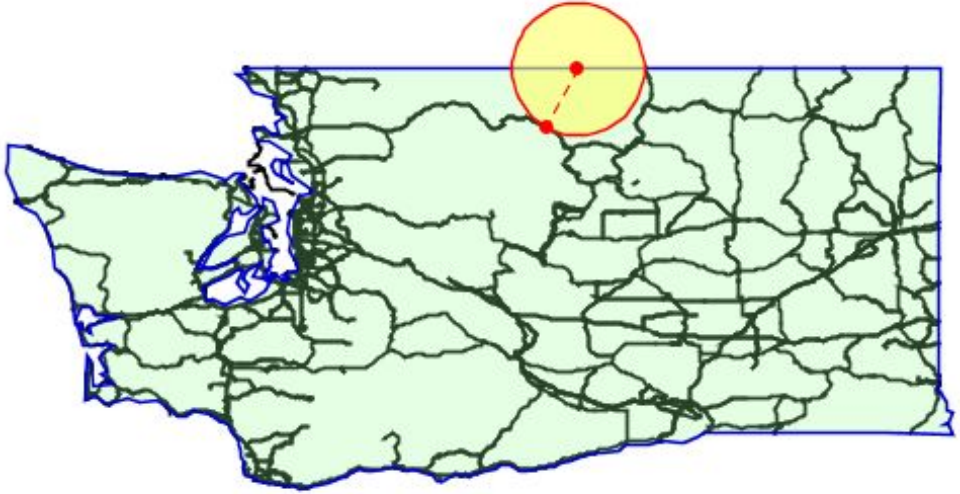
Largest Empty Circle

- Largest circle containing no obstacles (lines / points)
  - Furthest point from obstacles
- Optional: constrain center to a boundary polygon

```
LargestEmptyCircle( geom, [ boundary ], accuracy );
```

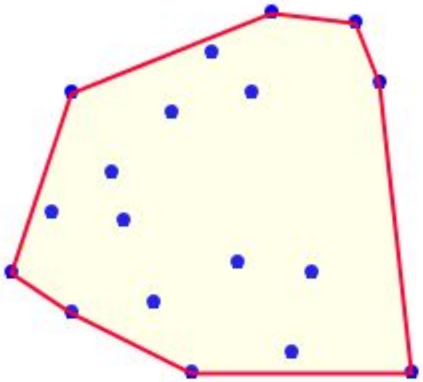


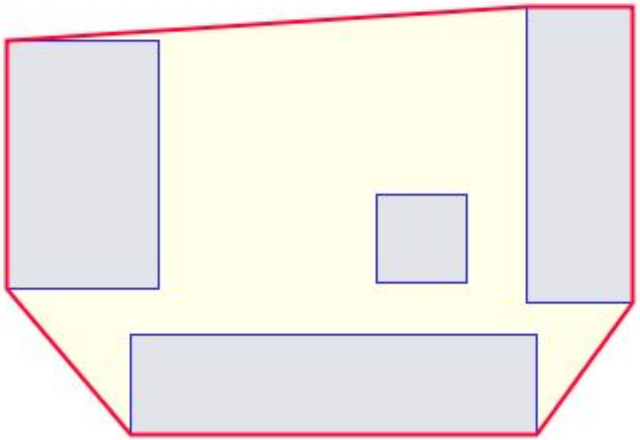
Hulls

Convex Hull

- The *unique* convex polygon containing input vertices
- As per the Simple Features specification
- Works for all geometry types

```
ConvexHull( geom );
```





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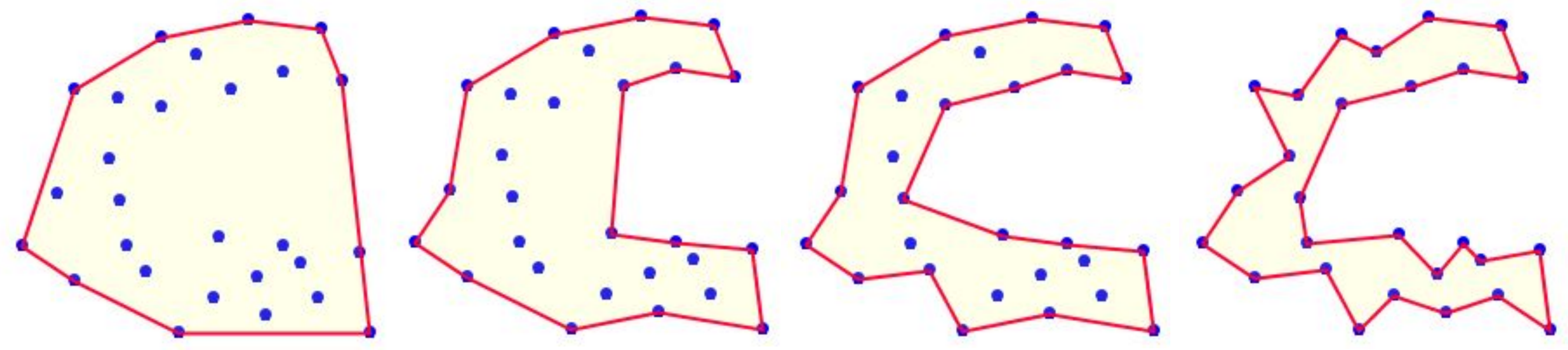
Concave Hull - Points

