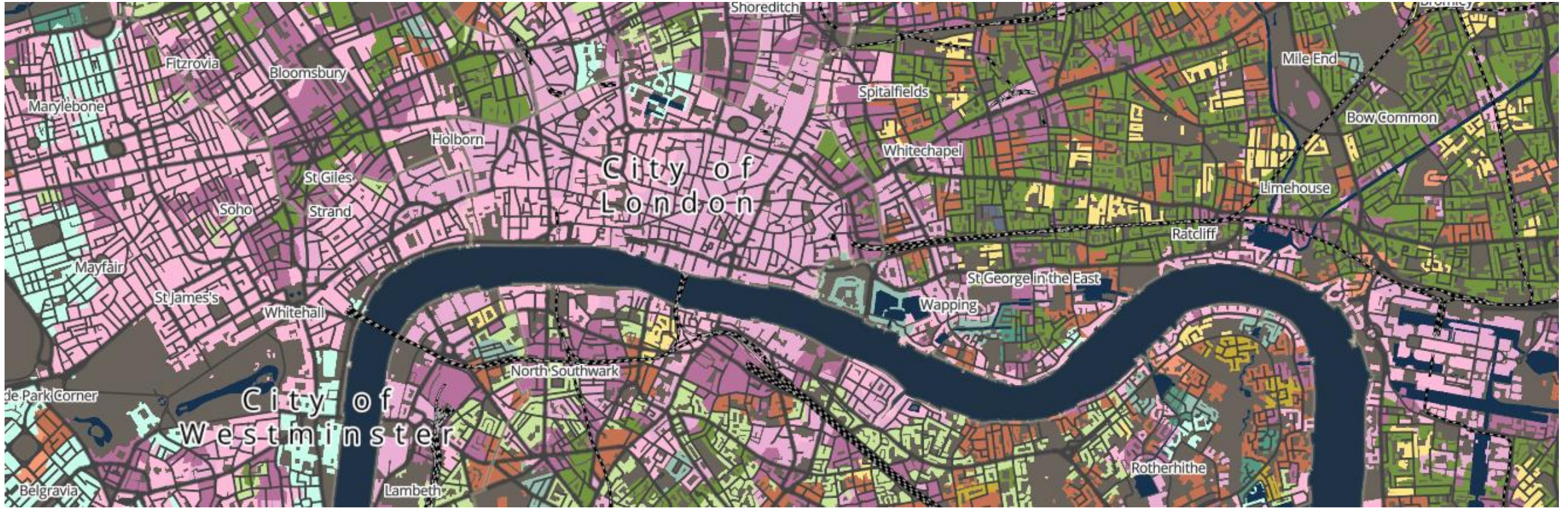# Geocomputation
Spatial Queries and Geometric Operations

Module outline

W1   Reproducible Spatial Analysis

W2   Spatial Queries and Geometric Operations

W3   Point Pattern Analysis

W4   Spatial Autocorrelation

W5   Spatial Models

W6   Raster Data Analysis

W7   Geodemographic Classification

W8   Accessibility Analysis

W9   Beyond the Choropleth

W10   Complex Visualisations

Core Spatial Analysis

Applied Spatial Analysis

Data Visualisation

This week

- Spatial properties.

- Attribute joins.

- Spatial operations.