- A *(possibly)* concave polygon containing input vertices
- Many possible hulls, determined by param `pctconvex`

```
ConcaveHull( geom, pctconvex );
```

pctconvex= 1.0 0.6 0.4 0.0



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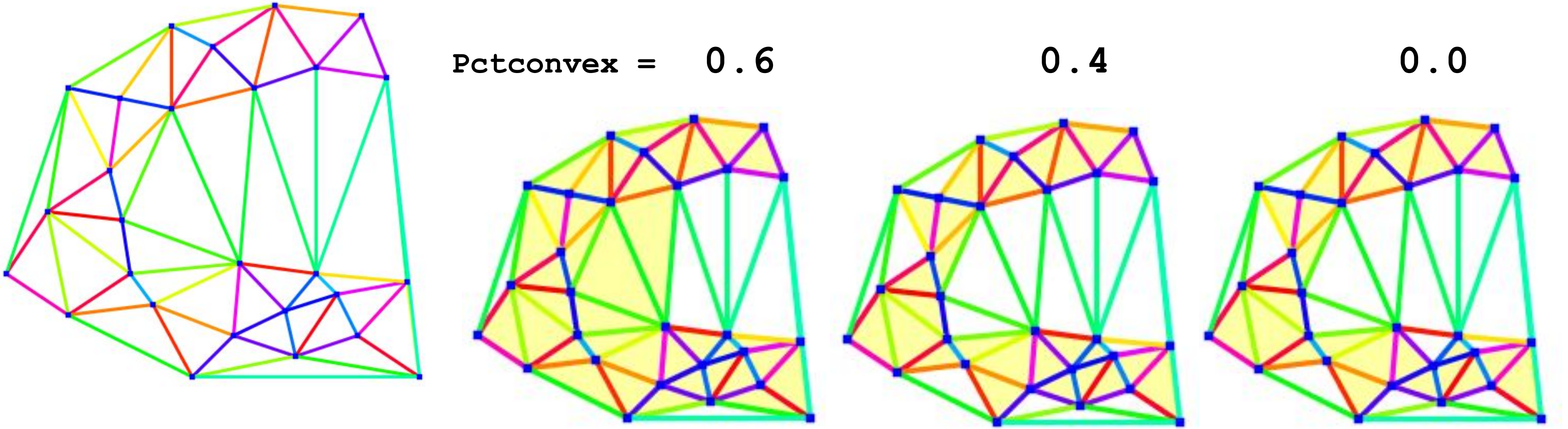
Concave Hull - Points: How it works

- Build Delaunay Triangulation on points
- Sort triangles by longest edge length
- Remove triangles, until tolerance is reached

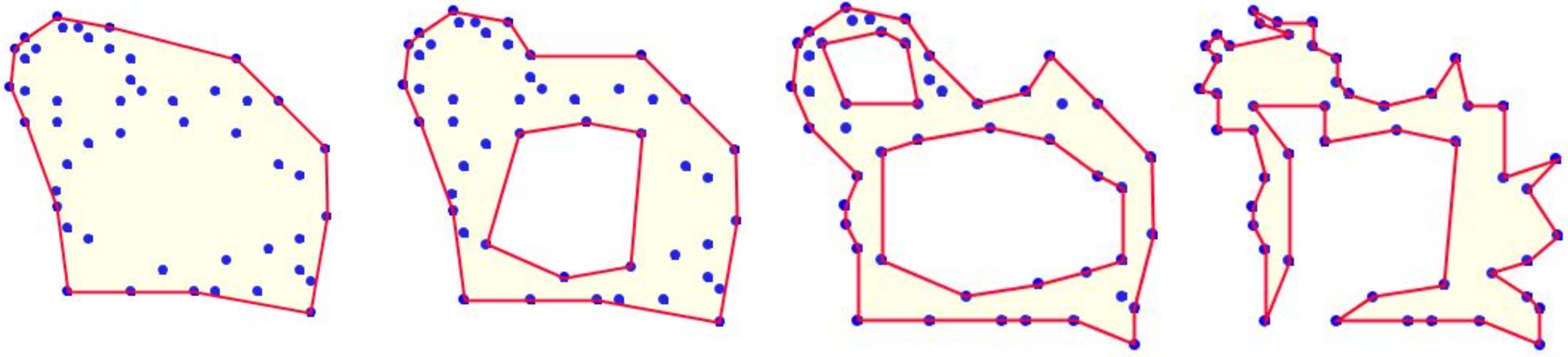


Concave Hull - Points, allowing holes

- Concave hull can contain holes
  - via optional parameter `allow_holes = true`

```
ConcaveHull( geom, pctconvex, true );
```

pctconvex = 0.6 = 0.5 = 0.25 = 0.0



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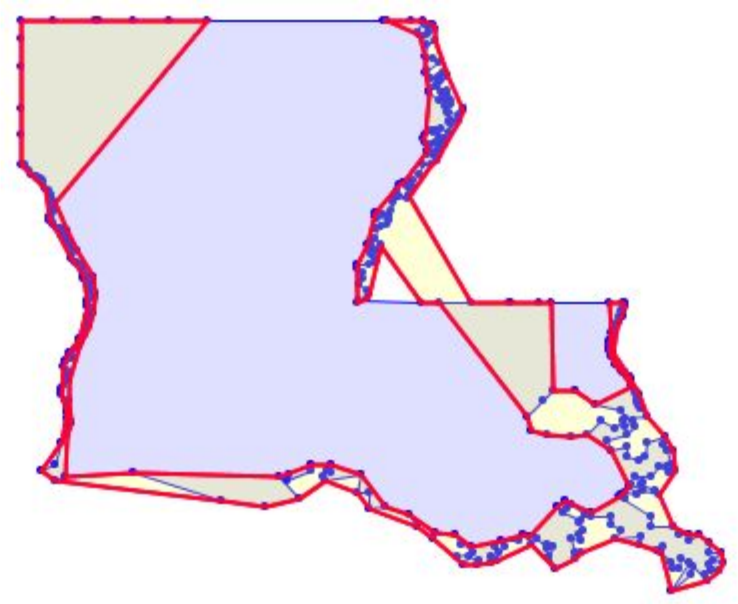
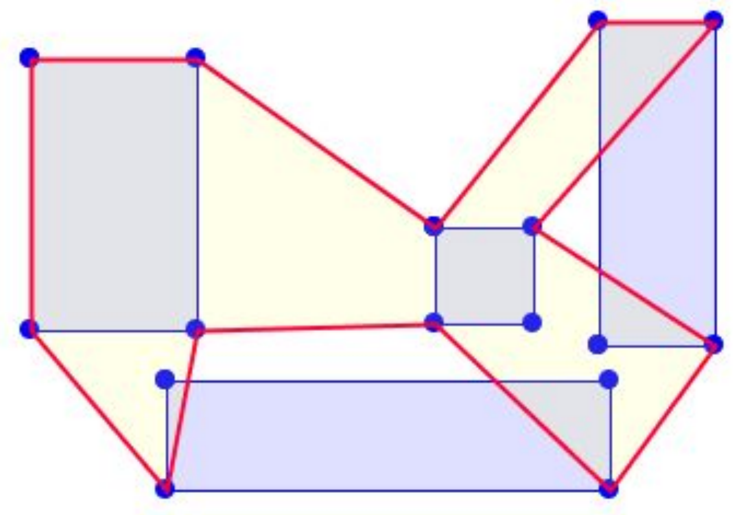
Concave Hull - Polygons?

- Standard Concave Hull algorithms only support points
- **Problem**! Does **not** respect polygon boundaries