Spatial properties

- Spatial data often requires performing mathematical operations on spatial properties.
- Key properties include areas of and distances between spatial objects.
- There are diverse ways to conceptualise and work with these properties depending on the analytical context and available data.
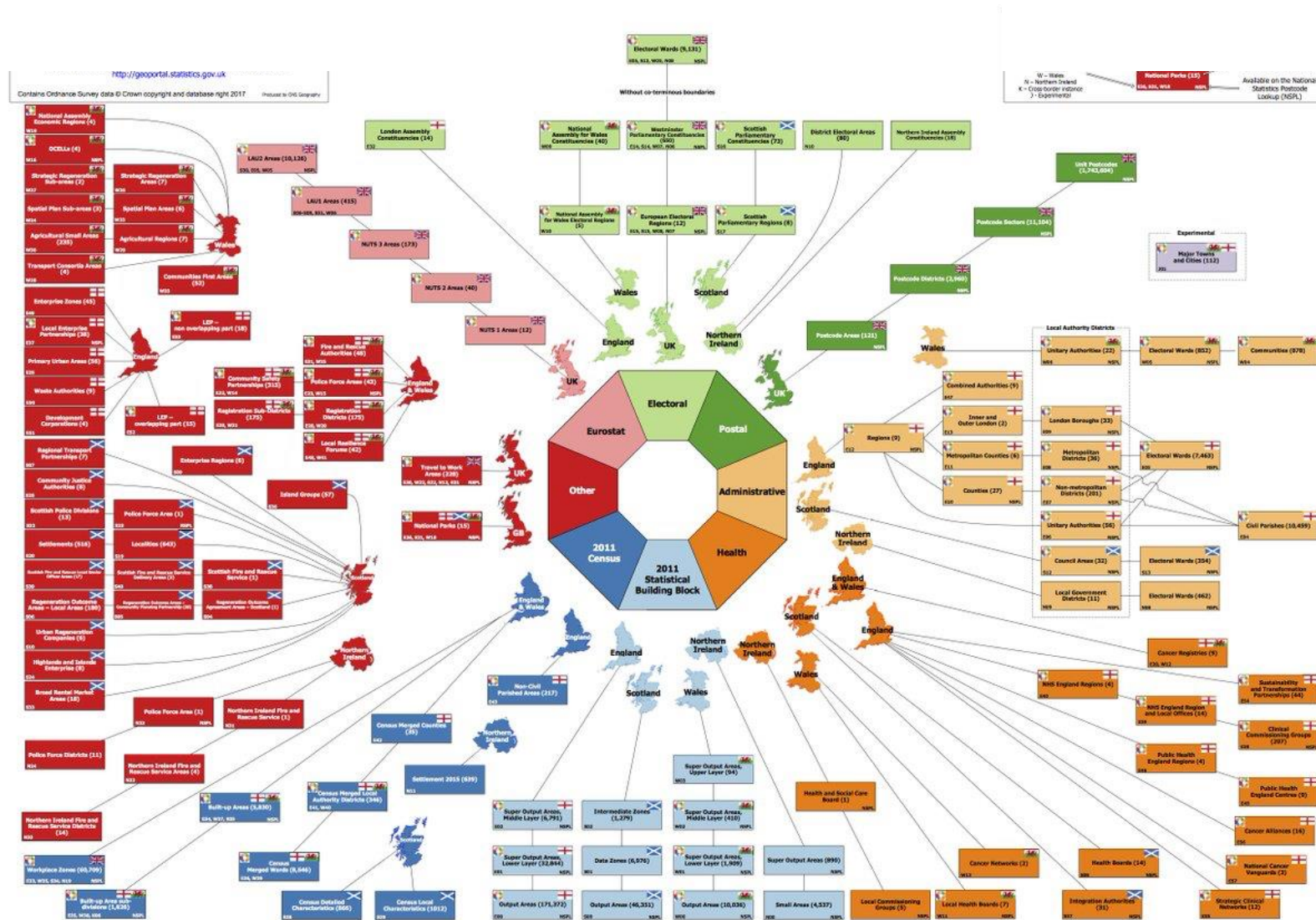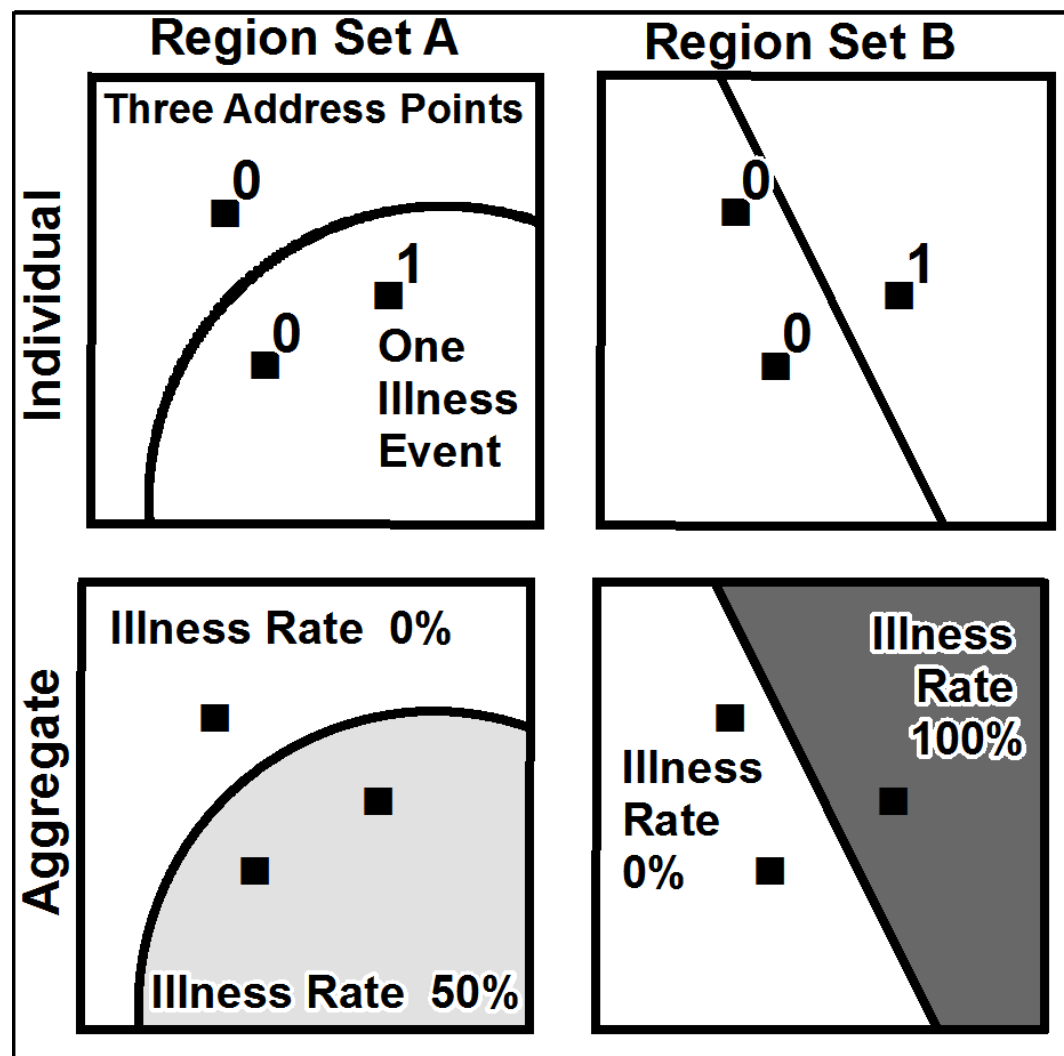
Distance
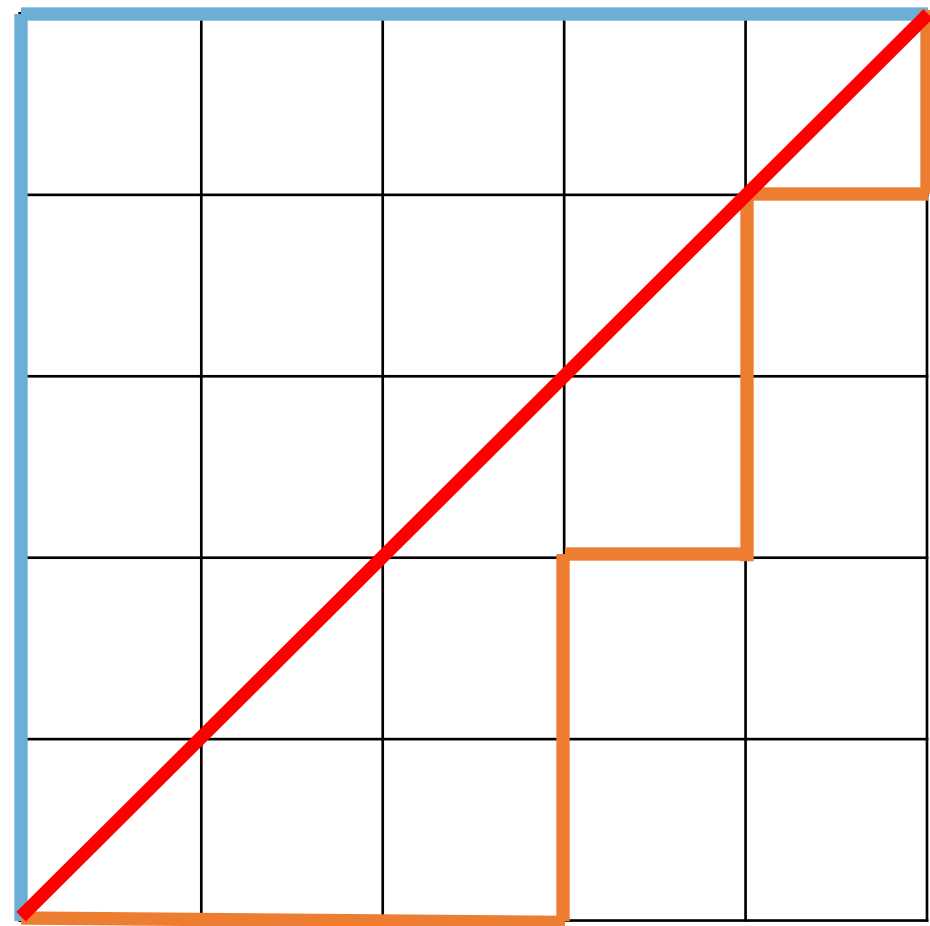
Area

Area

Area

Spatial features

- Features: Objects created in a spatial dataset, representing geographic entities such as points, lines, or polygons.
- Attributes: Characteristics or properties of features, often stored as data in GIS, describing specific details about the feature.

Point vector

Characteristics of a point vector in a GIS data model:

- Single XY location (coordinate).

- Has no area.

- Has no length.

- Geometry consists of a single node or vertex.

- Used for: discrete features or events.
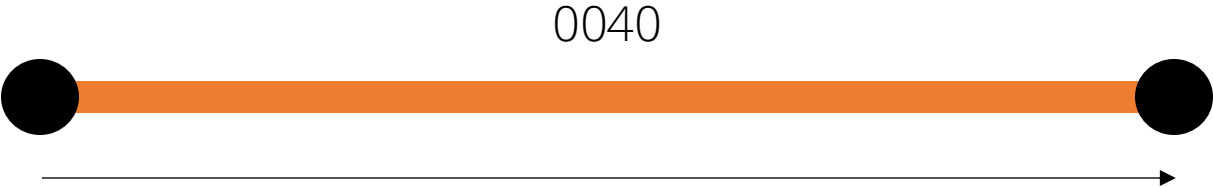
Point vector
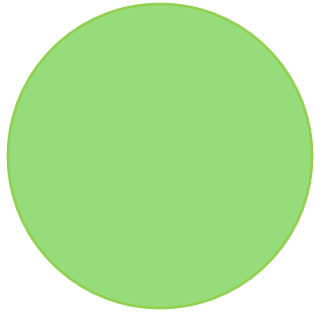
Point vector

Point vector

FeatureID	Type	Height
0030	Ent	500

Polyline vector

Characteristics of a polyline vector in a GIS data model:
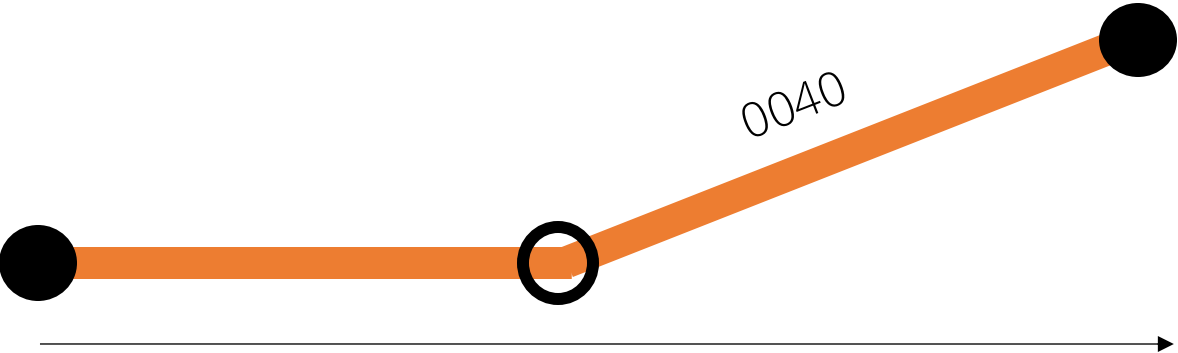
-   Series of XY locations (coordinates) that form a line.

-   Has no area.

-   Has a length.

-   Has a direction (importance when it comes to roads, rivers, etc.).

-   Can be connected to other polyline vectors to form a network.

-   Geometry consists of two nodes (start node and end node) and can have one or more vertices.

-   Used for: features without an area but with a length.
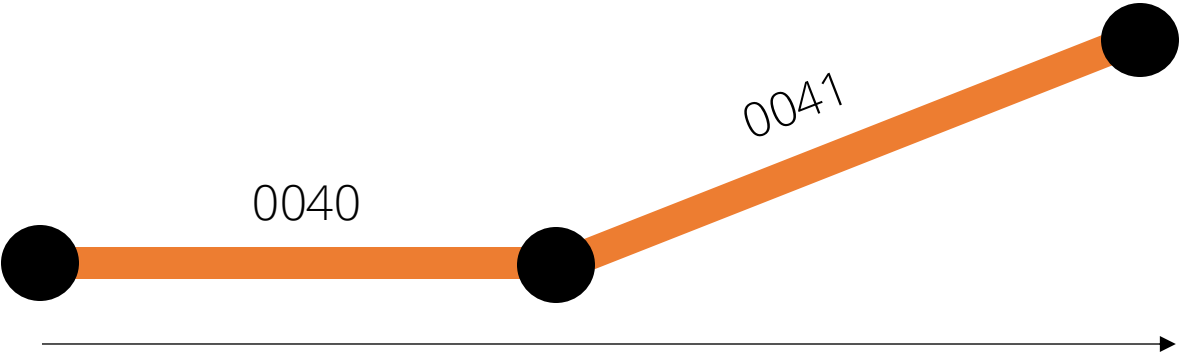
Polyline vector

0040

FeatureID	Type	Length
0040	Bicycle lane	1,500

Polyline vector

FeatureID	Type	Length
0040	Bicycle lane	1,650

Polyline vector

FeatureID	Type	Length
0040	Bicycle lane	600
0041	Bicycle lane	1,050

Polygon vector

Characteristics of a polyline vector in a GIS data model:

- Series of XY locations (coordinates) to form an enclosed region.