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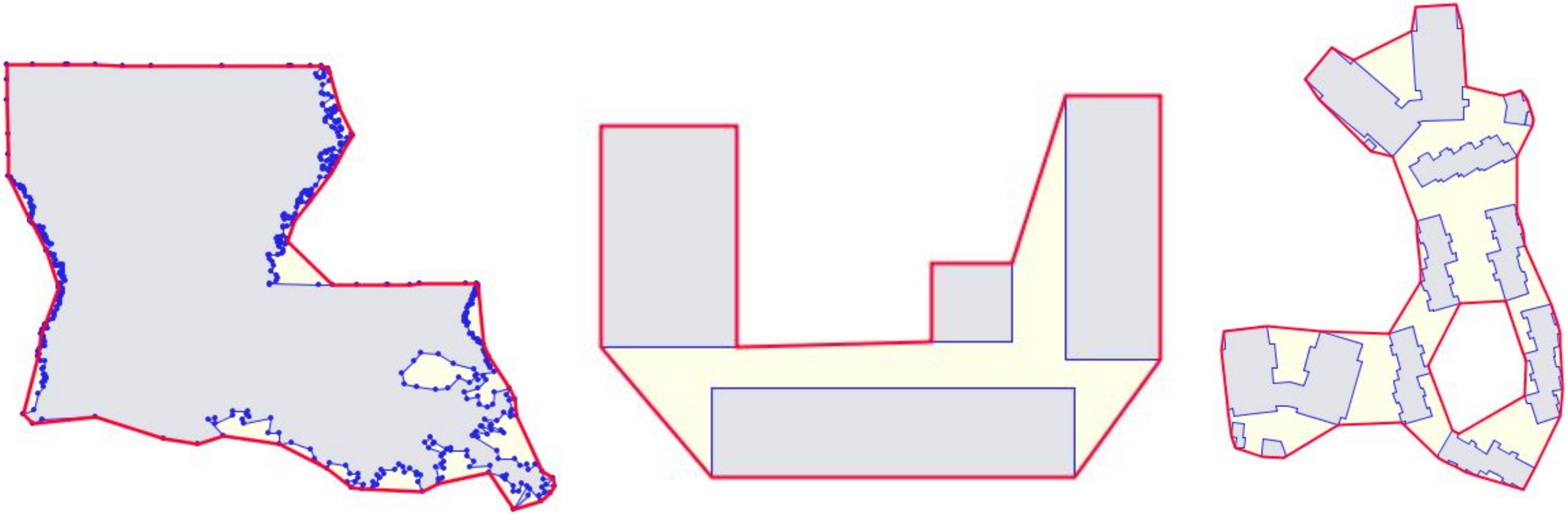
Concave Hull - Polygons

- New algorithm to compute Concave Hull for polygon(s)
    - constrained by polygon boundaries



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Polygon Hull Simplification

- Computes **Outer** and **Inner Hulls** of polygonal geometry
- Preserves polygonal topology, including holes and MultiPolygons
- Parameter: `vertex_fraction` = fraction of vertices kept

```
SimplifyPolygonHull( geom, vertex_fraction, is_outer );
```

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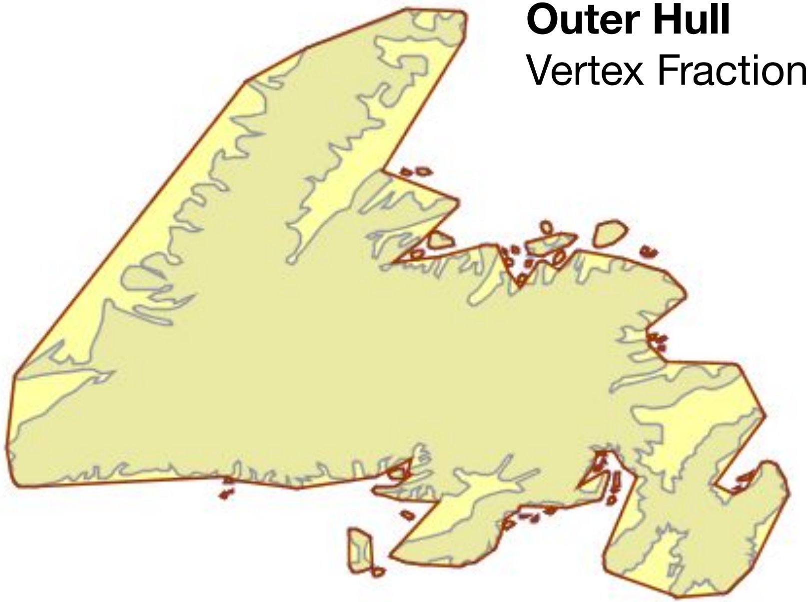
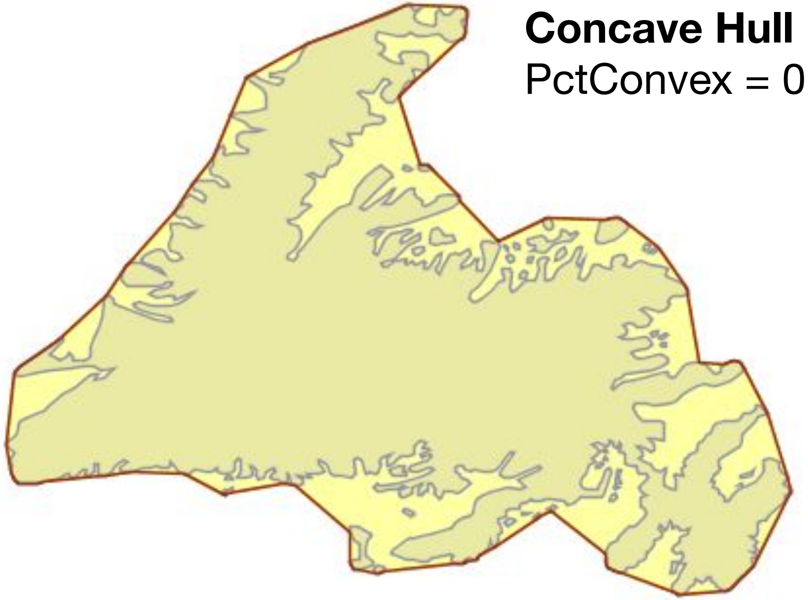
Polygon Outer Hull VS Concave Hull

- Preserves Holes/MultiPolygon VS Single Polygon
- Parameter: Vertex Fraction VS Percent Convex



Outer Hull
Vertex Fraction = 0



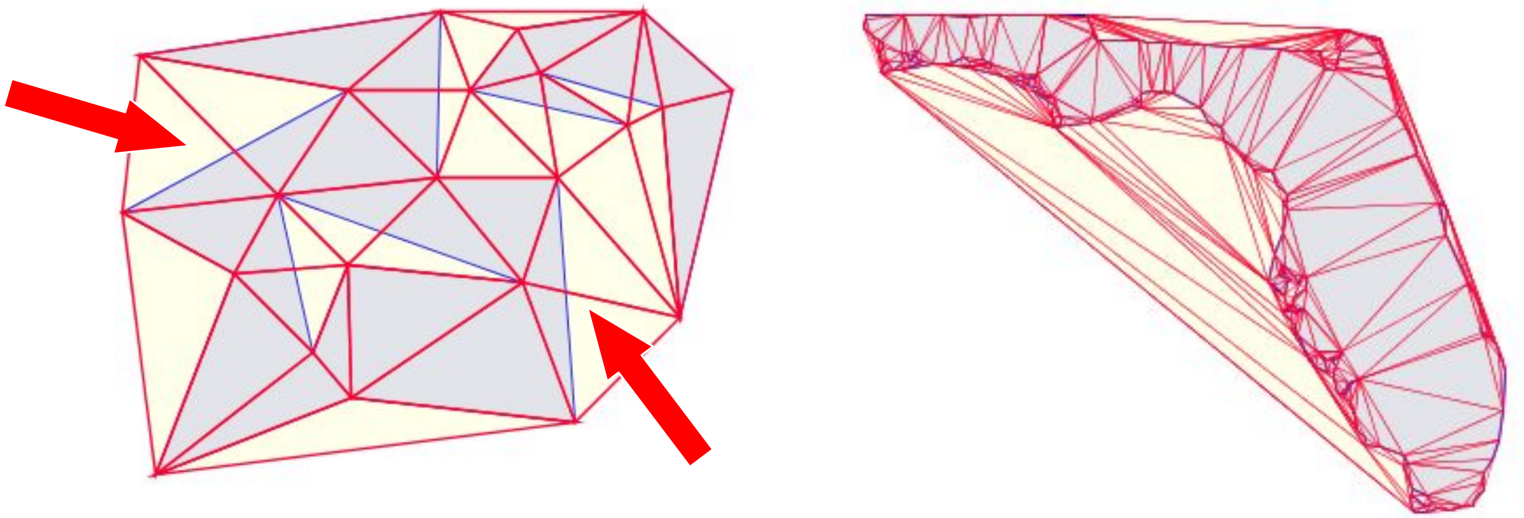
Concave Hull
PctConvex = 0.2

Triangulations

Delaunay Triangulation

- Computes the **Delaunay Triangulation** of points
- Processes vertices **only**
  - *does not respect polygon linework*
  - *does not handle holes or MultiPolygons*

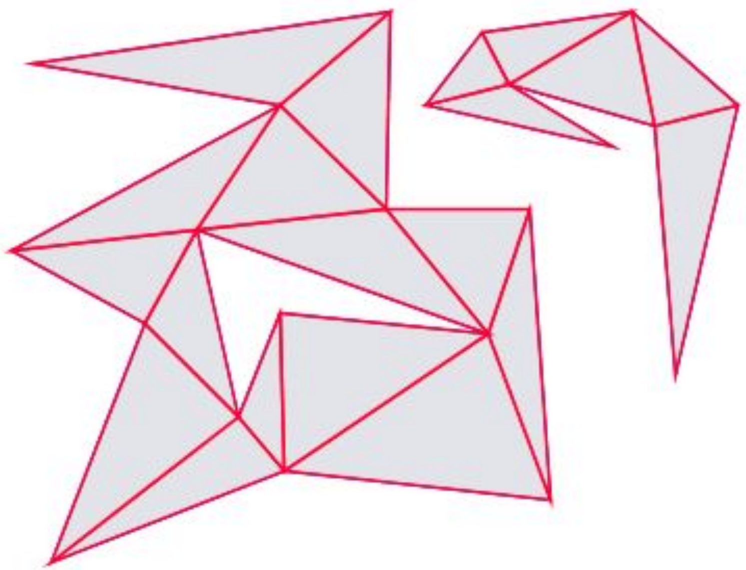
```
SELECT ST_DelaunayTriangles( geom );
```