- Has an area.

- Has no length.

- Geometry consists of at least three nodes or vertices whereby the first node or vertex connects with the last one.

- Used for: features with enclosed regions such as buildings and administrative areas.

Polygon vector

FeatureID	Type	Area
0050	University building	2000

Representation

Representing the North-West Wing Building

Attribute joins

GeoID	Population
GEO0030	540
GEO0031	320

Attribute joins

GEO0030

FeatureID	GeoID
0050	GEO0030

Attribute joins

GEO0030

FeatureID	GeoID
0050	GEO0030

GeoID	Population
GEO0030	540
GEO0031	320

Attribute joins

GEO0030

FeatureID	GeoID
0050	GEO0030

GeoID	Population
GEO0030	540
GEO0031	320

Attribute joins

<div style="border: 3px solid black; text-align: center; padding: 80px;">
GEO0030
</div>

FeatureID	GeoID	Population
0050	GEO0030	540

Left joins

The Data School. 2019. *SQL Join Types Explained Visually*.

Inner joins

The Data School. 2019. *SQL Join Types Explained Visually*.

Outer joins

The Data School. 2019. *SQL Join Types Explained Visually.*

Spatial data formats

```
## Simple feature collection with 100 features and 6 fields
## geometry type:  MULTIPOLYGON
## dimension:      XY
## bbox:           xmin: -84.32385 ymin: 33.88199 xmax: -75.45698 ymax: 36.58965
## epsg (SRID):    4267
## proj4string:    +proj=longlat +datum=NAD27 +no_defs
## precision:      double (default; no precision model)
## First 3 features:
##   BIR74 SID74 NWBIR74 BIR79 SID79 NWBIR79                           geom
## 1  1091     1      10  1364     0      19 MULTIPOLYGON(((-81.47275543...
## 2   487     0      10   542     3      12 MULTIPOLYGON(((-81.23989105...
## 3  3188     5     208  3616     6     260 MULTIPOLYGON(((-80.45634460...
```

Simple feature

Simple feature geometry list–colum (sfc)

Simple feature geometry (sfg)

Spatial data formats

- Several commonly used file formats that store spatial data exist.

- Different file formats for vector data and raster data.

- Common vector formats: shapefile, GeoJSON, GeoPackage

- Common raster formats: GeoTIFF, GeoPackage

Shapefiles

- Perhaps the most (in)famous file format.

- Widely used, despite being `outdated`, especially limitations of `.dbf` format.

- A shapefile is not a single file, but a collection of files of which at least three are needed for the data to be displayed in GIS software.

Shapefiles

- `.shp`   contains the feature geometry. *Mandatory.*
- `.shx`   index file which stores the position of the feature's ID in the `.shp` file.
  Mandatory.
- `.dbf`   stores alle attribute information associated with the records. *Mandatory.*
- `.prj`   contains the coordinate system information and projection. *Optional but not really.*
- `.xml`   general metadata. *Optional.*
- `.cpg`   encoding information. *Optional.*
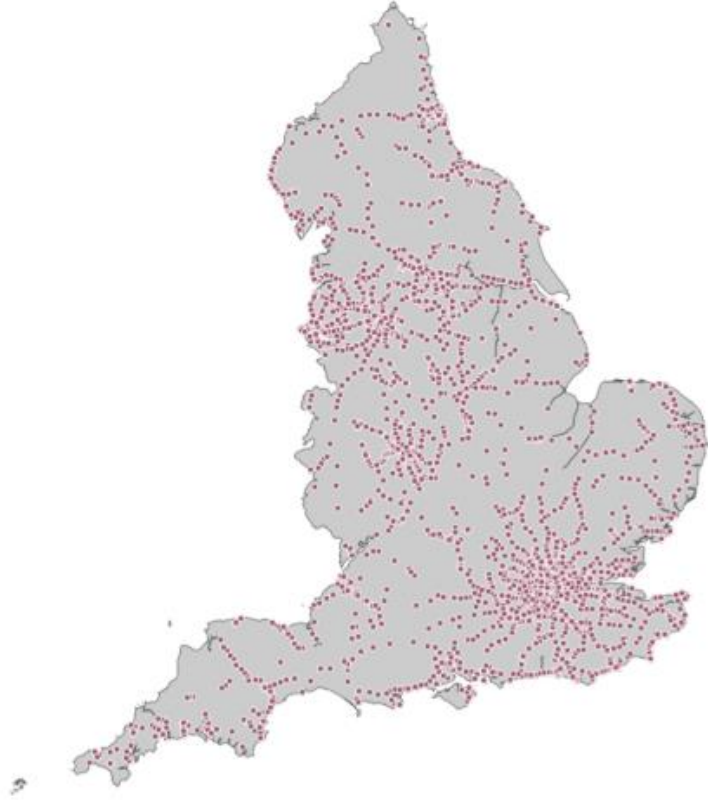- `.sbn`   optimisation file for spatial queries. *Optional.*
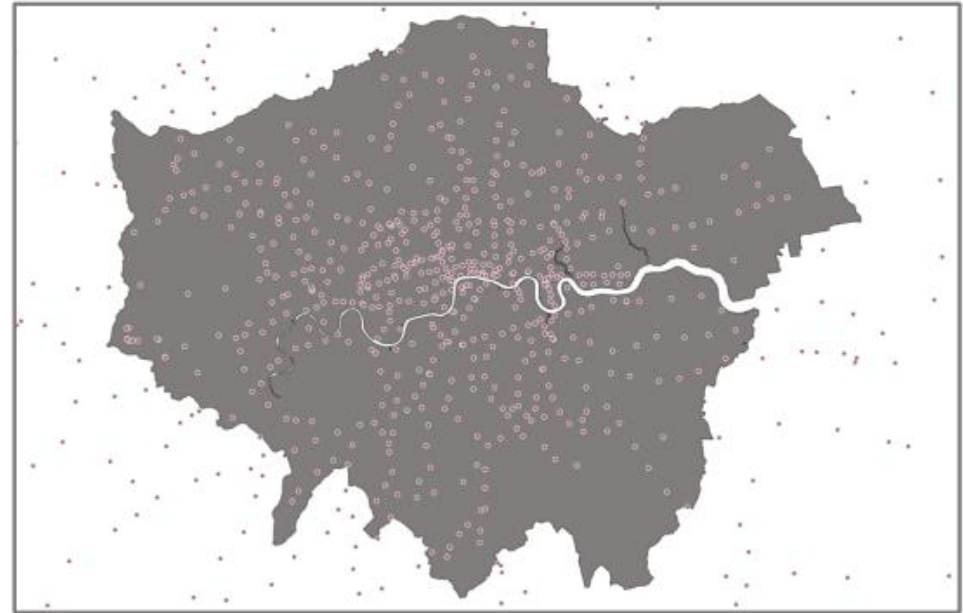
Shapefiles