Polygon Triangulation

- Computes the **Constrained Delaunay Triangulation** of polygons
  - *respects polygon linework*
  - *handles holes and MultiPolygons*

```
SELECT ST_TriangulatePolygon( geom );
```



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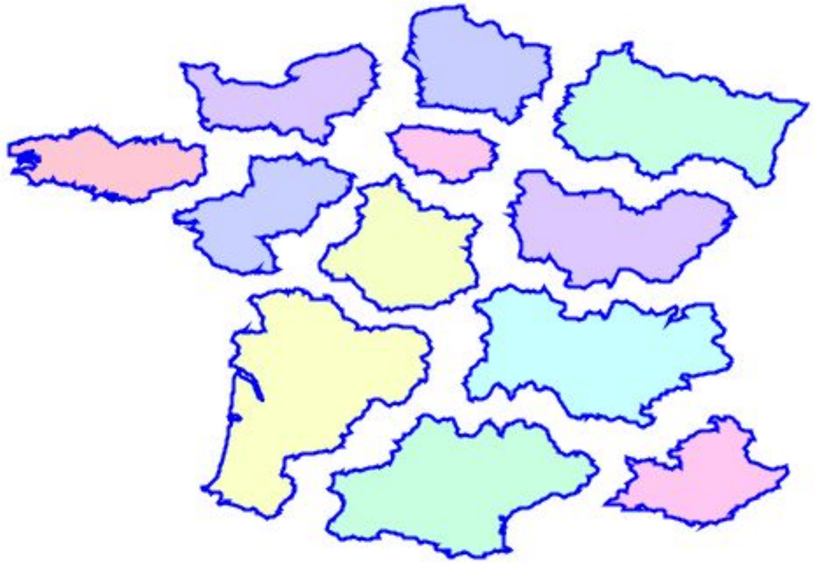
Polygonal Coverages

Polygonal Coverages

- A set of non-overlapping polygons
- Many use cases
    - *Cadastral parcels*
    - *Political jurisdictions*
    - *Land use*
    - *Geological regions*
    - *Etc, etc*
- Can be represented as a full topological model
    - e.g. **PostGIS Topology**
- Another option…

Simple Polygonal Coverage

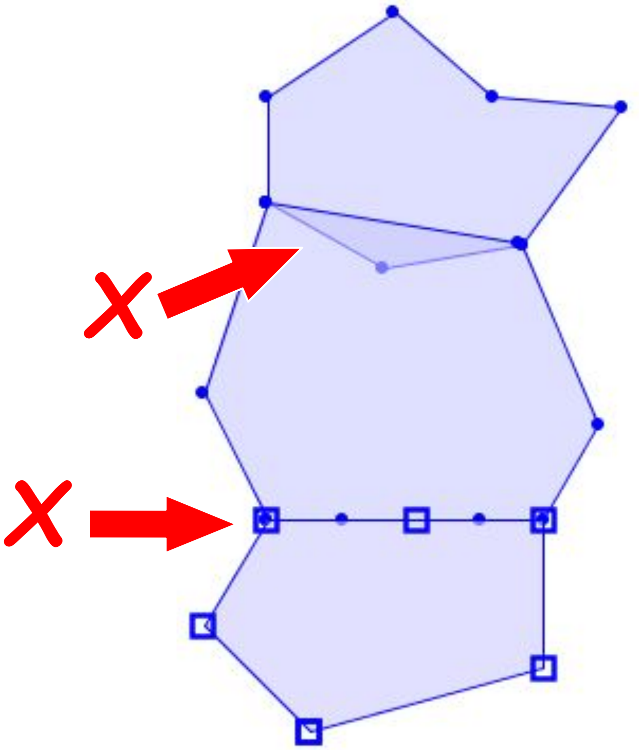
- Represent Polygonal Coverage as **discrete polygons**
  - A set of Polygons and MultiPolygons
  - Allows holes, disjoint regions
  - Implicit topology
- Advantages
  - Simple
  - Performant
  - Works with existing functions



Polygonal Coverage - Validity

- Coverage Validity required for:
  - Correct operation of coverage functions
  - Accurate modelling and analysis

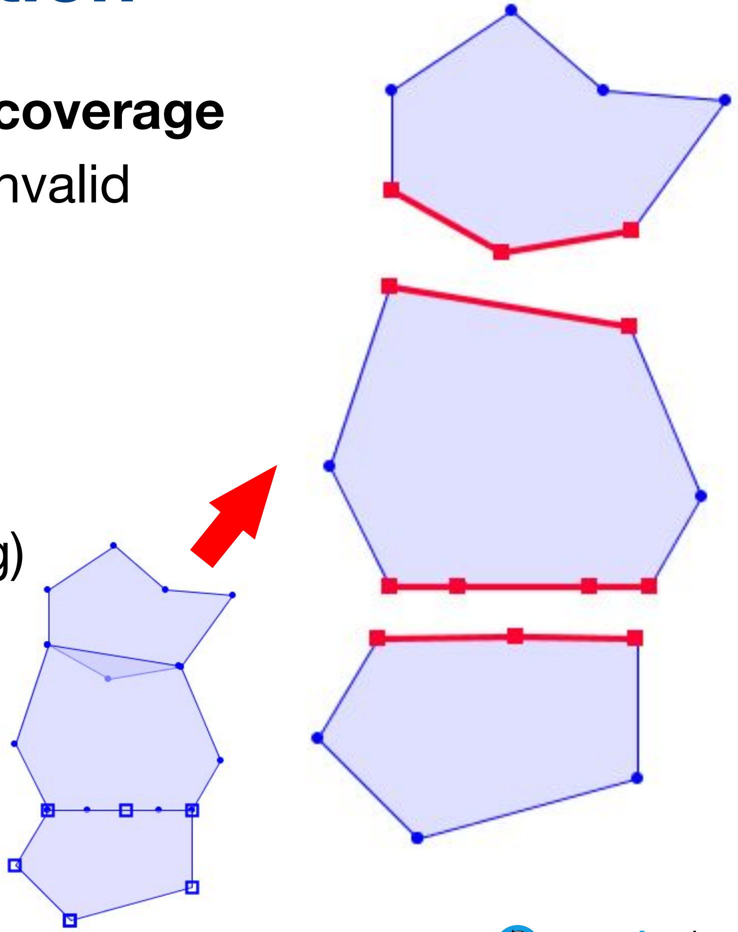
- A set of polygons is a valid coverage if:
  - Polygons are **valid**
  - Polygons are **non-overlapping**
    - *interiors do not intersect*
  - Adjacent polygons are **edge-matched**
    - *shared lines have identical vertices*



Polygonal Coverage - Validation

- Tests if a set of **valid** polygons is a **valid coverage**
- For **coverage-invalid** polygons, reports invalid sections of polygon boundary:
  - Overlapping edges
  - Non edge-matched adjacent edges
- For each polygon returns
  - **Invalid**: invalid edges (MultiLineString)
  - **Valid**: empty or null

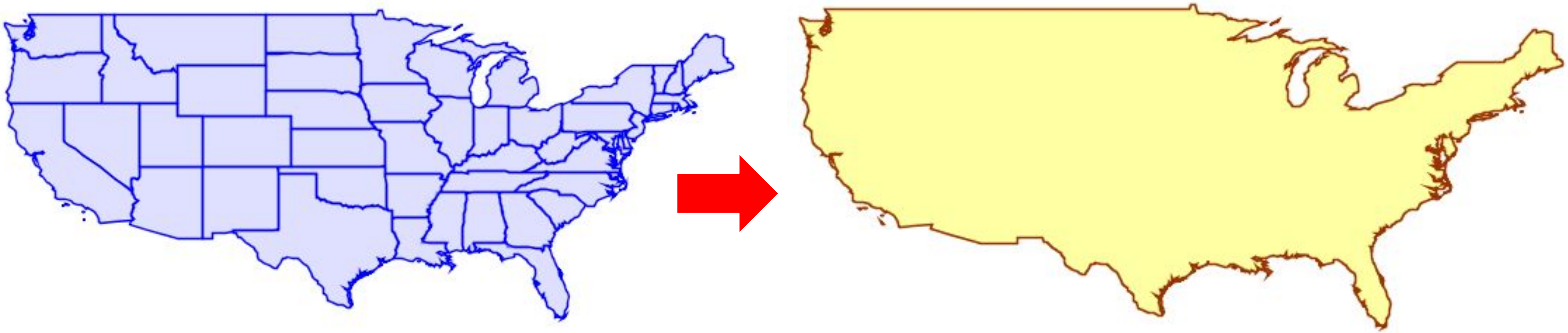
```
CoverageValidate( geom[] )
   => MultiLineString[]
```