GeoPackage

- A GeoPackage is an open, standards-based, platform-independent, portable, self-describing, compact format for transferring geospatial data.
- It stores spatial data layer as a single file, based upon an SQLite database.
- How to spot in the wild: .gpkg

Spatial operations

Spatial operations

- Spatial relationships describe how the exteriors, interiors, and boundaries of different geometries interact, often referred to as <mark>topological relationships</mark>.

- Spatial operations make use of these spatial relationships between spatial objects to combine, identify, extract information.

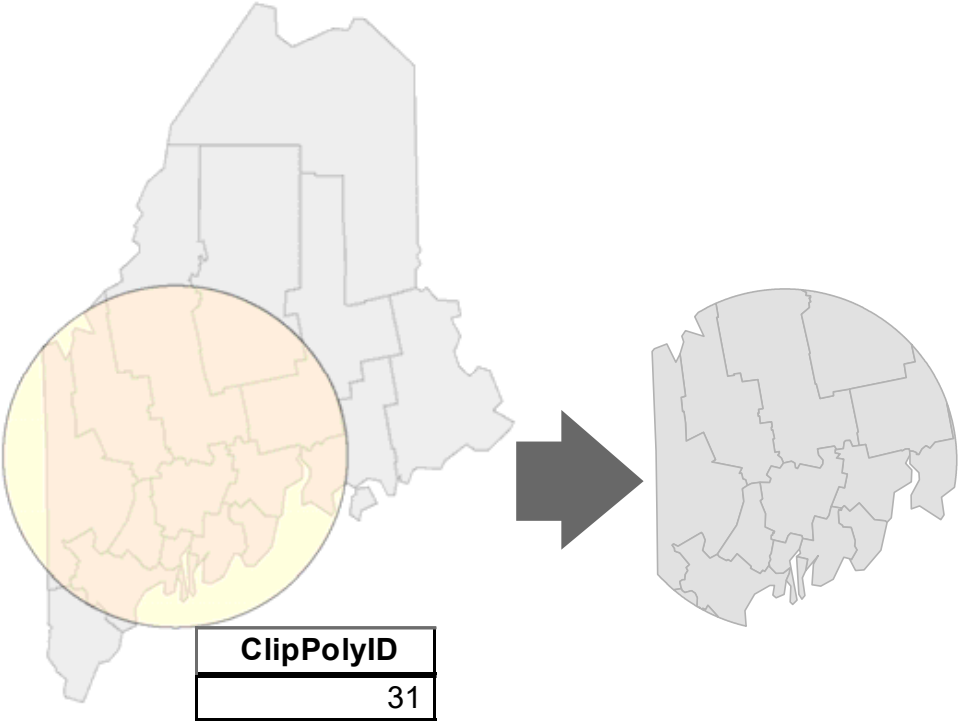- Difference between spatial queries and geometric operations.
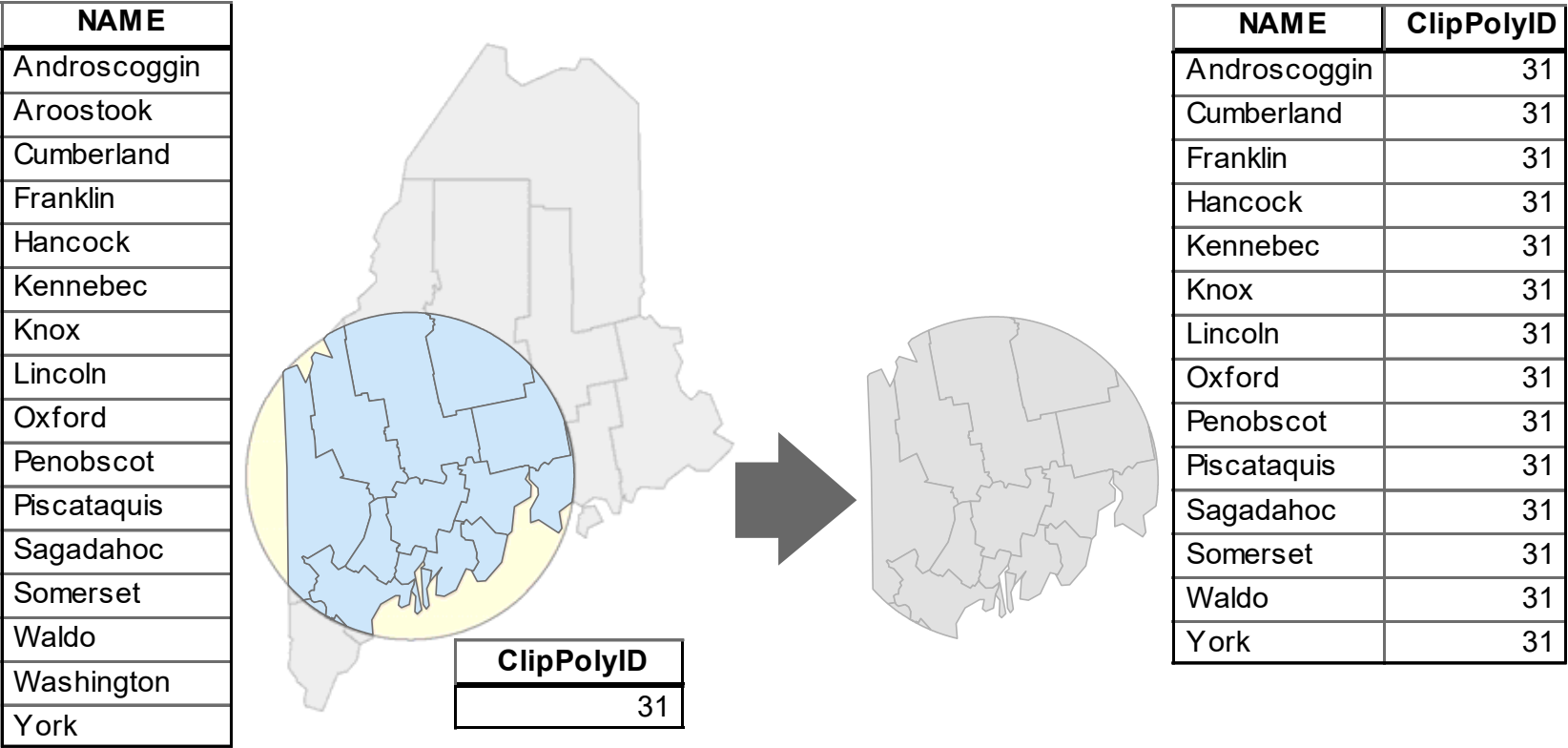
Attribute query
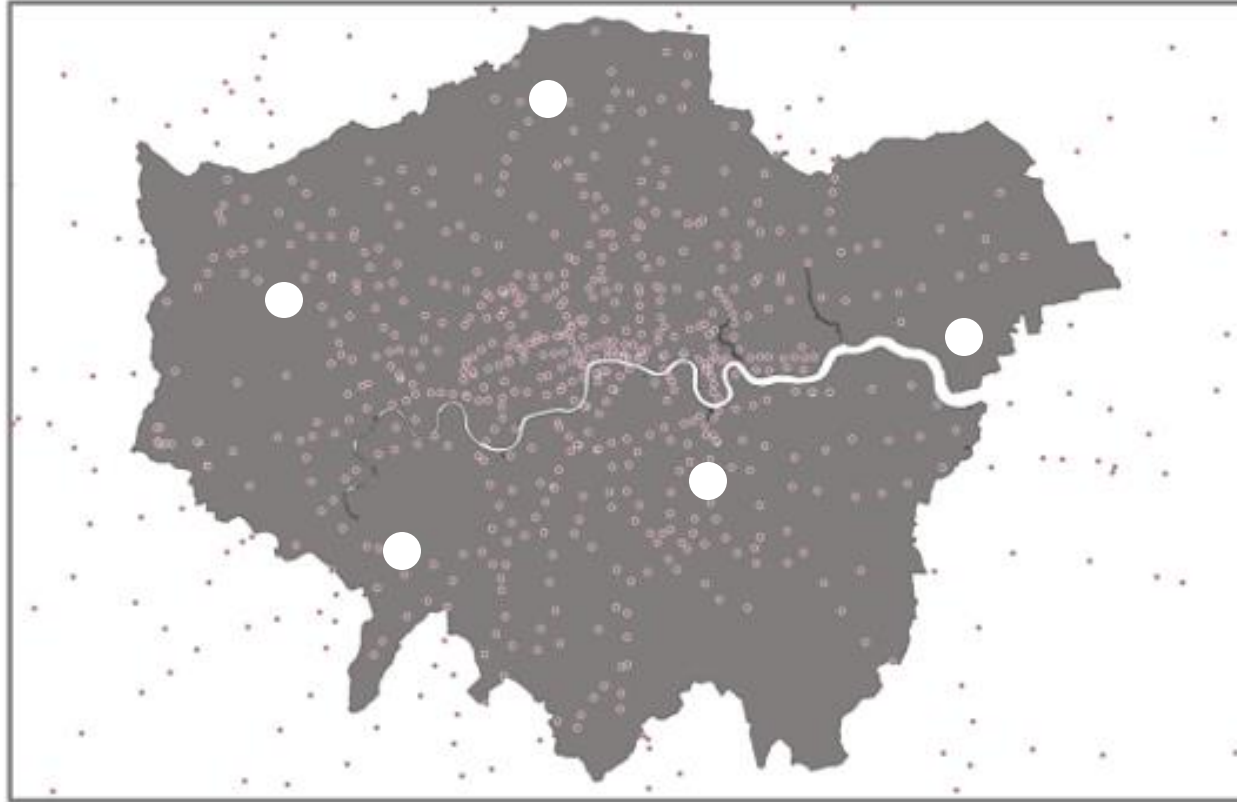
Spatial query
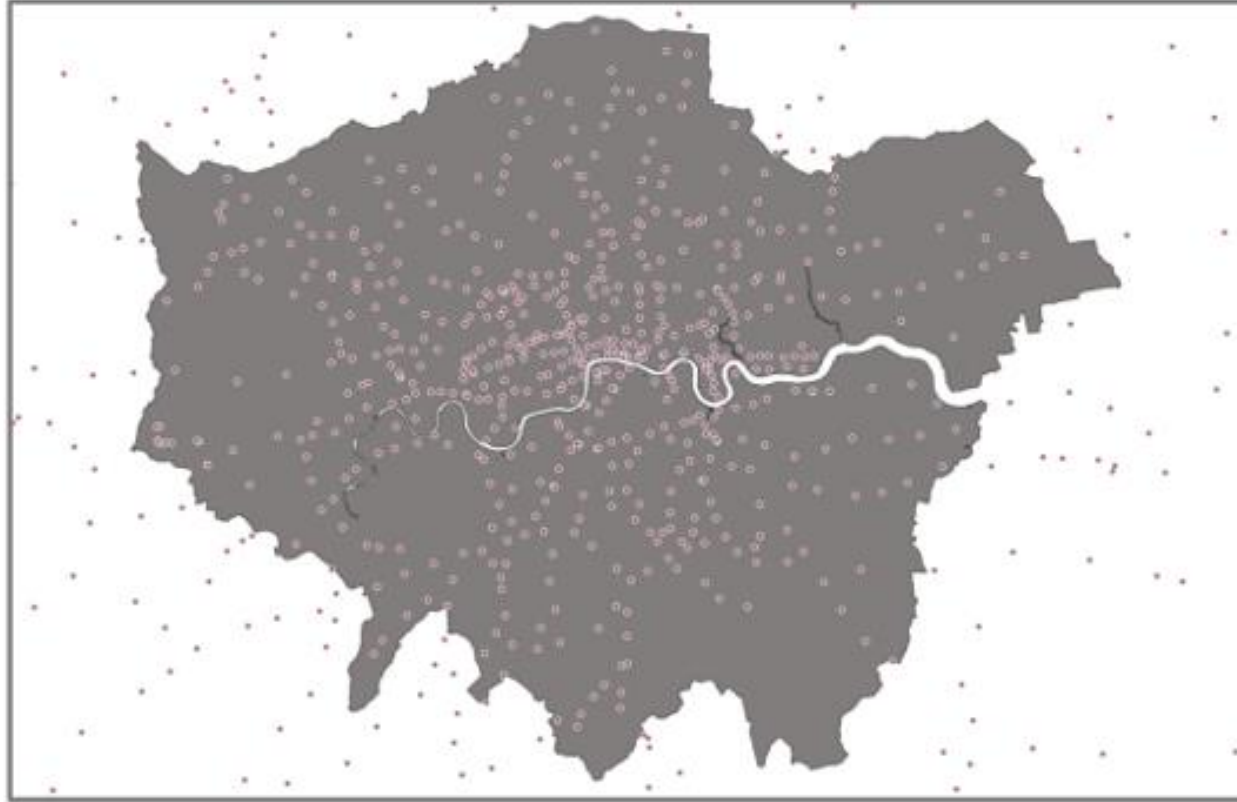
Geometric operations