Polygonal Coverage - Union

- Computes the union of a set of coverage polygons
- Aggregate function, returns polygonal geometry
- Very fast (can be 100x faster than general-purpose union)

```
CoverageUnion( geom[] ) => MultiPolygon
```



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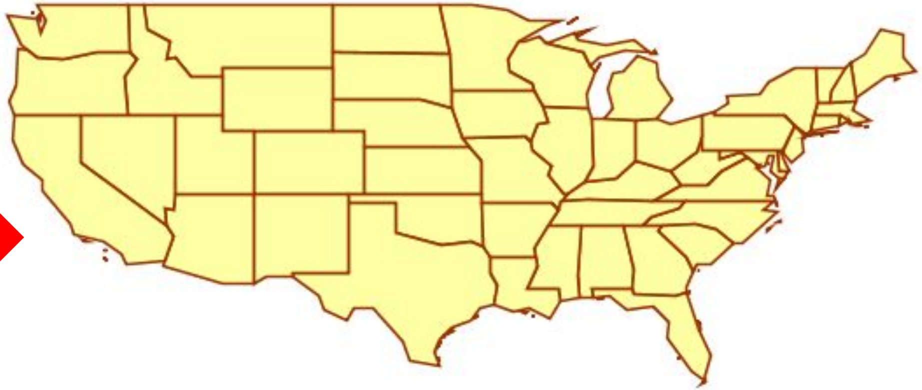
Polygonal Coverage - Simplification

- Simplifies the boundaries of a set of coverage polygons
- Preserves topology; result is a valid coverage with identical structure

```
CoverageSimplify( geom[], tolerance ) => geom[]
```

Size: **11,481 pts**

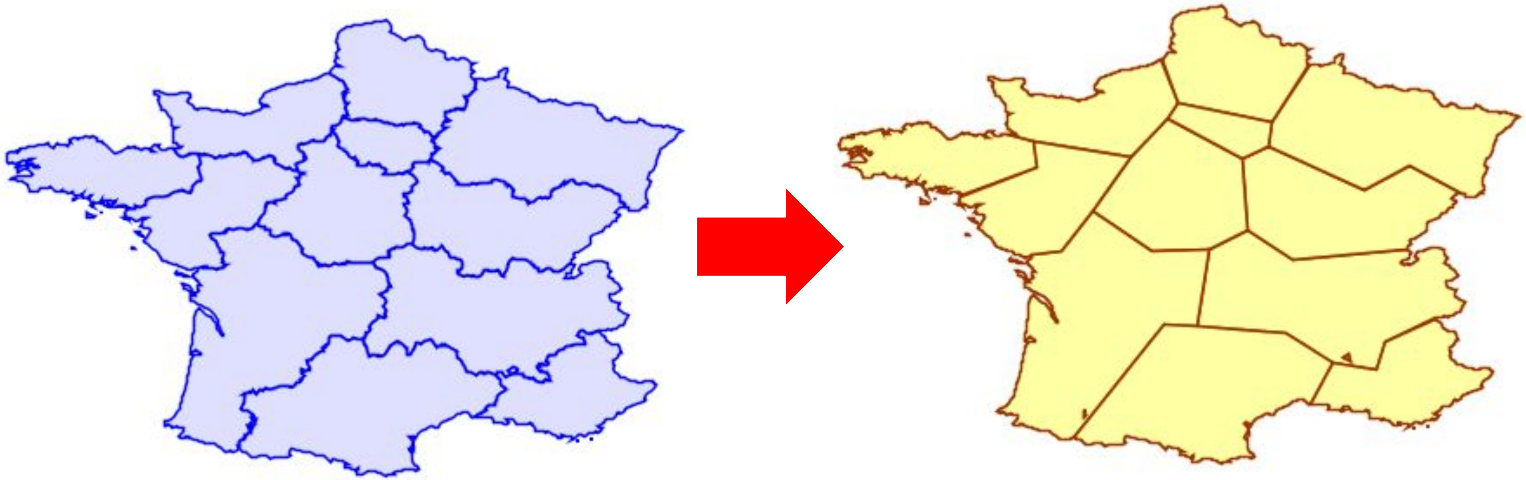
Size: **739 pts**



Polygonal Coverage - Inner Simplification

- Simplifies the **inside boundaries** of a set of coverage polygons
- Preserves topology; result is a valid coverage with identical structure

```
CoverageSimplifyInner( geom[], tolerance ) => geom[]
```



Future Work

- **Polygonal Coverage functions**
  - Find Gaps
  - Clean
  - Precision Reduce
  - Overlay