NAME
Androscoggin
Aroostook
Cumberland
Franklin
Hancock
Kennebec
Knox
Lincoln
Oxford
Penobscot
Piscataquis
Sagadahoc
Somerset
Waldo
Washington
York

ClipPolyID
31

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Cumberland
Franklin
Hancock
Kennebec
Knox
Lincoln
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Penobscot
Piscataquis
Sagadahoc
Somerset
Waldo
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Gimdond, M. 2021. Intro to GIS and Spatial Analysis. [online]
https://mgimond.github.io/Spatial/introGIS.html

Geometric operations

NAME
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Somerset
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ClipPolyID
31

NAME	ClipPolyID
Androscoggin	31
Cumberland	31
Franklin	31
Hancock	31
Kennebec	31
Knox	31
Lincoln	31
Oxford	31
Penobscot	31
Piscataquis	31
Sagadahoc	31
Somerset	31
Waldo	31
York	31

Gimdond, M. 2021. Intro to GIS and Spatial Analysis. [online]
https://mgimond.github.io/Spatial/introGIS.html

Geometric operations

Gimdond, M. 2021. Intro to GIS and Spatial Analysis. [online]
https://mgimond.github.io/Spatial/introGIS.html
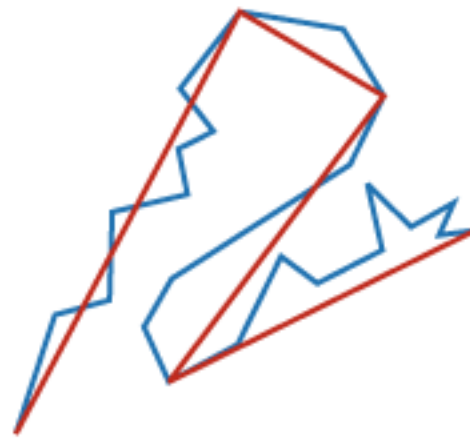
Geometric operations

INPUT → OUTPUT
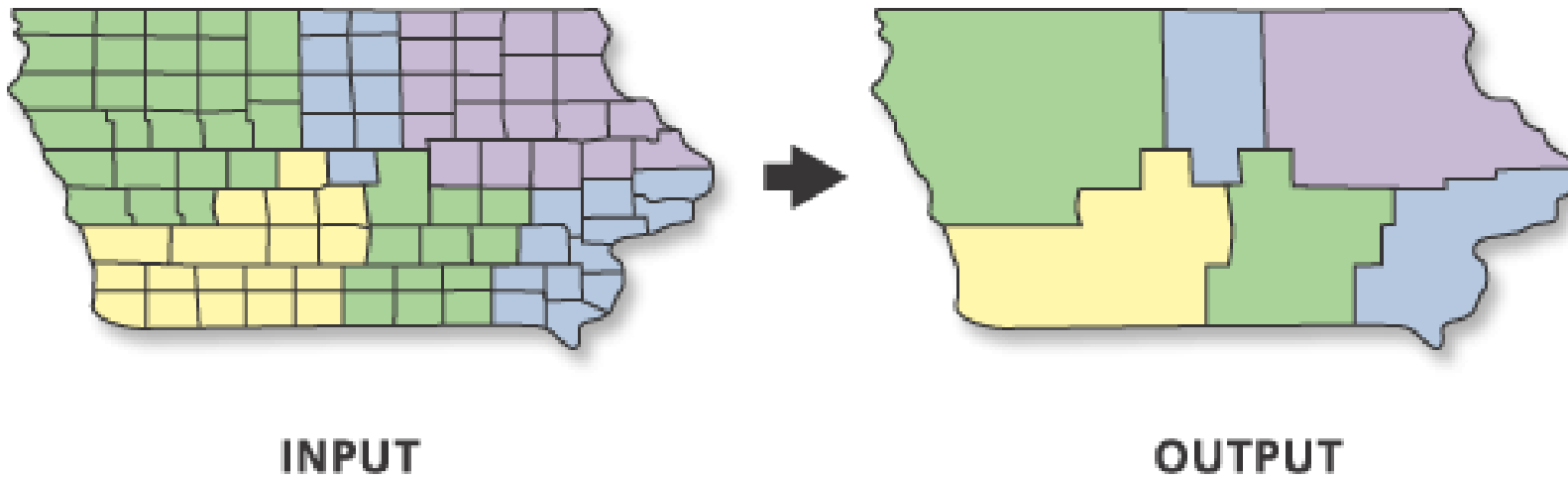
ESRI. 2025. Dissolve. [online]
https://pro.arcgis.com/en/pro-app/latest/tool-reference/data-management/dissolve.htm

Geometric operations

ESRI. 2025. Buffer (Analysis). [online]
https://pro.arcgis.com/en/pro-app/latest/tool-reference/analysis/buffer.htm
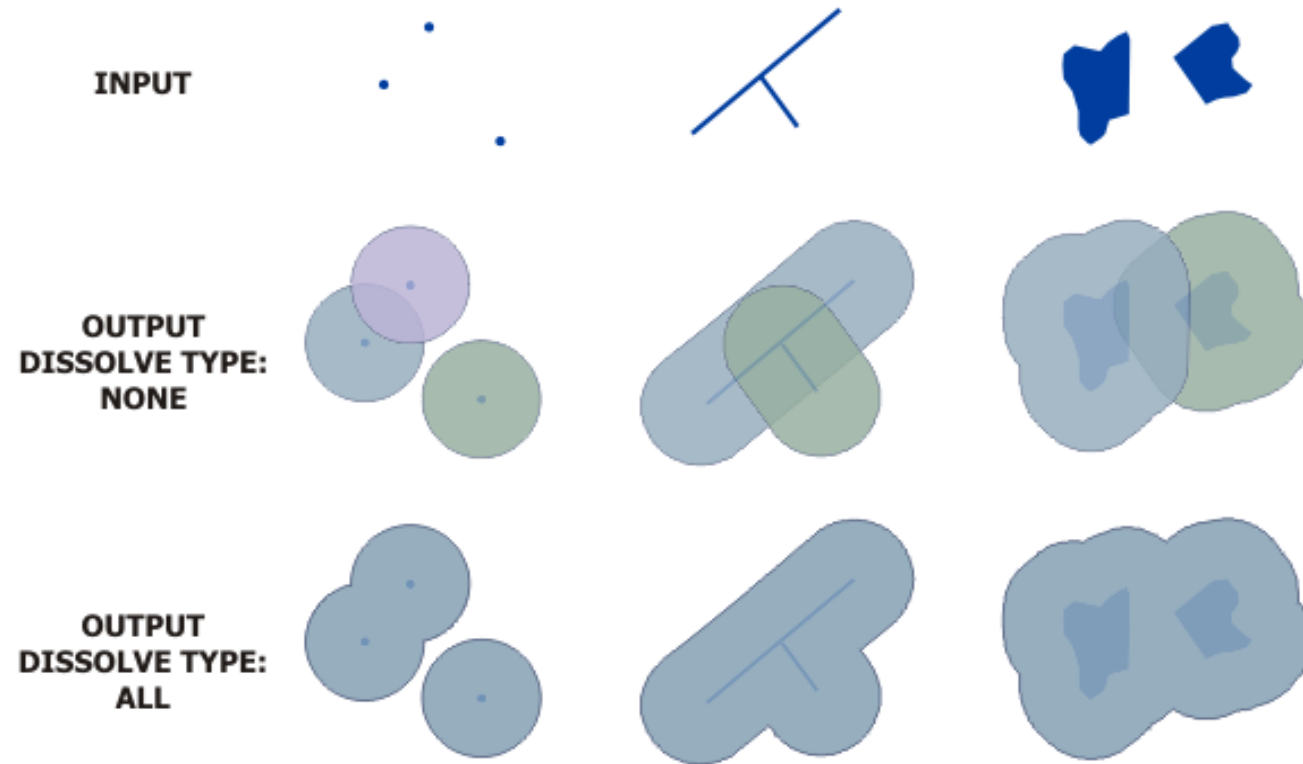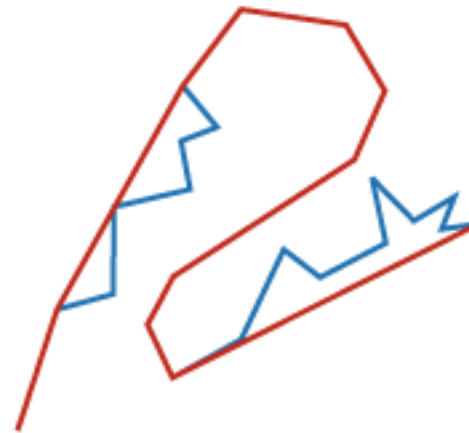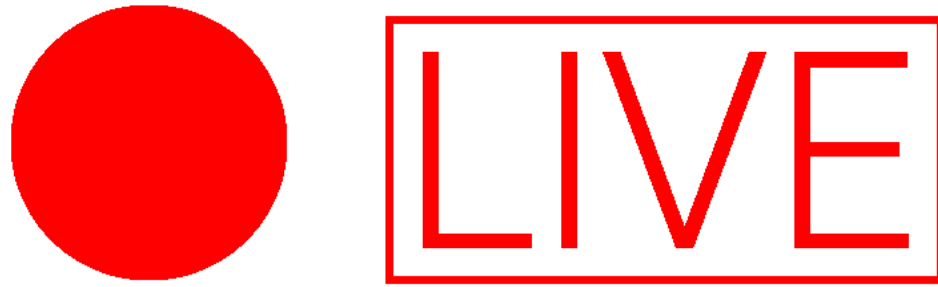
Geometric operations

POINT REMOVE   BEND SIMPLIFY

ORIGINAL
SIMPLIFIED

ESRI. 2025. Simplify line. [online]
https://desktop.arcgis.com/en/arcmap/10.3/tools/cartography-toolbox/simplify-line.htm

Geometric operations

RStudio

Conclusion

- The core of spatial analysis comes down to conducting spatial queries and executing geometric operations.

- Spatial analysis relies therewith on the spatial properties of an object as well as on the spatial relationships both *within* and *between* spatial objects.

Questions

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UCL